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COMMONWEALTH OF AUSTRALIA

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CONTENTS

PERMIAN FORAMINIFERA FROM BMR BORES 6, 7, 8, and 9, WESTERN AUSTRALIA

by D. J. Belford

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SUMMARY

Permian Foraminifera from four stratigraphic and structural bores drilled by the Bureau of Mineral Resources in the Carnarvon Basin, Western Australia, have been examined. Foraminifera occur over three intervals in bore BMR 7; the assemblage in BMR 6, with an upper limit at 495 feet, is correlated with the second fossiliferous interval in BMR 7, with an upper limit at 1087 feet. Correlations between bores BMR 8 and 9 are not as clear, but a distinctive assemblage occurs in the Callytharra Formation in each bore; the palaeontological horizon in BMR 9 is about 200 feet below the top of the Callytharra Formation.

Distribution charts show the species occurring in each bore, and a composite chart shows the known distribution of recorded species in the Minilya River and Wooramel River sections. The species *Tolypammina undulata* Parr is here referred to *Ammovertella; Glomospira adhaerens* Parr to *Lituotuba;* and *Streblospira australae* Crespin & Belford and *S. meandrina* Crespin & Belford to *Meandrospira.*

FORAMINIFERAL ASSEMBLAGES AND CORRELATIONS

Bores BMR 6, 7, 8, and 9 were drilled to provide stratigraphic and structural information on the Permian rocks of the Carnarvon Basin, Western Australia. Bores 6 and 7 were drilled in 1958 on Middalya station, 88 miles north-east of Carnarvon, in the north-central part of the Kennedy Range 1 : 250,000 Sheet area, and were reported on by Perry (1964). Foraminifera from these bores were examined by Belford (1960, 1961). Bores 8 and 9 were drilled in 1959 on Byro and Coordewandy stations respectively, within the Glenburgh 1 : 250,000 Sheet area, and were reported on by Mercer (1966); some of the formation boundaries shown by Mercer have been changed to those suggested by J. M. Dickins and M. C. Konecki (pers. comm.).

Eleven cores from BMR 6 were examined, between 110 and 1001 feet, and 25 cores from BMR 7, between 110 feet and 1997 feet. Species recorded are as follows, those species common to both bores being marked by an asterisk:

**Flectospira prima*Crespin & Belford, 1957
Frondicularia aulax Crespin, 1958
**F. parri* Crespin, 1945
F. woodwardi Howchin, 1894
Hemigordius harltoni Cushman & Waters, 1928
**Rectoglandulina serocoldensis* (Crespin, 1945)
**Hyperammina coleyi* Parr, 1942
**H. elegans* (Cushman & Waters, 1928)
H. fusta Crespin, 1958
H. expansa (Plummer, 1945)
H. sp.
**Thuramminoides sphaeroidalis* Plummer, 1945
**Geinitzina triangularis* Chapman & Howchin, 1905
**Calcivertella* sp. cf. *C. palata* Crespin, 1958
C. sp.

Calcitornella heathi Cushman & Waters, 1928
**Ammodiscus nitidus* Parr, 1942
**Pseudohyperammina radiostoma* Crespin, 1958
**Giraliarella travesi* Crespin, 1958
Ammobaculites woolnoughi Crespin & Parr, 1941
Nodosaria conico-densestriata Paalzow, 1935
**N. raggatti* Crespin, 1958
N. sp. cf. *N. striatella* (Paalzow, 1935)
N. sp.
Glomospirella nyei Crespin, 1958
**Trochammina subobtusa* Parr, 1942
**Ammovertella undulata* (Parr, 1942)
Psammosphaera pusilla Parr, 1942
Pelosina ampulla Crespin, 1958

The distribution of species in BMR 6 and BMR 7, and the depth ranges of these species common to the two bores, are compared in Text-figure 1.

Foraminifera occur at three levels in BMR 7, from cores 2-5, 15-18, and 23-25, separated by unfossiliferous intervals. Foraminifera occur only rarely in BMR 6 above core 6, taken between 495 feet and 505 feet.

With the exception of the highest fossiliferous zone in BMR 7, the species of Foraminifera recorded occur only rarely in each sample, but the restricted levels of their occurrence permit a correlation between the two bores. The assemblage occurring in BMR 7 from cores 2 to 5 is not represented in BMR 6; but the assemblages from BMR 6 and the second fossiliferous interval of BMR 7 are in good agreement. The most important species for correlating these intervals are *Flectospira prima, Rectoglandulina serocoldensis, Hyperammina coleyi, Ammodiscus nitidus, Hyperammina elegans, Nodosaria raggatti,* and *Trochammina subobtusa.* Several species are first recorded in bore BMR 6 below 495 feet, probably because of the rarity of their occurrence in the section, while *Geinitzina triangularis* is recorded above this level. In spite of these irregularities it is possible to recognize a well defined upper limit in BMR 6 at 495 feet; the upper limit of the second fossiliferous interval in BMR 7 is clearly defined at 1087 feet.

In my opinion, BMR 6 began in the unfossiliferous beds between the first and second fossiliferous zones in BMR 7. The assemblage from BMR 6 is correlated with that of the second fossiliferous zone in BMR 7; the upper limits of these zones are placed at 495 feet and 1087 feet respectively. The foraminiferal correlations do not aid in deciding which of the two possible structural interpretations, fault or depositional, is correct; this was discussed by Perry (1964).

Thirty cores were examined from bore BMR 8 between 100 feet and 3004 feet, and 23 cores from BMR 9, between 91 feet and 2299 feet. In each bore Foraminifera occur abundantly over only a small interval, between cores 12 and 14 in BMR 8 and cores 10 and 12 in BMR 9.

Foraminifera identified from BMR 8 are:

Tetrataxis conica Ehrenberg, 1843
Geinitzina triangularis Chapman & Howchin, 1905
Calcitornella stephensi (Howchin, 1894)
Calcivertella palata Crespin, 1958
Trepeilopsis australiensis Crespin, 1958

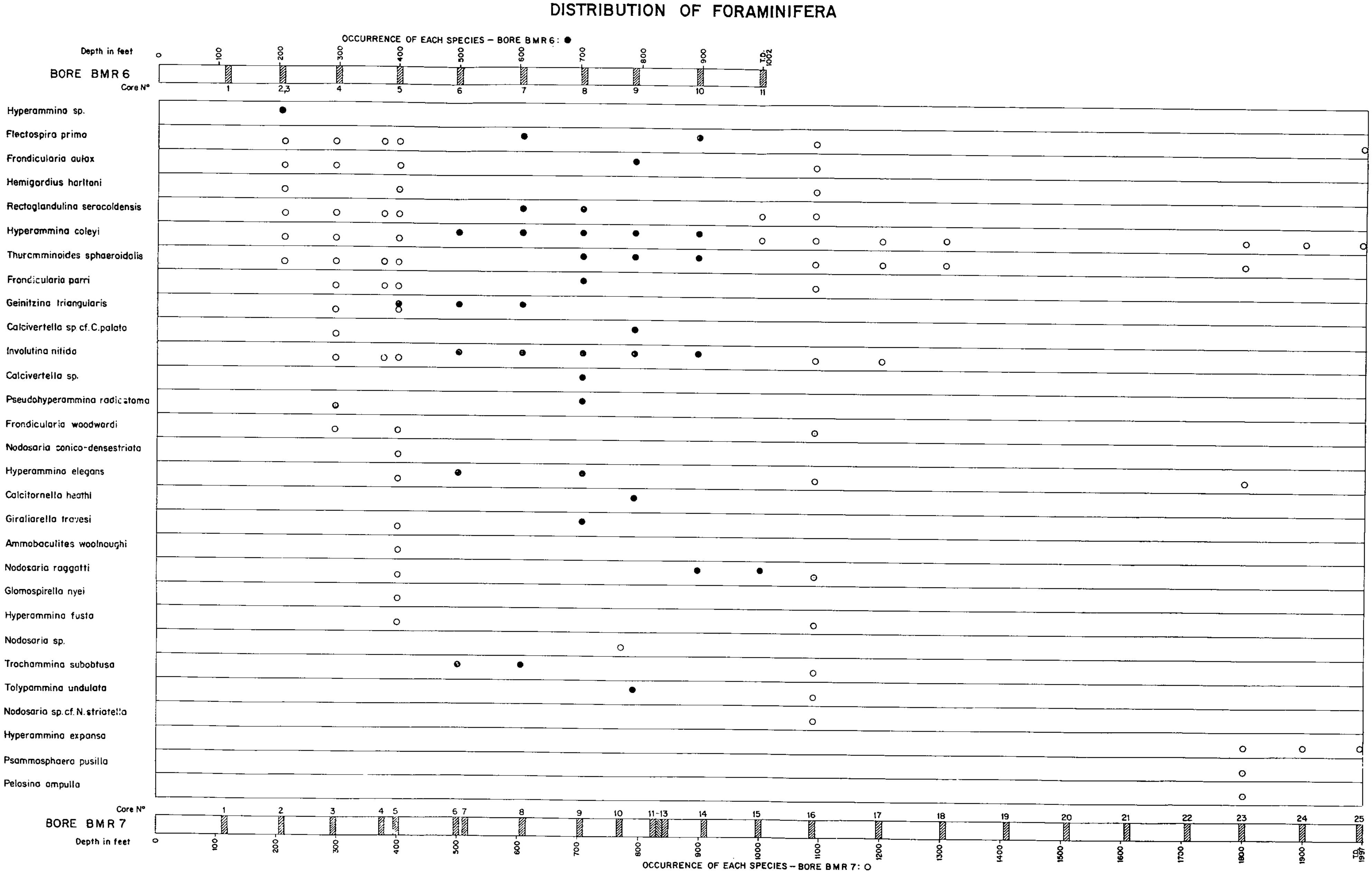

Fig. 1. Distribution of Foraminifera, BMR 6 and 7

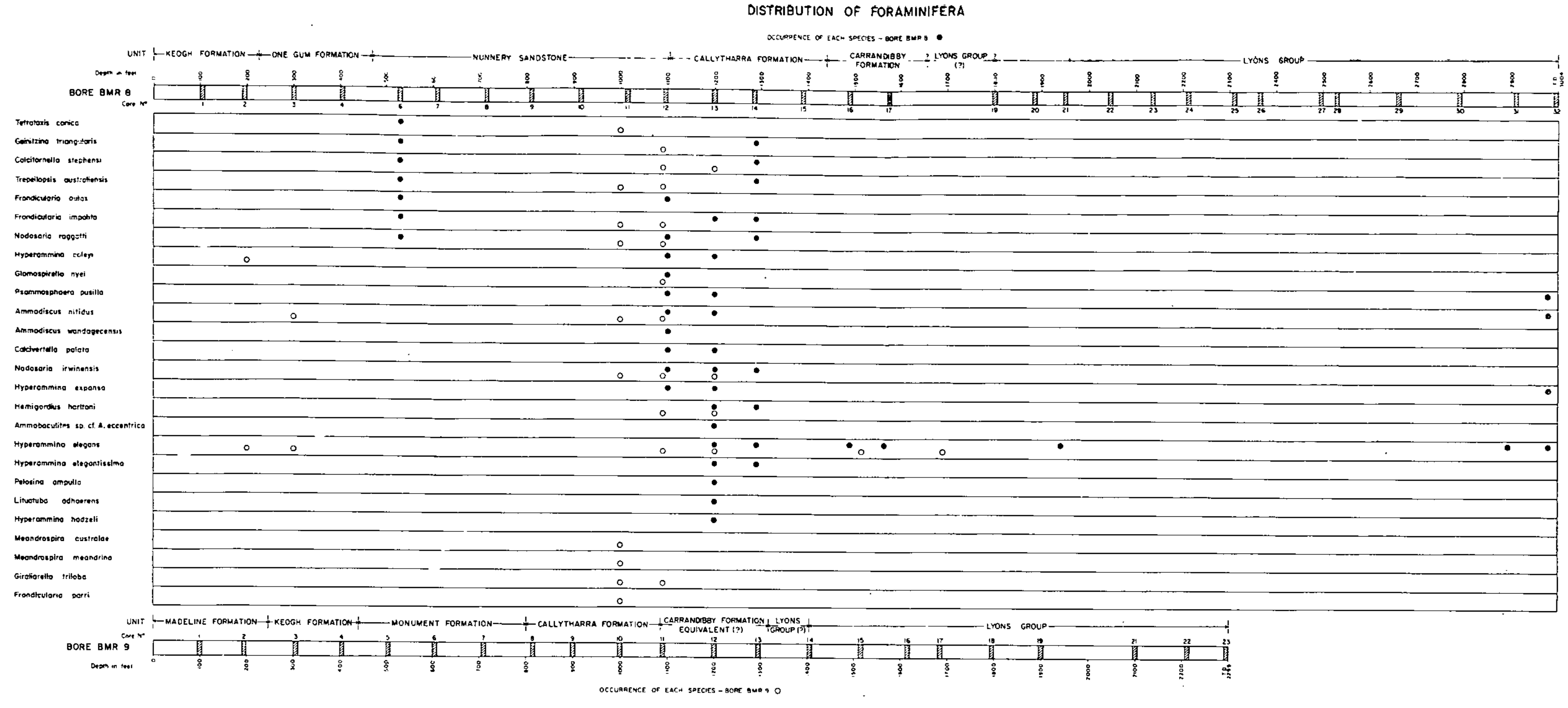

Fig. 2. Distribution of Foraminifera, BMR 8 and 9

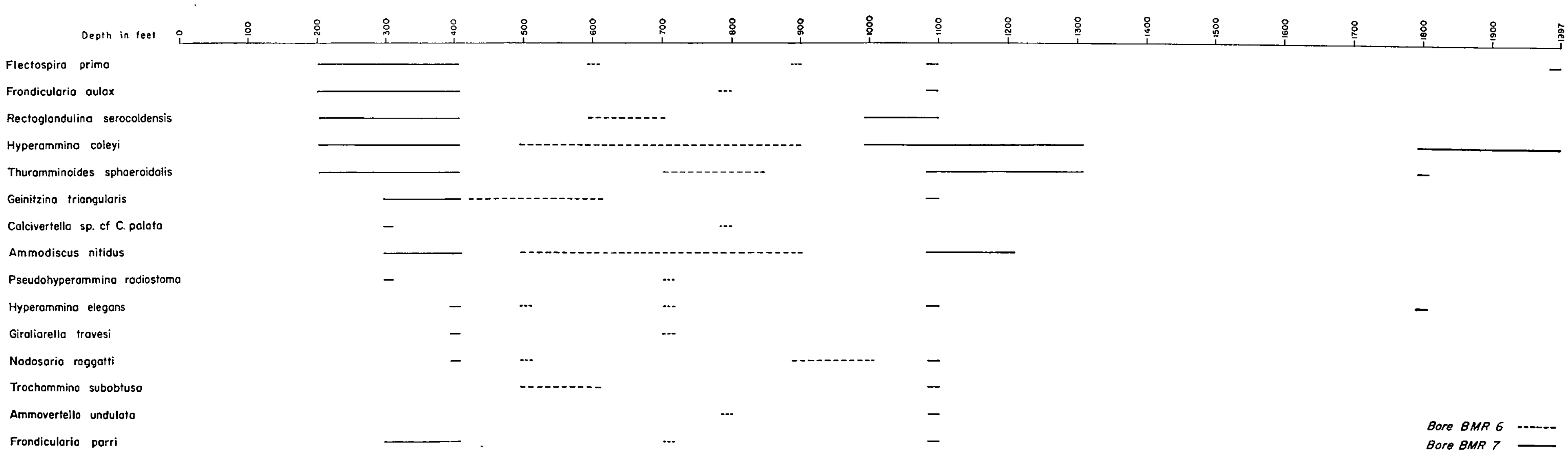

Fig. 3. Distribution chart of Foraminifera

Frondicularia aulax Crespin, 1958
F. impolita Crespin, 1958
Nodosaria raggatti Crespin, 1958
N. irwinensis Howchin, 1894
Hyperammina coleyi Parr, 1942
H. expansa (Plummer, 1945)
H. elegans (Cushman & Waters, 1928)
H. elegantissima Plummer, 1945
H. hadzeli Crespin, 1958
Glomospirella nyei Crespin, 1958
Psammosphaera pusilla Parr, 1942
Ammodiscus nitidus Parr, 1942
A. wandageeensis Parr, 1942
Hemigordius harltoni Cushman & Waters, 1928
Ammobaculites sp. cf. *A. eccentrica* Crespin, 1958
Pelosina ampulla Crespin, 1958
Tolypammina adhaerens (Parr, 1942)

Foraminifera identified from BMR 9 are:

Tetrataxis conica Ehrenberg, 1843
Hyperammina elegans (Cushman & Waters, 1928)
H. coleyi Parr, 1942
Ammodiscus nitidus Parr, 1942
Meandrospira australae (Crespin & Belford, 1957)
M. meandrina (Crespin & Belford, 1957)
Frondicularia impolita Crespin, 1958
F. parri Crespin, 1945
Nodosaria raggatti Crespin, 1958
N. irwinensis Howchin, 1894
Trepeilopsis australiensis Crespin, 1958
Giraliarella triloba Belford, 1961
Hemigordius harltoni Cushman & Waters, 1928
Geinitzina triangularis Chapman & Howchin, 1905
Calcitornella stephensi (Howchin, 1894)
Glomospirella nyei Crespin, 1958
Plummerinella? sp.

The assemblage from cores 2 and 3 of BMR 9 has not been recorded from BMR 8, and that in core 6 of BMR 8 is not known from BMR 9. The distinctive fauna occurring in the Callytharra Formation in each bore enables a correlation to be made between them, but the palaeontological horizon in BMR 9 is about 200 feet below the top of the Callytharra Formation. The scattered occurrences of *Hyperammina elegans* below the zone of abundant Foraminifera is also the same in each bore. The beds containing the fauna found in cores 31 and 32 of BMR 8 were not reached by BMR 9.

Information from these four bores has extended the previously known geographical extent of many species and has also added to knowledge of their stratigraphical distribution. The accompanying distribution chart (Text-fig. 3) has been compiled from the additional information and from the ranges given by Crespin (1958): it must be regarded as provisional and subject to revision when further data become available.

NOTES ON SOME SPECIES

Ammovertella undulata (Parr); originally described as *Tolypammina.*

Conkin (1961) discussed the generic differentiation between *Tolypammina* and *Ammovertella;* he concluded that *Tolypammina* is more or less free of attachment, with a sinuous and tortuous second chamber not winding in the same general plane. *Ammovertella* was stated to have a sinuous back-and-forth second chamber in the same general plane, fusing into a planoconvex unit. The backward and forward winding of the second chamber is mentioned in the original description of *undulata* by Parr (1942) and also by Crespin (1958) in specimens from the Hunter River area, New South Wales. Because of the nature of the second chamber this species is here referred to *Ammovertella.*

Lituotuba adhaerens (Parr); originally described as *Glomospira.*

Lituotuba differs from *Glomospira* in having an uncoiled rectilinear later stage. This feature is included in the original description of *adhaerens,* which is therefore here referred to *Lituotuba.*

Meandrospira australae (Crespin & Belford) and *Meandrospira meandrina* (Crespin & Belford); originally described as *Streblospira.*

Loeblich & Tappan (1964) revised the generic diagnosis of *Meandrospira* to include species with streptospiral coiling. Such coiling is not described in the type species *M. washitensis* Loeblich & Tappan, and is not obvious from illustrations. However, the species *Glomospira glomerata* Höglund, also referred by Loeblich & Tappan to *Meandrospira,* appears to have streptospiral coiling. It seems that the placing of the generic name *Streblospira* in the synonymy of *Meandrospira* is justified.

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PLATE 1

Fig. 1 — *Pelosina ampulla* Crespin, CPC 6822, BMR 7, core 23, 1793-1802 feet, side view, x 22.

Figs 2-3 — *Psammosphaera pusilla* Parr, CPC 6823-6824, side views.
2, BMR 7, core 23, 1793-1802 feet, x 56.
3, BMR 8, core 13, 1197-1207 feet, x 56.

Fig. 4 — *Thuramminoides sphaeroidalis* Plummer, CPC 6825, BMR 6, core 8, 701-711 feet, side view, x 22.

Figs 5-7 — *Ammodiscus nitidus* Parr, CPC 6826-6828.
5, BMR 7, core 3, 293-303 feet, x 98.
6, BMR 7, core 5, 397-403 feet, x 38.
7, BMR 8, core 13, 1199-1207 feet, x 35.

Fig. 8 — *Ammodiscus wandageeensis* Parr, CPC 6829, BMR 8, core 12, 1095-1101 feet, x 27.

Fig. 9 — *Ammobaculites* sp. cf. *A. eccentrica* Crespin, CPC 6830, BMR 8, core 13, 1199-1207 feet, x 60.

Fig. 10 — *Ammobaculites woolnoughi* Crespin & Parr, CPC 6831, BMR 7, core 5, 397-403 feet, x 35.

Figs 11-12 — *Trochammina subobtusa* Parr, CPC 6832, BMR 7, core 16, 1087-1095 feet. 11, ventral view; 12, dorsal view, both x 94.

Figs. 13-15 — *Hyperammina expansa* (Plummer), CPC 6833-6835. 13, BMR 7, core 23, 1793-1802 feet, x 22; 14-15, BMR 8, core 32, 2994-3004 feet, both x 42.

Figs 16-18 — *Hyperammina coleyi* Parr, CPC 6836-6838. 16, BMR 7, core 2, 204-214 feet, x 22; 17, BMR 6, core 8, 701-711 feet, x 22; 18, BMR 8, core 13, 1199-1207 feet, x 16.

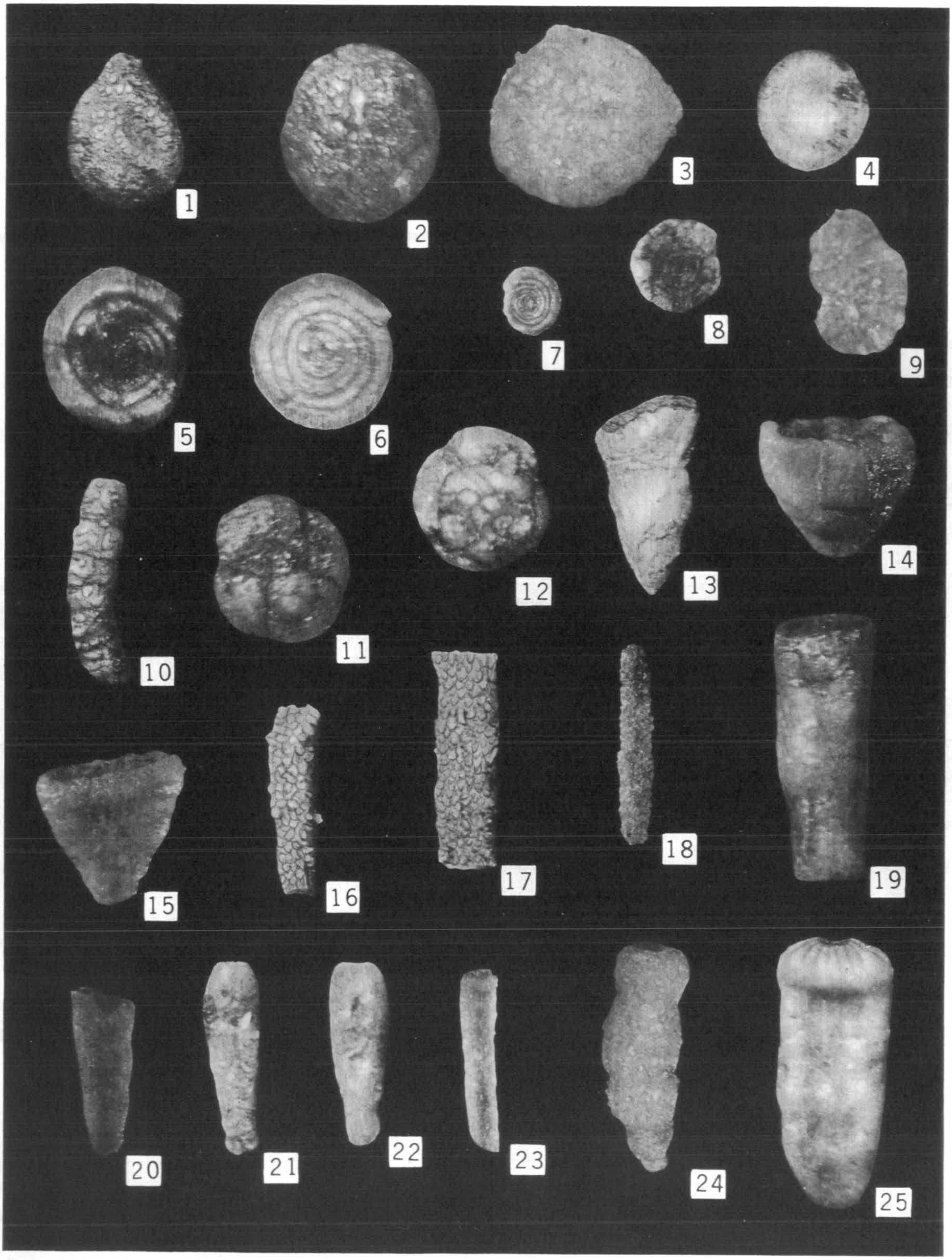
Figs 19-20 — *Hyperammina elegans* (Cushman & Waters), CPC 6839-40. 19, BMR 7, core 5, 397-403 feet, x 56; 20, BMR 8, core 13, 1199-1207 feet, x 17.

Figs 21-22 — *Hyperammina fusta* Crespin, CPC 6841-6842, BMR 7, core 16, 1087-1095 feet, both x 35.

Fig. 23 — *Hyperammina elegantissima* Plummer, CPC 6843, BMR 8, core 13, 1199-1207 feet, x 26.

Fig. 24 — *Hyperammina hadzeli* Crespin, CPC 6844, BMR 8, core 13, 1199-1207 feet, x 30.

Fig. 25 — *Pseudohyperammina radiostoma* Crespin, CPC 6845, BMR 7, core 3, 293-303 feet, x 35.



Permian Foraminifera

PLATE 2

Figs 1-2 — *Glomospirella nyei* Crespin, CPC 6846-6847. 1, BMR 7, core 5, 397-403 feet, x 56. 2, BMR 9, core 11, 1083-1093 feet, x 82.

Figs 3-6 — *Giraliarella travesi* Crespin, CPC 6848-6849. 3-4, BMR 7, core 5, 397-403 feet; 3, x 35; 4, x 60; 5-6, core 8, 701-711 feet.

Figs 7-11 — *Giraliarella triloba* Belford. 7-9, holotype, CPC 3856, BMR 9, core 11, 1083-1093 feet, x 39; 10, paratype A, CPC 3857, locality as for holotype, x 39. 11, paratype B, CPC 3858, locality as for holotype, x 39.

Fig. 12 — *Ammovertella undulata* (Parr), CPC 6850. BMR 7, core 16, 1087-1095 feet, x 49.

Fig. 13 — *Lituotuba adhaerens* (Parr), CPC 6851. BMR 8, core 13, 1199-1207 feet, x 36.

Figs. 14-16 — *Hemigordius harltoni* Cushman & Waters, CPC 6852-6854. 14, BMR 7, core 5, 397-403 feet, x 40; 15-16, BMR 9, core 11, 1083-1093 feet, x 53.

Figs 17-18 — *Calcitornella heathi* Cushman & Waters, CPC 6855, BMR 6, core 9, 785-795 feet, x 35.

Figs 19-20 — *Calcitornella stephensi* (Howchin), CPC 6856. BMR 8, core 14, 1280-1290 feet, x 51.

Figs. 21-22 — *Calcitornella* sp., CPC 6857, BMR 6, core 8, 701-711 feet, x 37.

Fig. 23 — *Calcivertella palata* Crespin, CPC 6858, BMR 8, core 12, 1095-1101 feet, x 30.

Fig. 24 — *Calcivertella* sp. cf. *C. palata* Crespin, CPC 6859, BMR 7, core 3, 293-303 feet, x 37.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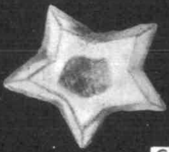
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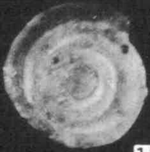
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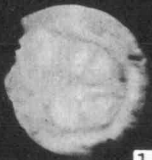
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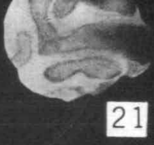
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Permian Foraminifera

PLATE 3

Figs 1-3 — *Trepeilopsis australiensis* Crespin, CPC 6860-6862. 1-2, BMR 9, core 11 1083-1093 feet, both x 51. 3, thin section, BMR 8, core 14, 1280-1290 feet, x 58.

Fig. 4 — *Tetrataxis conica* Ehrenberg, CPC 6863, BMR 9, core 10, 992-1002 feet, x 90.

Figs 5-7 — *Nodosaria raggatti* Crespin, CPC 6864-6866. 5, BMR 7, core 16, 1087-1095 feet, x 55. 6-7, BMR 9, core 11, 1083-1093 feet, both x 61.

Fig. 8 — *Nodosaria* sp. cf. *N. striatella* (Paalzow), CPC 6867. BMR 7, core 16, 1087-1095 feet, x 86.

Fig. 9 — *Nodosaria conico-densestriata* Paalzow, CPC 6868. BMR 7, core 5, 397-403 feet, x 35.

Fig. 10 — *Nodosaria irwinensis* Howchin, CPC 6869, BMR 9, core 11, 1083-1093 feet, x 49.

Fig. 11 — *Rectoglandulina serocoldensis* (Crespin), CPC 6870, BMR 7, core 2, 204-214 feet, x 38.

Figs 12-13 — *Frondicularia aulax* Crespin, CPC 6871-6872. 12, BMR 7, core 16, 1087-1095 feet, x 57; 13, BMR 8, core 6, 527-537 feet, x 27.

Fig. 14 — *Frondicularia impolita* Crespin, CPC 6873. BMR 8, core 14, 1280-1290 feet, x 78.

Fig. 15 — *Frondicularia parri* Crespin, CPC 6874. BMR 7, core 3, 293-303 feet, x 38.

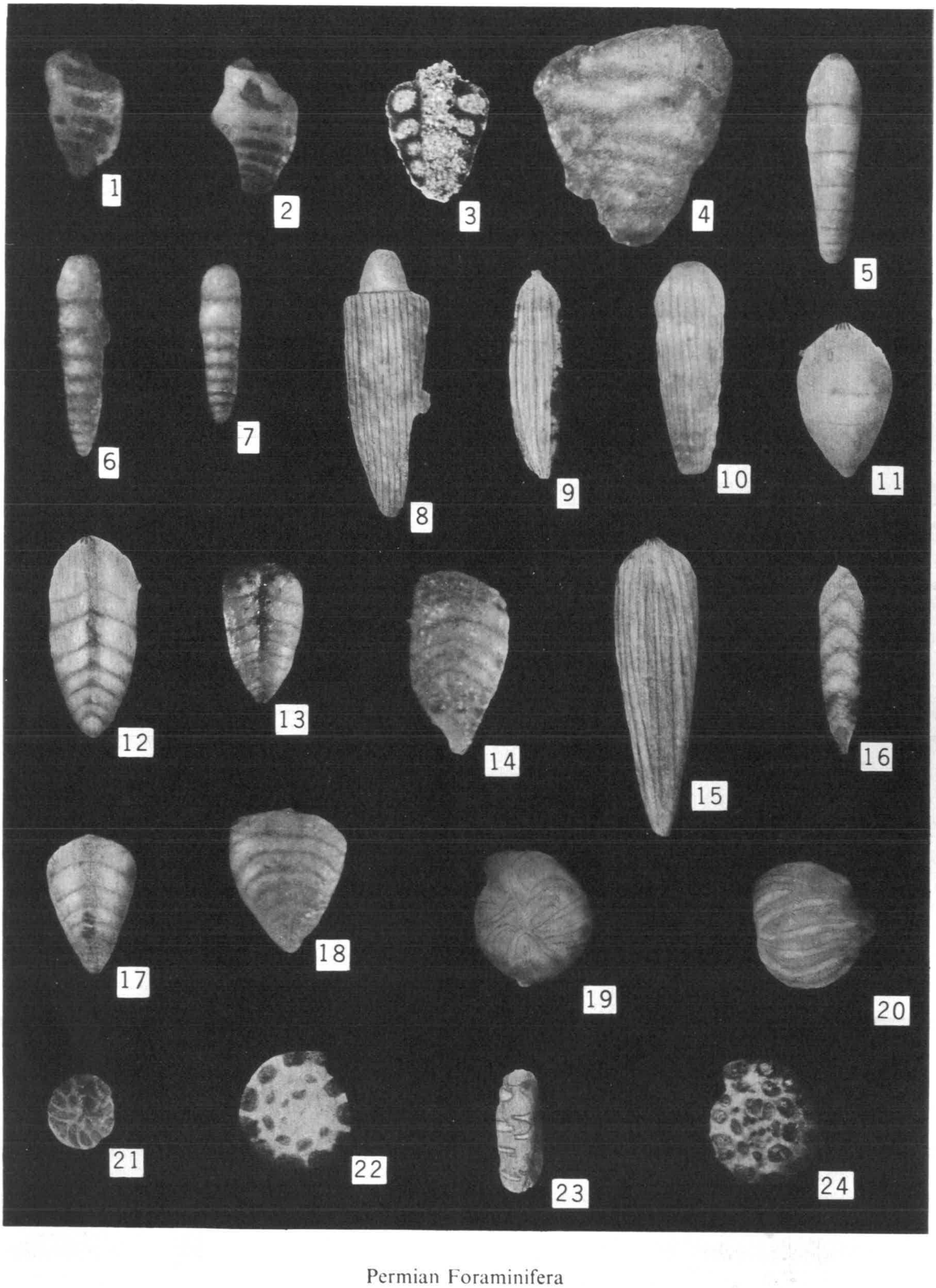
Fig. 16 — *Frondicularia woodwardi* Howchin, CPC 6875. BMR 7, core 5, 397-403 feet, x 35.

Figs 17-18 — *Geinitzina triangularis* Chapman & Howchin, CPC 6876-6877. 17, BMR 7, core 5, 397-403 feet, x 37; 18, BMR 9, core 11, 1083-1093 feet, x 60.

Figs 19-20 — *Meandrospira australae* (Crespin & Belford), CPC 6878. BMR 9, core 10, 992-1002 feet, x 81.

Fig. 21 — *Meandrospira meandrina* (Crespin & Belford), CPC 6879. BMR 9, core 10, 992-1002 feet, x 42.

Figs 22-24 — *Flectospira prima* Crespin & Belford, CPC 6880-6881. BMR 7, core 16, 1087-1095 feet, all x 56.



Permian Foraminifera

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DISCOVERY OF THE CRINOID CALCEOLISPONGIA IN THE PERMIAN OF QUEENSLAND

by J. M. Dickins

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SUMMARY

A newly recognized species, *Calceolispongia kalewaensis,* is described. The crinoid appears to be most closely related to *C. bifurca* (Wanner, 1937) from the lower Upper Permian Basleo Beds of Timor. It is found in the Barfield Formation in the upper part of the Back Creek Group (or Middle Bowen Beds) of the Bowen Basin, and therefore tends to confirm an early Upper Permian age for this part of the sequence.

INTRODUCTION

The profusion of *Calceolispongia* in the Permian of Western Australia, both in numbers and species, has been recorded in the monograph by Teichert (1949). This profusion has been emphasized by later collecting, and additional species await description. Teichert (1954) also described a closely related genus from the Permian of Western Australia, *Jimbacrinus.* Outside Western Australia, however, only a few species have been described — from Timor (Wanner, 1916, 1924, 1937; Gerth, 1936; Oyens, 1940), India (Reid, 1928), and Tasmania (Sieverts-Doreck, 1942). To this is now added *Calceolispongia kalewaensis* from Queensland.

ACKNOWLEDGMENTS

I am grateful to Professor Dorothy Hill of the Department of Geology of the University of Queensland for making specimens available for study, and to F. S. Colliver, Curator of Collections, and B. N. Runnegar of the same Department for supplying information and latex casts respectively.

OCCURRENCE AND AGE

The specimens of *C. kalewaensis* described are from two localities, which are shown on the accompanying map (Fig. 1). Although the localities are a considerable distance apart (69 miles), both are in the Barfield Formation of the Back Creek Group, or Middle Bowen Beds, of the south-eastern portion of the surface part of the Bowen Basin. The first specimens were found by the author in 1958 when he accompanied Professor Dorothy Hill and Dr W. G. H. Maxwell of the Department of Geology of the University of Queensland on a visit to the Bowen Basin. Basal, radial, and 1st and 2nd brachial plates were found near Baralaba (University of Queensland, Field No. L.1859). During

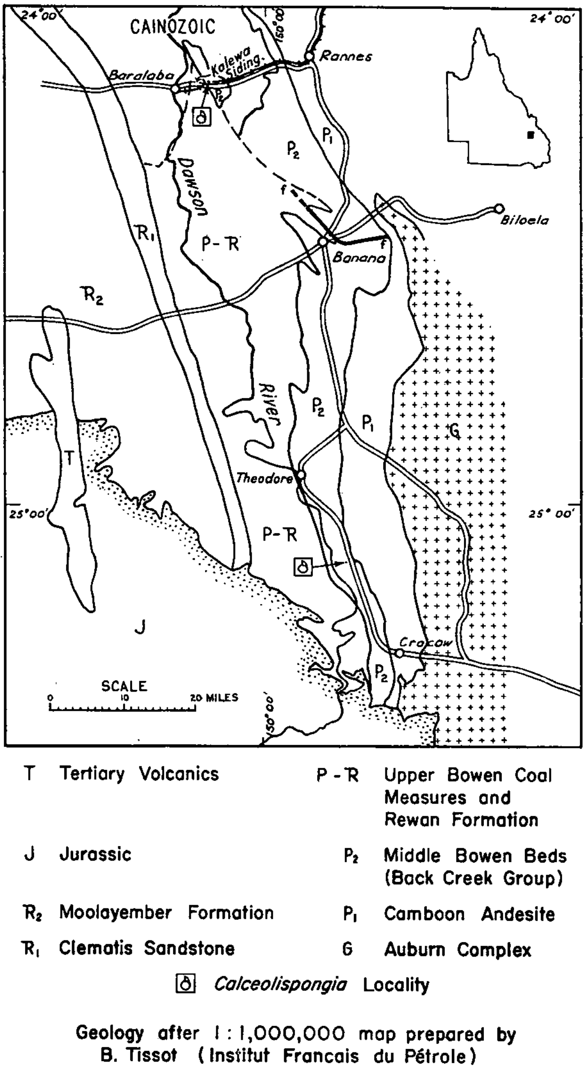

Fig. 1. Specimen localities of *Calceolispongia kalewaensis,* **south-east Bowen Basin**

the joint regional survey of the Bowen Basin undertaken by the Bureau of Mineral Resources and the Geological Survey of Queensland, additional specimens (Field No. Ba321) were collected in 1964 at the same locality, including part of two cups found by Prof. Hill. Basal and 1st and 2nd brachial plates were also collected farther south, between Theodore and Cracow, in 1964 (Field Nos T109 and T110).

The stratigraphical sequence in this area, together with its age and relationship to the sequences in other parts of the basin, is shown in Figure 2. The basis

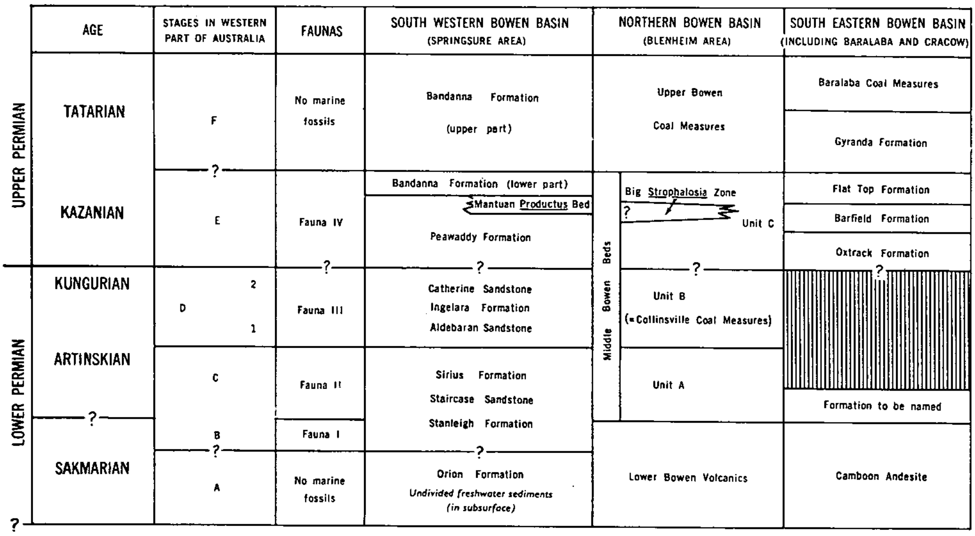

Fig. 2. Correlation and age of the Permian formations of the Bowen Basin

of these relationships is discussed in detail elsewhere (Dickins, 1964, a & b; MS) — the lower boundary of the Stanleigh Formation is, however, shown slightly lower down in Figure 2. The faunal divisions shown (Faunas I, II, III and IV) are those found in the Bowen Basin. In Dickins (MS.) the evidence is discussed for the probably early Upper Permian (Kazanian) age of the upper part of the Back Creek Group (including the Barfield Formation). The conclusion on the age was based largely on the occurrence in the upper part of the Middle Bowen Beds of *Atomodesma bisulcatum* Dickins, 1961, and *Licharewia* sp. nov., and the entry of forms related to *Parallelodon subtilistriatus* Wanner, 1922, *Astartila fletcheri* Dickins, 1954, and *Schizodus kennedyensis* Dickins, 1956, which, in the Carnarvon Basin of Western Australia, are found high in the Permian sequence. Later in this paper it is concluded that *C. kalewaensis* is closely related to *C. bifurca* (Wanner, 1937) from the Basleo Beds of Timor, which are regarded as early Upper Permian. It less closely resembles the species from Western Australia, which all appear to be of Lower Permian (Sakmarian, Artinskian, and probably Kungurian) age, and *C. noetlingi* (Sieverts-Doreck, 1942) from the Permian of Tasmania. This relationship is therefore compatible with the conclusions already made on the age of the upper part of the Back Creek Group or upper Middle Bowen Beds, and adds further information on the widespread changes at about this time, which allowed freer communication between faunas in different parts of Australia, Europe, and Asia than had existed previously (see Dickins, 1963).

DESCRIPTION

Genus CALCEOLISPONGIA Etheridge Jnr, 1915

Synonyms: *Dinocrinus* Wanner, 1916, *Calceospongia* Bassler, 1938 (typographical error).

Type Species: *Calceolispongia hindei* Etheridge Jnr, 1915, p. 9-13, pl. 4, figs 1-9; pl. 7, figs 5, 6, by monotypy.

The newly recognized species, *Calceolispongia kalewaensis,* can be referred to to *Calceolispongia* and distinguished from *Jimbacrinus* Teichert (1954) by its bulky and spinose 2nd brachial plates and the lozenge-shape and concave character of the infrabasals.

CALCEOLISPONGIA KALEWAENSIS sp. nov.

(Pl. 4)

1964 *Calceolispongia* sp. nov. Dickins in Hill & Woods, (pl. 4), p. XII, figs 21 a-d.

Diagnosis

Cup of moderate size, five small infrabasals set in depression of cup, stem ossicles apparently rounded and of two sizes, basals convex with very variable shape — from fairly evenly rounded with slight dorsal and ventral protuberances to having two distinct spines, radials plain and rather wide, 1st brachial plates plain but 2nd brachial with two distinct spines, external surface granular.

Description

Holotype: Shows part of a cup with basal plates, radial, and 1st brachial. Stem ossicles found immediately underneath the cup may belong to this specimen. The basal plates are pentagonal and have only dorsal and ventral protuberances — possibly the external surface has been partly eroded away. The stem ossicles associated with the cup are of two widths and one of the ossicles is possibly pentagonal.

Paratype A: Is the base of a cup. The protuberances of the basal plates are more distinct than in the holotype, but there is considerable variation from plate to plate. The five infrabasals are small, concave, and petal or lozenge-shaped. The impression of the first stem ossicle is rounded.

Other Paratypes: Paratypes B-D, M, and N show the variation in the shape of the basal plates. In general, the protruberances are better developed in the larger plates, and in Paratype M a distinct spine is formed dorsally. Paratype E is the internal of a basal plate and shows part of the nervous system. It is truncated dorsally, apparently for the reception of the anal plate into the cup. Paratype F shows the internal of another basal plate and Paratype G the facet of a basal plate. Paratype J and K are two asymmetrical radials. The asymmetry could be caused by insertion of the anal plate or could indicate the presence of a supernumerary basal (see Teichert, 1949, p. 19).

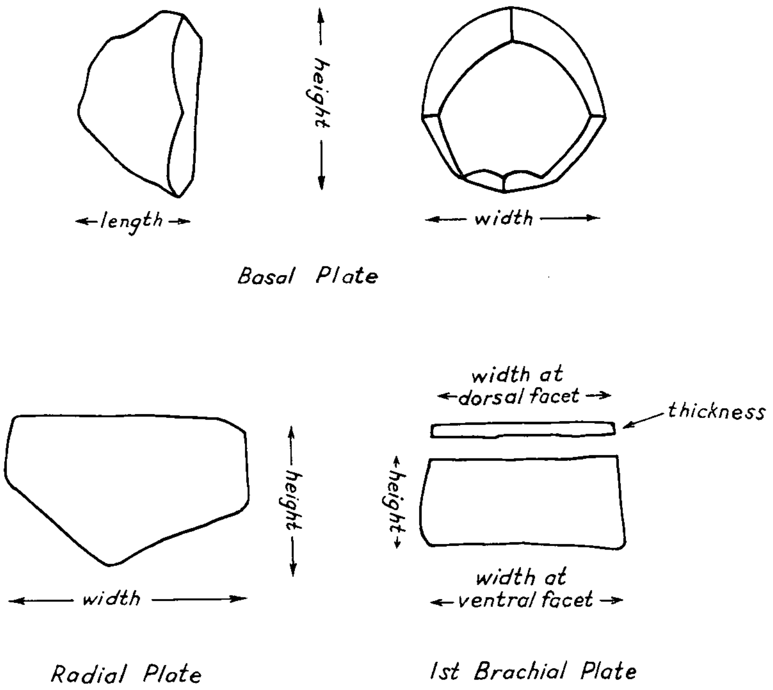

Fig. 3. Dimensions of plates of *Calceolispongia kalewaensis*

Dimensions (these follow those proposed by Teichert, 1949, and are shown in Fig. 3). Volume is in ccm, linear dimensions in mm.

Basal Plates:	*Height*	*Width*	*Length*	*Volume*
Holotype	13.00	13.00	5.00	—
Paratype A	11.00	9.00	5.00	—
Paratype B	7.00	7.00	4.00	0.06
Paratype C	9.00	6.50	6.50	0.19
Paratype D	10.50	9.50	4.50	—
Paratype M	15.00	12.00	10.00	0.48
Paratype N	18.00	16.00	12.00	1.10

Radial Plates:	*Height*	*Width*	*Thickness*
Paratype A(a)	8.50	18.00	—
Paratype A(b)	9.00 (approx.)	18.00	—
Paratype J	5.00	8.00	—
Paratype K	5.00	10.00	1.50

1st Brachial Plates:	*Height*	*Width* (dorsal facet)	*Width* (ventral facet)	*Thickness*
Paratype H	6.00	—	1.50	2.00 (approx.)
Paratype I	2.50	6.00	6.50 (approx.)	—

2nd Brachial Plate:	*Height*	*Width* (at inside of plate)	*Length of Spine*
Paratype L	6.50	7.00	9.00

Occurrence

Holotype, UQF* 46,215; Paratype A, UQF 46,216; Paratype B, UQF 27,055; Paratype C, UQF 27,047; Paratype D, UQF 27,054; Paratype E, UQF 46,217; Paratype F, UQF 46,218; Paratype G, UQF 46,219; Paratype H, UQF 27,056; Paratype I, UQF 27,051; Paratype J, UQF 27,048; Paratype K, UQF 27,059; and Paratype L, UQF 27,049; all from Baralaba Range Railway, 5 miles east of Baralaba and ½ mile east of Kalewa Siding (Field Nos L1859 and Ba321). Paratype M, CPC 6206, 2.3 miles north-north-west of Cracow-Theodore road crossing of Delusion Creek, in small creek on west side of road (Field No. T109) and Paratype N, CPC 6707, from 200 yards west of Paratype M locality (Field No. T110).

Additional material consists of numerous separate plates from the holotype locality and a few separated plates from T109 and T110.

Discussion

C. kalewaensis shows some resemblance to *C. spinosa* Teichert, 1949 (p. 92-93, pl. 2, figs 46-72) from the Upper Sakmarian or Lower Artinskian Callytharra Formation of Western Australia. The basal plates are similar in outline, both from the side and front, but except in small plates, *C. spinosa* has more than two tubercles (Teichert, 1949, p. 92). On the other hand *C. kalewaensis* never has more than two and the tubercles may be poorly developed or almost absent. The two spines of the 2nd brachial plate also seem to be more robust in *C. kalewaensis*.

C. noetlingi (Sieverts-Doreck, 1942, p. 228-229, Abb. 5 a-c, 6 a-b) from the Permian rocks of Tasmania, is represented only by basals and a radial plate. The basals somewhat resemble those of *C. kalewaensis,* but the outline from the side is more rounded and no protuberances are visible in the figures, although Sieverts-Doreck implies that a slight transverse groove is found in one of the basals: 'in einem anderen ist der zentrale Buckel schwach quergeteilt'.

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Rounded basal plates of *C. kalewaensis* are somewhat similar in shape to those of *C. mammeata* (Wanner, 1924) (p. 244, pl. 13, figs 3-5, pl. 14, figs 11-17, pl. 15, figs 1-5) from the Permian of Timor.

C. kalewaensis, however, seems closest to *C. bifurca* (Wanner, 1937) (p. 183, pl. 12, figs 4-6, text-fig. 60), refigured by Teichert (1949, pl. 25, figs 25-27) from the early Upper Permian of Basleo, Timor, which it resembles in the shape and tuberculation of the basal plates.

The species is named after Kalewa Siding, close to where most of the type specimens, including the holotype, were found.

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PLATE 4

Calceolispongia kalewaensis sp. nov.

Figs 1-3 — Paratype B, UQF 27,055; side, internal, and external views of a basal plate, x 2.

Fig. 4 — Paratype E, UQF 46,217, internal view of latex cast of a basal plate, x 2.

Figs 5-7 — Paratype C, UQF 27,047, side, internal, and external views of a basal plate, x 2.

Figs 8-9 — Paratype D, UQF 27,054, side and external view of an incomplete basal plate.

Fig. 10 — Paratype F, UQF 46,218, internal view of a latex cast of a basal plate, x 2.

Fig. 11 — Paratype G, UQF 46,219, impression of inside and one of the dorsal facets of a basal plate, x 2.

Fig. 12 — Paratype J, UQF, 27,048, external view of a radial plate, x 2.

Figs 13-15 — Paratype L, UQF 27,049, top, side, and external views of a 2nd brachial plate, x 2.

Fig. 16 — Paratype I, UQF 27,051, external view of a 1st brachial plate, x 2.

Figs 17-18 — Paratype K, UQF 27,059, top and external views of a radial plate, x 2.

Fig. 19 — Paratype H, UQF 27,056, external view of a 1st brachial plate, x 2.

Figs 20-22 — Paratype M, CPC 6706, side, internal, and external views of a basal plate x 1.

Figs 23-25 — Paratype N, CPC 6707, side, internal, and basal views of a basal plate, x 1.

Fig. 26 — **Holotype,** UQF 46, 215, latex cast showing cup with basis, radials, and 1st brachial, x 1.

Fig. 27 — Paratype A, UQF 46,216, latex cast showing base of cup with infrabasals, basals, and part of radials, x 1.

(Photographs taken by J. E. Zawartko, photographer, and H. M. Doyle, technical assistant, of the Bureau of Mineral Resources, Geological Branch).


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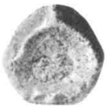
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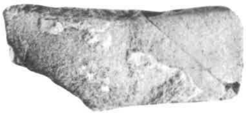
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Calceolispongia from Queensland

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CORRELATION OF THE PERMIAN OF THE HUNTER VALLEY, NEW SOUTH WALES, AND THE BOWEN BASIN, QUEENSLAND

by J. M. Dickins

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SUMMARY

Marine macrofossils from 24 localities have been examined and their identifications are listed. The collections have been made from all the marine formations of the Permian sequence of the Hunter Valley, to allow faunal comparisons with the Bowen Basin.

Fauna I, the oldest marine fauna in the Bowen Basin, is regarded as being younger than the fauna of the Lochinvar Formation. It is probably slightly younger than that of the Allandale Formation, and equivalent in age to the Rutherford Formation. On this basis all or part of the 'Undivided Freshwater Beds' of the Springsure area and all or part of the Lower Bowen Volcanics, excepting the upper beds which contain Fauna I, may be equivalent in age to the Lochinvar and Allandale Formations.

Fauna II, found in the Bowen Basin in the lower part of the Middle Bowen Beds, occurs in the Farley Formation and apparently in the lower part of the Branxton Formation. The '*Fenestella* Zone' does not appear to be younger than Fauna IIIA. Fauna III, found in the Bowen Basin in the middle part of the Middle Bowen Beds, appears to be represented in the upper part of the Branxton, and Fauna IV, from the upper part of the Middle Bowen Beds, in the Muree and Mulbring Formations.

The faunal evidence available suggests closer links between the two basins during Fauna II and IV time than in Fauna III time. A widespread transgressive phase associated with the incoming of Fauna IV, possibly accompanied by a breakdown of previous barriers, may explain the entry of some new species into the Bowen Basin. A consistently cooler climate is suggested for the Sydney Basin.

The foraminifers have been examined by A. R. Lloyd, who considers the samples too few to permit any conclusions on their vertical and horizontal distribution. He records calcareous foraminifers from the Mulbring Formation — previously it was thought that they did not occur above the Branxton Formation.

INTRODUCTION

The collection of fossils on which this paper is based was made by E. A. Hodgson and myself in February 1962. At the same time, Hodgson made a special collection of samples for palynological examination.

Although large collections of fossils from the Hunter Valley are available, particularly at the Australian Museum, Sydney, the localities of many of the specimens are not set out in enough detail to allow precise conclusions on their stratigraphical position to be formed. The present collection was made from known stratigraphical horizons in order that the faunal sequence could be examined and compared with that in the Bowen Basin, where I have been working since 1960.

Arrangements for the visit were made with Dr F. W. Booker, Government Geologist of the Geological Survey of New South Wales, and Mr A. Ritchie of the University of Newcastle. We were taken to localities in the field by Mr M. G. McKellar, at that time seconded from the Geological Survey of New South Wales to the Hunter Valley Foundation, and by Mr B. Engel and Mr A. Ritchie of the University of Newcastle. These and Mr J. H. Rattigan of the University of Newcastle supplied important information, and we are most grateful to them all for the trouble they have taken for this study.

Except for the spiriferoids, species have been identified from the published descriptions. Most of the spiriferoids (including the Ingelarellinae) are so badly in need of review that, in most cases, use of formal names has been avoided. Some comparisons, however, have been made with species recently described by K. S. W. Campbell (1959, 1960, and 1961) from Queensland. The species, as a whole, have been especially compared with those occurring in the Bowen Basin, Queensland. The dielasmatids from the collection have not been considered as they have been forwarded to K. S. W. Campbell of the Department of Geology, School of General Studies, Australian National University, who has included them in his recently completed description of the Australian Permian terebratuloids (Campbell, 1965).

The fossils appear to range in age from lowermost Permian to Upper Permian (using a twofold division of the Permian). The evidence for this is reviewed elsewhere (Dickins, MS.).

The foraminifers, which are listed with the other phyla, have been identified by A. R. Lloyd. He concludes that 'the important result of the investigation was the discovery of calcareous foraminifers, *Frondicularia* cf. *limpida* Crespin, 1958, and *Rectoglandulina serocoldensis* (Crespin, 1945) ? (originally placed in the genus *Nodosaria*), from the Mulbring Formation. Crespin, in Raggatt & Crespin (1940) and in Appendix 4 in Reynolds (1956), considered that calcareous foraminifers, and in particular the genera *Frondicularia, Nodosaria,* and *Geinitzina,* did not extend above the Branxton. This discovery of calcareous foraminifers in the Mulbring adds support to the statement of Reynolds (1956, p. 16), that "they are not limited to any stratigraphical horizon but rather restricted by some factor such as ecological conditions". It also indicates that the presence of calcareous foraminifers is not a valid criterion for correlation with the Branxton Formation.'

CORRELATIONS

Recently four main faunal assemblages referred to as Faunas I, II, III, and IV, in ascending order of stratigraphical position, have been recognized in the marine rocks of the Bowen Basin. Fauna III has been further subdivided into Faunas IIIA, IIIB, and IIIC (Dickins, 1964a, 1966; Dickins, Malone, & Jensen, 1964). Fauna I is from the top part of the Lower Bowen Volcanics and Faunas

	STAGES OF URAL AREA	STAGES IN WESTERN PART OF AUSTRALIA		PERTH BASIN (Irwin River Area)	CARNARVON BASIN (North end of Kennedy Range)		CANNING BASIN (Fitzroy River Area)	BOWEN BASIN			SYDNEY BASIN (Hunter Valley)
									(Blenheim Area)	(Springsure Area)	
UPPER PERMIAN	TATARIAN	F		▥	▥		Liveringa Fm. Upper marine beds incl. Hardman Member	Upper Bowen Coal Measures		Bandanna Fm. (upper part)	Newcastle Coal Measures Tomago Coal Measures
	KAZANIAN	E		▥	Kennedy Gp.	Binthalya Fm.* Mungadan Sst.	Liveringa Fm. middle part	Middle Bowen Beds	Unit C (upper part of Middle Bowen Beds)	Bandanna Fm. (lower part) Mantuan *Productus* Bed Peawaddy Fm.	Mulbring Fm. Muree Fm.
LOWER PERMIAN	KUNGURIAN ?	D	2	▥	Byro Gp.	Coolkilya Gw. Baker Fm.	Liveringa Fm. (lower marine part) Lightjack and Balgo Members		? Unit B (=middle part of Middle Bowen Beds =Collinsville Coal Measures)	? Catherine Sst. Ingelara Fm.	? Upper part of Branxton Fm.
	ARTINSKIAN		1	Wagina Sst. Mingenew Fm.		Nalbia Gw. Wandagee Fm. Cundlego Fm. Bulgadoo Sh. Mallens Gw. Coyrie Fm.	Noonkanbah Fm.			Aldebaran Sst.	" *Fenestella* Zone" Lower part of Branxton Fm.
	?	C		Caryngina Fm. Irwin River Coal Measures High Cliff Sst.	Wooramel Gp.		Poole Sst. (upper part)		Unit A (lower part of Middle Bowen Beds)	Sirius Fm. Staircase Sst. Stanleigh Fm.	Greta Coal Measures Farley Fm.
	SAKMARIAN	B		Fossil Cliff Fm.	Callytharra Fm.		Nura Nura Member of Poole Sst.	Lower Bowen Volcanics		? Sediments with *Glossopteris* and lacking marine fossils (incl. Orion Fm.)	Rutherford Fm.
		A		Holmwood Shale* Nangetty Glacial Fm.	Lyons Gp. (with Carrandibby Fm. at top)		Grant Fm.				Allandale Fm. Lochinvar Fm.

**Either position doubtful or only partly referable to the subdivision*

Fig. 1. Correlation of Australian Permian sequences

II, III, and IV from the lower, middle, and upper parts, respectively, of the Middle Bowen Beds (Units A, B, and C of Dickins, Malone, & Jensen).

Each of these faunas is in turn compared with the faunas from the Hunter Valley. Previously published data, where relevant, as well as those derived from the present collection, are used in the comparison.

Correlations shown in the accompanying chart (Fig. 1), taken from Dickins (MS.), are based on conclusions made in this report.

Fauna I

Fauna I is similar to Fauna II (for faunal references see references given above). It is distinguished by containing *'Megadesmus'* cf. *antiquatus, 'Pachymyonia'* cf. *etheridgei,* a species of *Aviculopecten* with unspecialized ribbing, and a distinct species of *Notospirifer.* The evidence for correlating Fauna II with the Farley Formation and for regarding it as younger than the Allandale Formation is considered in the next section. The same arguments apply also to Fauna I, except for the four distinctive species. Of these, however, only *'Megadesmus'* cf. *antiquatus* would suggest correlation with the Allandale, above which it has not so far been recorded in New South Wales. *'P'. etheridgei* has been recorded from both the Allandale and Farley Formations, and in part seems synonymous with *Myonia farleyensis.* Specimens similar to *Aviculopecten* sp. are found in the Farley, and *Notospirifer* sp. is not known from New South Wales. Unfortunately the faunas from the Rutherford Formation are poorly known, but taking into consideration the conclusions from the next section, the evidence seems to indicate that Fauna I is slightly younger than the fauna from the Allandale Formation. If no break occurs above the Allandale, Fauna I may be equivalent in age to the Rutherford Formation. This is slightly higher than the correlation suggested from the base of the marine sequence in the Springsure area of the Bowen Basin by Fletcher (1945, p. 296; 1947, p. 354).

Because Fauna I is found in the top part of the Lower Bowen Volcanics and Fauna I or II in the bottom part of the Stanleigh Formation (the lowest marine formation in the Springsure area), all or most of the main part of the Lower Bowen Volcanics and the 'Undivided Freshwater Beds', underlying the Stanleigh Formation, are probably equivalent to the Lochinvar and Allandale Formations. The Lochinvar and Allandale Formations contain volcanics not dissimilar to those of the Lower Bowen. Both the Lower Bowen Volcanics and 'Undivided Freshwater Beds' (shown in the chart as 'Sediments with *Glossopteris* and lacking marine fossils'), contain *Glossopteris,* and are transitional into and do not appear to be substantially older than the beds above.

Fauna II

Fauna II has many resemblances to the fauna found in the Farley Formation in New South Wales. It also resembles that from the lower part of the Branxton

Formation, below the '*Fenestella* Zone'. The new species in common with the Allandale Formation appear to range higher both in New South Wales and Queensland.

Species in the present collection from the Farley Formation which are conspecific or closely related to species in Fauna II are:

Strophalosia cf. *jukesi*
Ingelarella cf. *plana* or *ovata**
Astartila? gryphoides
Megadesmus nobilissimus
Chaenomya sp.
Eurydesma hobartense
Aviculopecten cf. *subquinquelineatus*
Peruvispira cf. *elegans*

Of the species identified in the Allandale Formation, only *Ingelarella* cf. *profunda, Eurydesma hobartense,* and *Aviculopecten* cf. *tenuicollis* are closely related to species in Fauna II. Of these, however, the stratigraphical position of *I.* cf. *profunda* is not clear, and similar forms are found higher in the sequence (e.g., in HV 1a, p. 00); *E. hobartense* is found in the Farley and *A. tenuicollis* is long ranging. The Allandale, in addition, contains different species of *Ingelarella, Megadesmus, Eurydesma, Deltopecten,* and *Peruvispira.*

That Fauna II is younger than the Allandale is suggested also by the correlation of this fauna, possibly with that of the Callytharra Formation and Nura Nura Member of Western Australia, or, more probably, with the Wooramel Group — the Allandale fauna, in turn, seems closely related to that of the Lyons Group. The basis for these correlations was suggested in Dickins (1961) and further evidence is considered in Dickins (MS.).

The fauna of the lower part of the Branxton Formation below the '*Fenestella* Zone' can be related to Fauna II because it contains *Deltopecten, Terrakea* sp., *Strophalosia valida* (closely related to *S. brittoni*), and a *Notospirifer* similar to *N. extensus.* Recent work in the Bowen Basin has shown that *N. extensus* is probably characteristic of Fauna II but may range into Fauna IIIA. The uppermost correlation of the lower part of the Branxton Formation is limited by the '*Fenestella* Zone', which appears to be not younger than Fauna IIIA.

In these circumstances, the appearance of two species of *Ingelarella* in the lower part of the Branxton, similar to *I. maga* and *I. isbelli* of Fauna IV of

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* These specimens seem to have some of the features of *I. plana* and some of *I. ovata.* They have a sulcus similar to that in *I. ovata* but brachial adminicula which vary from those found in *I. ovata* to those found in *I. plana.* They are very similar to specimens in Fauna II from the St Lawrence Sheet area and from the Stanleigh Formation of the Bowen Basin (Dickins, 1964b).

Bowen Basin, might appear puzzling. Detailed examination has shown, however, that the *magna*-like form has a consistently sharper umbo than *I. magna* and that, in both, the adminicula are shorter and at a more primitive stage of development than in *I. magna* and *I. isbelli* and are similar to those found in *I. plana*. The data, therefore, from these two *Ingelarellas* are compatible with the other faunal evidence.

The ammonoid *Neocrimites meridionalis* Teichert & Fletcher, 1943, recorded apparently from the lower part of the Branxton Formation (see Glenister & Furnish, 1961), does not have a great deal of bearing on the correlation of the New South Wales and Queensland sequences, although its occurrence is compatible with the conclusions made.

Fauna III

Fauna III, which in the Bowen Basin is found in the middle part of the Middle Bowen Beds, is poorly represented in the collection made from the Hunter Valley, and indeed seems poorly developed in other areas of Permian outcrop in New South Wales. Only a relatively few species are recorded from the '*Fenestella* Zone', although the Zone is rich in numbers of specimens. *Strophalosia* cf. *jukesi* or *preovalis* and *Ingelarella* related to *I. plica* and *I. plana* suggest an age not younger than Fauna II, whereas *Notospirifer* sp. and *Myonia* sp. suggest equivalence to Fauna III. It seems unlikely that the '*Fenestella* Zone' can be younger than Fauna IIIA.

The fauna of the upper part of the Branxton Formation is represented only by a few species from a single locality. It is probably equivalent to Fauna III.

Fauna IV

Fauna IV, which in the Bowen Basin is found in the upper part of the Middle Bowen Beds, is well developed in the Muree and Mulbring Formations. Because of lack of information from the uppermost part of the Branxton Formation it is not known whether it first appears somewhat lower down in the sequence.

Its presence in the Muree Formation is indicated especially by forms closely related to or conspecific with *Terrakea solida, Strophalosia ovalis,* and *Neospirifer* sp. B. In the Mulbring it is indicated by *Myonia carinata* and *Chaenomya* sp. It seems likely that the upper boundaries of the Mulbring Formation and the Middle Bowen Beds are not very different in age. The occurrence of *Keeneia*-like forms throughout the sequence in the Hunter Valley into the highest part of the Mulbring is of interest, as this genus is not known in the Bowen Basin above the basal part of the beds with Fauna II.

PALAEOGEOGRAPHICAL IMPLICATIONS

Marine faunas equivalent in age to those of the Lochinvar and Allandale Formations seem to be absent from the Bowen Basin and, therefore, whereas Permian marine sedimentation started in the Hunter Valley in early Sakmarian time, it did not begin in the Bowen before late Sakmarian.

The close relationship of Faunas II and IV with faunas in New South Wales indicates similar climatic and sedimentary environments and probably direct links, at these times, between the two basins. Faunas equivalent to Fauna III are poorly developed in New South Wales, and the two basins were possibly isolated either by climatic or geographical factors. During this time, however, some links were apparently maintained between Queensland and Western Australia (see Dickins MS.). In these circumstances Fauna II species may have lingered on longer in New South Wales than in Queensland and the '*Fenestella* Zone' may be younger than IIIA. The alternative explanation accepted in the previous section, that the '*Fenestella* Zone' is not younger than IIIA, is regarded as more probable.

The close relationship of Fauna IV with that of the Muree and Mulbring Formations may indicate the breaking down of a barrier between the two basins and may explain the absence from the Bowen Basin of forms apparently ancestral to *I. magna* and *I. isbelli,* which occur in the lower part of the Branxton Formation. The incoming of Fauna IV in the Bowen Basin, and probably also in the Sydney Basin, corresponds to a widespread transgressive phase.

The occurrence of the *Keeneia* group of forms as late as the Mulbring Formation and the consistently greater differences between the New South Wales and Western Australian faunas may indicate persistent cooler conditions in New South Wales.

On the basis of conclusions presented in this paper the pelecypod genus *Deltopecten* is believed to have disappeared from Western Australia, Queensland, and New South Wales at about the same time.

IDENTIFICATIONS

Dalwood Group (Lower Marine)

Lochinvar Formation

HV6. 0.3 miles north of Lochinvar station in small cut on western side of road from station to convent on New England Highway — 'Gastropod horizon', recorded as 1280 feet above base of formation.

Gastropods

Peruvispira allandalensis Fletcher, 1958.

Foraminifera
  Bathysiphon sp.

Allandale Formation

HV7. Railway cutting between Lochinvar and Allandale stations, under overhead bridge. Singleton 4-mile Sheet, 444E, 955 N.

Brachiopods
  Ingelarella sp. A. (wide with shallow sulcus and low fold).

Pelecypods
  Phestia sp.
  Merismopteria sp.
  Eurydesma cordatum Morris, 1845.
  Eurydesma hobartense (Johnston, 1887).
  Aviculopecten sp. (moderate rib complexity).
  Schizodus sp. A. (umbo rather rounded, slightly carinate).
  Schizodus sp. B. (umbo rather sharp and more carinate than sp. A.)
  Small *Stutchburia* or *'Megadesmus' cuneatus* Sowerby, 1838.

Gastropods
  Planikeeneia cf. *minor* Fletcher, 1958.

HV9a. Railway cutting between Lochinvar and Allandale stations, 400 yards east of Allandale station.

Brachiopods
  Ingelarella sp. A.

Pelecypods
  'Megadesmus' antiquatus Sowerby, 1838 (the more elongated form is referred to as *'M' antiquatus*. It may be a synonym of *'M' cuneatus*).

HV10. Harpurs Hill, cutting on south side of New England Highway, near crest of hill, apparently same horizon as HV9a. Singleton 4-mile Sheet, 443E, 957N.

Brachiopods
  Ingelarella sp. A.
  Neospirifer sp. ind.

Pelecypods
  Possible small *'Megadesmus' cuneatus*.
  Megadesmus globosus Sowerby, 1838.
  Merismopteria sp.
  Eurydesma hobartense
  Stutchburia sp. ind.
  Schizodus sp. B.
  Minilya sp. nov.

Gastropods
  Keeneia ocula (Sowerby, 1838).

Conulariid

HV21. Pokolbin Area. ¼ mile south-east of road junction at foot of Mount View (junction of Bellbird and Cessnock roads, near abandoned farm house).

Brachiopods

Ingelarella cf. *profunda* Campbell, 1961.
Neospirifer sp.

Pelecypods

Eurydesma hobartense.

Conulariid

Aviculopecten cf. *tenuicollis* (Dana, 1847).

Fenestellid and stenoporid bryozoans.

Top of Allandale Formation or Base of Rutherford

HV8. From erosion channels on stock route, 200 yards east of Allandale station.

Foraminifera

Ammobaculites sp.
Haplophragmoides sp.
Bathysiphon sp.

HV9b. Railway cutting between Lochinvar and Allandale stations, 300 yards east of Allandale station.

Brachiopods

Ingelarella sp. A.
Neospirifer sp. A.
Pseudosyrinx sp.

Pelecypods

Myonia cf. farleyensis Dun, 1932.
Deltopecten sp. ind.
Streblopteria cf. parkesi (Fletcher, 1929).

Fenestellid and stenoporid bryozoans

Rutherford Formation

HV24. Near Jacksons Hill. On obscure track to south of road. About 3½ miles east-north-east of Cessnock. Singleton 4 mile Sheet, 431E, 942.5N.

Pelecypods

Stutchburia cf. *randsi* (Etheridge Jnr, 1892).
Aviculopecten sp. ind.

Fenestellid bryozoans

Farley Formation

HV12. Ravensfield (Browns) Quarry, south-west of Farley. 'Ravensfield Sandstone'.

Brachiopods

Ingelarella sp.
Pseudosyrinx sp.

Pelecypods

Megadesmus nobilissimus (de Koninck, 1877).
Astartila? gryphoides (de Koninck, 1877).
Astartila? sp. (could be an *Astartella*).

Pyramus? sp.

Chaenomya sp. (similar to species from Fauna II of Bowen Basin, but may be a different species).

Palaeosolen? sp.

Merismopteria sp.

Eurydesma cf. *hobartense* (other specimens in the BMR Museum from the Ravensfield quarry confirm the occurrence of *E. hobartense*).

Aviculopecten cf. *subquinquelineatus* (McCoy, 1847).

Stutchburia farleyensis Etheridge Jnr, 1900 (not very different from *S. compressa.* Some specimens may have radiating ornament).

Schizodus sp. C. (rather rounded carina, umbo pointed towards front).

Gastropods

Warthia sp.

Mourlonia sp.

Peruvispira cf. *elegans* Fletcher, 1958 (differs from *P. allandalensis* and is similar to species from Fauna II of the Bowen Basin. It shows, however, some differences from *P. elegans*).

Macrochilina sp.

Conulariid

HV13. Farley Road. About 120 yards north of railway bridge crossing road immediately east of station. Stratigraphically in middle part of formation.

Brachiopods

Lissochonetes sp.

Ingelarella cf. *plana* or *ovata* Campbell (very similar to specimens from 'Eurydesma Limestone', Dilly, Bowen Basin).

Pelecypods

Astartila? gryphoides.

Myonia farleyensis.

Merismopteria sp.

Atomodesma sp.

Stutchburia farleyensis.

Schizodus sp. C.

Gastropods

Keeneia sp. ind.

Foraminifera

Ammobaculities woolnoughi Crespin & Parr, 1940 (abundant).

HV22. About ½ mile along track running south from old Mountain View school. Fossils are from 2nd ridge along the track.

Brachiopods

Strophalosia cf. *jukesi* Etheridge Jnr, 1880.

Ingelarella cf. *plana* or *ovata.*

Pelecypods

Phestia sp. (similar to species at HV16 from lower Branxton).

Myonia farleyensis.

Stutchburia farleyensis.

Gastropods

Peruvispira cf. *elegans.*

Maitland Group (Upper Marine)

Branxton Formation

(a) Lower Part.

HV16. In Redhouse Creek about ½ mile east of junction of Dalwood Road with New England Highway, at junction with small tributary. Singleton 4-mile Sheet 438E 963N.

Brachiopods

Terrakea sp. (not thickened at umbo, similar or conspecific with species in Faunas II and IIIA of Bowen).

Strophalosia (Wyndhamia) valida Booker, 1929 (these specimens are close to or possibly even conspecific with *S. brittoni* Maxwell, 1954, from Fauna II, which they resemble in the flattish, thickened brachial valve and the shape of the pedicle valve and its elongated abductor muscle scars).

Ingelarella sp. B (similar to *I. isbelli* but dorsal adminicula short and of *I. plana* type).

Ingelarella sp. C (somewhat similar to *I. magna* but umbo sharper and adminicula of less advanced type).

Notospirifer sp. (similar to *N. hillae* or *N. extensus* and same as at HV1b).

Neospirifer sp. A.

Trigonotreta sp. (same as in sandstone at Jervis Bay. Differs from alate form in Fauna IV by lesser complexity of ribbing in sulcus).

Pelecypods

Phestia sp. (may be new, same as in sandstone at Jervis Bay).

Deltopecten sp.

HV23. Dalwood Road. From Redhouse Creek about 1 mile east of junction with New England Highway. Close in stratigraphical position to HV16.

Brachiopods

Ingelarella sp. B.

Notospirifer sp. (same as at HV16).

Neospirifer sp. A.

Trigonotreta sp. (same as at HV16).

Gastropods

Keeneia cf. *occasa* Fletcher, 1958.

(b) '*Fenestella* Zone'

HV1a. Railway cutting between 1100 and 1600 yards west of Branxton station, 117 feet above base of zone (from section measured by M. G. McKellar).

Brachiopods

Ingelarella spp. (forms comparable to *I. profunda, I. plana,* and *I. plica* seem present).

Notospirifer sp. (similar to species at HV16 and HV23 — short adminicula in brachial valve).

Pelecypods

Merismopteria sp.

Fenestellid bryozoans

HV1b. As for HV1a, 137-140 feet above base of zone (from section measured by M. G. McKellar).

Brachiopods

Terrakea sp.

Strophalosia cf. *jukesi* Etheridge Jnr, 1880, or *preovalis* Maxwell, 1954 (seems identical with Queensland species).

Ingelarella cf. *plica* or *angulata* Campbell (one specimen has furrow in sulcus as in *I. plica,* others lack it as in *I. angulata,* adminicula relatively short).

Ingelarella cf. *plana* Campbell, 1960 (flattish sulcus).

Notospirifer sp. (as in HV1a).

Neospirifer sp. A.

Trigonotreta sp. (sulcus relatively simple).

Cancellospirifer? sp.

Pelecypods

Astartila sp. (seems to be an undescribed species).

Myonia sp. (not *M. carinata* — similar to *Myonia* in Fauna III and possibly Fauna II of Bowen Basin).

Gastropods

Keeneia sp. ind.

Solitary corals

Fenestellid bryozoans

Foraminifera

Bathysiphon sp.

HV2. Railway bridge at Branxton: Cessnock-Branxton road, Singleton 1-mile Sheet, 360E, 617N. Exact stratigraphical position not clear but close to '*Fenestella* Zone'.

Brachiopods

Strophalosia cf. *preovalis.*

Neospirifer sp. A.

Pseudosyrinx sp.

Bryozoan encrusting pebble 1 inch across.

(c) Upper Part

HV20. Bow Bow Creek, in section measured by M. G. McKellar from 151°24′50″E, 32°53′40″S (5.2 miles south-east Cessnock post office) to 151°26′15″E, 32°55′30″S, between '*Fenestella* Zone' and Muree Formation (or Member), 753 feet above top of '*Fenestella* Zone'.

Brachiopods

Strophalosia cf. *jukesi* (spines fine — definitely not *S. clarkei,* but could be species in Ingelara Formation and is very similar to that in the '*Fenestella* Zone' and at Nowra Hill).

Pelecypods

Atomodesma (*Aphanaia*)? sp. (as in Fauna IV of Bowen Basin).

Streblopteria sp.

Corals

Thamnopora sp.

Crinoid stems

Fenestellid bryozoans

Foraminifera

- *Ammodiscus multicinctus* Crespin & Parr, 1940.
- *Bathysiphon* sp.
- *Textularia* sp.
- *Ammobaculites* sp.

Glendonites

Muree Formation

HV5. Quarry immediately north of convent school. Newcastle 4-mile Sheet, 456E, 955N.

Brachiopods

- *Terrakea* sp. (small and not thickened at umbo).
- *Strophalosia clarkei* (Etheridge Snr, 1872) (approaches *S. ovalis*).
- *Ingelarella angulata* Campbell, 1959.
- *Notospirifer* cf. *minutus* Campbell, 1960.
- *Trigonotreta* sp. (fairly simple rib pattern in sulcus).

Pelecypods

- *Chaenomya* sp. (close to *Chaenomya* from Fauna IV of Bowen Basin).
- *Pyramus*? cf. *undatus* (Dana, 1847).

HV14a. Newcastle-Singleton railway line, cutting 2 miles west of Branxton station, east end.

Brachiopods

- *Strophalosia clarkei.*
- *Ingelarella* sp.
- *Neospirifer* sp. A.
- *Neospirifer* cf. sp. B.
- *Trigonotreta* spp. (one fairly alate with one rib in sulcus, others with considerable subdivision in sulcus).

HV14b. As for HV14a, in cutting 100 yards to west.

Brachiopods

- *Strophalosia clarkei.*
- *S. ovalis* Maxwell, 1954.

Pebbles from this locality include acidic volcanics.

HV14c. As for HV14a and b, west end of cutting about 50 yards west of HV14b.

Brachiopods

- *Strophalosia ovalis.*
- *Ingelarella* sp.?
- *Neospirifer* sp. A.
- *Trigonotreta* sp.?
- *Cancellospirifer*? sp.

Many pebbles of acidic volcanic material and fragments of yellow and greenish clay.

HV18b. Base of 'Bolwarra Conglomerate' in Bow Bow Creek. In same section as HV20 — from base of Muree Formation (or Member).

Brachiopods

Ingelarella sp. (very flat sulcus).

Ingelarella oviformis (McCoy, 1847)?

Neospirifer sp. A.

Neospirifer sp. B.

Trigonotreta sp. (alate form with complex rib pattern in sulcus and on fold).

Cancellospirifer? sp.

HV18c. As for 18b, but scree in creek derived from base of 'Bolwarra Conglomerate'.

Brachiopods

Ingelarella sp. (lacks sulcus and much thickened at umbo).

Ingelarella oviformis (McCoy, 1847)? (some specimens have groove in sulcus, but others lack groove).

HV19. Bow Bow Creek, below top cliff-forming unit of Muree. In same section as HV20, HV18b, and HV18c, 139 feet above base of Muree (from section measured by M. G. McKellar).

Brachiopods

Terrakea sp. (externally similar to *T. solida,* but could be identified as *T. brachythaera*).

Strophalosia ovalis.

Strophalosia cf. *clarkei.*

Ingelarella sp. (of all specimens in collection is the one most like *I. magna*).

Neospirifer sp. B.

Mulbring Formation

HV3. Junction of Minimbah stock route and New England Highway. Singleton 1-mile Sheet, 138E, 644N.

Foraminifera

Ammodiscus multicinctus Crespin & Parr, 1940 (common).

A. erugatus Crespin, 1958?

Bathysiphon sp.

Textularia bookeri Crespin, 1958?

HV4. Singleton railway bridge, north or left bank immediately west of bridge. Singleton 1-mile Sheet, 161E, 740N.

Brachiopods

Terrakea cf. *brachythaera.*

Ingelarella sp. (large, of *I. magna* type, but umbo sharper and sulcus different).

Pelecypods

Myonia carinata.

Chaenomya sp. (similar to or identical with species in Fauna IV. Among described species possibly similar to *C. etheridgei* of de Koninck (1877), *C. audax* of Dana (1849) and *C. curvatum* of Morris (1845).

Stutchburia? sp. ind.

Gastropods

Warthia sp.

Planikeeneia occasa Fletcher, 1958?

Large Crinoid Cups

Large Stenoporid Bryozoans

Ostracods

Foraminifera

Textularia bookeri Crespin, 1958 (abundant).

T. improcera Crespin, 1958.

Ammobaculites woolnoughi Crespin & Parr, 1940 (common).

Ammodiscus multicinctus Crespin & Parr, 1940.

Bathysiphon sp.

Frondicularia cf. *limpida* Crespin, 1958.

Rectoglandulina serocoldensis (Crespin, 1945)?

Glendonites

HV17. Mt Vincent-Ellalong road, about 3½ miles from Mt Vincent.

Foraminifera

Ammodiscus multicinctus Crespin & Parr, 1940 (abundant).

Bathysiphon sp.

Sun Oil Bore

The bore was drilled immediately west of Ravensfield quarry, inside of entrance gate on the north side of the road. J. H. Rattigan has supplied the information that the drilling began just below the Ravensfield Sandstone at the base of the Farley Formation. The base of the Rutherford Formation was reached at about 1248 feet. Beneath this, alternating basalt and lapilli tuff with a small amount of sandstone and mudstone were encountered, which indicate the Allandale or Lochinvar Formation. The following results were obtained, but the fauna was too poor to permit any correlation:

1005-1107 feet	*Nodosaria raggatti* Crespin, 1958?
1107 feet; 1185 feet; 1195 feet; 1245 feet	Barren.
1255-1300 feet	*Ammobaculites sp.; Haplophragmoides?* sp.
1430 feet	*Ammodiscus erugatus* Crespin, 1958?
1435-1440 feet	Barren.
1450 feet	Fragmentary Foraminifera.
1583 feet; 1697-1710 feet; 1897 feet; 1960 feet	Barren.

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EARLY MIDDLE CAMBRIAN TRILOBITES OF THE LITCHFIELD AREA, N.T.

by C. G. Gatehouse

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SUMMARY

Early Middle Cambrian trilobites from the Litchfield area of the Northern Territory include *Gunnia lutea* gen. et sp. nov., *Probowmania(?) fortis* sp. nov., *Ellotia dimota* gen. et sp. nov., and *Piaziella cherria* sp. nov., all of which are described here. *Redlichia* occurs only as a free cheek; its presence indicates an early Middle Cambrian age for the 'Tindall Limestone'.

INTRODUCTION

The Litchfield area occupies the western edge of the Pine Creek 1 : 250,000 Sheet area of the Northern Territory. It is about 20 miles east of Anson Bay and the mouth of the Daly River. The area, which is of low relief, is drained by the Reynolds and Daly Rivers. According to Malone (1962) the 'western plains consist of extensive swamps, alluvial flats and low gently undulating plains'.

A history of geological investigations conducted in this area has been given by Malone (1962). Noakes (1964), as a result of his reconnaissances proposed the name Elliot Creek Formation for 'a succession of apparently thin beds of sandstone, shale and limestone which lie horizontally in most of the outcrops examined . . . . .' and described it as 'basal beds of hardened sandstone overlain by brown somewhat flaggy rocks similar in appearance and grainsize to sandstones of the Daly River Group. Shale, sandstone and limestone appear higher in the sequence and appear to alternate . . . . . the age seems to be Palaeozoic'.

According to Öpik (1956), M. A. Randal in 1955 discovered ptychopariid trilobites and *Paterina*-like brachiopods in the Elliot Creek Formation; Öpik also reported that, below and conformable with the ptychopariid horizon, *Redlichia* occurs in limestone interbeds.

On the Pine Creek 1 : 250,000 Geological Sheet (Malone, 1962), Noakes' Elliot Creek Formation is mapped as 'Tindall Limestone' and 'Daly River Group'. The two localities described below are both represented as 'Tindall Limestone' though the identification is somewhat doubtful (Walpole et al., 1967).

PALAEONTOLOGY

The trilobites described in this paper were collected by M. A. Randal and A. A. Öpik of the Bureau of Mineral Resources from two localities, NT6 and NT7. Both lie just west of Elliot Creek and 13 kilometres north-west of Litchfield homestead.

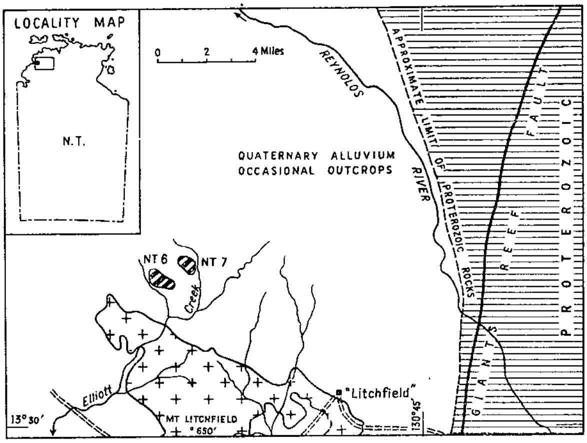

Fig. 1. Litchfield area of Pine Creek 1:250,000 sheet, showing Localities NT6 and NT7

NT6, the more southerly outcrop, is a dark grey mottled bituminous sandy limestone. Digestion of part of the sample in acid revealed no trace of microfossils. NT7, 2 kilometres north-east from NT6, is a ferruginous brown fine-grained mudstone; it is thinly bedded with fossils on bedding planes only.

Fossils contained in these rocks are ptychoparioid and ptychopariid trilobites; *Redlichia; Paterina*-like brachiopods (Öpik, 1956); *Biconulites;* and occasional sponge spicules. The presence of *Redlichia* and *Biconulites* suggests an early Middle Cambrian age (Öpik, 1956). The age of the ptychoparioid (and ptychopariid) trilobites, which are associated with *Biconulites,* is also early Middle Cambrian.

The trilobites from NT7 appear to fall into four genera and five species; two of the genera and all the species are new and undescribed. Their preservation, as casts and moulds in mudstone, has erased much detail: all the carbonate material has been leached out, and only the phosphatic brachiopods retain their original shells.

Family REDLICHIDAE Poulsen, 1927

Genus REDLICHIA Cossman, 1902

REDLICHIA sp.

(Pl. 6. fig. 3.)

Material

Two right free cheeks, one of which is here illustrated (CPC 6818, Pl. 6, fig. 3).

Description

Eye base long, almost reaching posterior margin, edge upturned. Border wide, almost flat; posterior border present, slightly crossed. Genal spine well advanced and continuous with lateral border. Advanced posterior margin straight. Angle between genal spine and margin 50°. Free cheek surface very slightly convex, surface probably very finely granulate. Genal spine with subparallel longitudinal terrace lines on upper surface. On internal surface, veins are only just visible.

Discussion

According to A. A. Öpik (personal communication) these free cheeks cannot be assigned to either *R. idonea* or *R. forresti,* which are the Australian species whose cheeks are known. *R. idonea* also has a straight margin and an angle of 50° between the spine and the posterior margin, but the cheek is relatively narrow. Moreover, free cheeks alone are insufficient for a specific identification in the absence of other parts.

Locality and age

The location of NT6 is given on the introduction, and the age of the rocks at NT6 is *Redlichia*-time, that is, early Middle Cambrian.

Superfamily PTYCHOPARIACEA Matthew, 1887

Familiae Incertae (?)

With the exception of *Redlichia, Probowmania (?),* and *Piaziella,* the trilobites here described are placed as 'familiae incertae(?)'. They are certainly Ptychopariacea, but because they are 'cranidial genera', and Öpik (1961, p. 149) has created new families on the basis of numbers of segments in the thorax, they cannot reasonably be included in the family Ptychopariidae. The assignment of cranidial genera to the family Ptychopariidae is therefore subject to query.

Genus GUNNIA nov.

GUNNIA LUTEA gen. nov. et sp. nov.

(Pl. 5, figs 10, 16; text-fig. 2.)

Material

Numerous almost complete cranidia, preserved in ferruginous mudstone. The holotype (CPC 6813) is an almost complete cranidium 8 mm long and very slightly flattened.

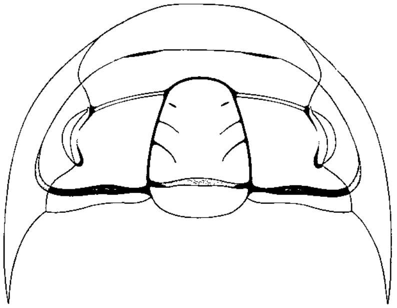

Fig. 2. *Gunnia lutea* **gen. nov. et sp. nov., cranidium.**

Description

Cranidium slightly wider than long, relatively large. Glabella half cranidial length, tapering with truncate front. Glabellar furrows partly effaced: three only are preserved; S3 forms a pit. Brim convex, downsloping in front, one-quarter of glabellar length. Rim flat, wide, width about half glabellar length, tapering laterally. Interocular cheeks slightly more than three-quarters of glabellar width, cheek surface slightly convex and rising up to palpebral lobes. Anterior ends of palpebral lobes narrow rapidly to form a small, sharp, outwardly directed peak extending over part of anterior facial suture. Posteriorly, palpebral lobes bluntly rounded; palpebral furrow distinct except for central portion, which is a broad shallow trough. Posterolateral limbs longer than wide, for half their length almost parallel-sided, tips bluntly triangular. Ocular ridges narrow, distinct, very slightly curved, forming angles of 110° with axis. Distinct gap between ridge and palpebral lobe, ridge apparently not crossing axial furrow. Anterior facial sutures diverging 20° from axial direction; converging in front of anterior marginal furrow, reaching margin at a point just adaxial to eyes. Occipital ring triangular, not bearing node; occipital furrow a little deeper at sides than on top. In front of glabella, axial furrow a change of slope only, laterally a distinct furrow. Fulcral points and suture at anterior margin equidistant from margin.

Free cheek narrow, almost flat, border half width of cheek, genal spine two-thirds cheek length.

Thorax and pygidium unknown.

Differential diagnosis

Gunnia lutea gen. nov. et sp. nov. is unique amongst the Ptychopariacea because of the combination of relatively large eyes, broad flat brim, and flat wide rim. *Gunnia lutea* can be compared with *Ptychoparia spitiensis* Reed, 1910, *Probowmania* Kobayashi, 1935, some members of the subfamily Antagminae, and some lower Cambrian Ptychoporiacea. *P. spitiensis* has small eyes, a relatively narrow interocular cheek, and a large glabella. *Probowmania* has similar general features, but has a subparallel-sided glabella. The latter genus, by its association with *Redlichia* in the Man-T'o shale in Shantung Province (Kobayashi, 1935) and Australian standards of dating, is of early Middle Cambrian age.

GUNNIA CONVEXA sp. nov.

(Pl. 6, fig. 1; text-fig. 3.)

Material

One cranidium, illustrated, preserved in ferruginous mudstone; holotype CPC 6815, Plate 6, figure 1.

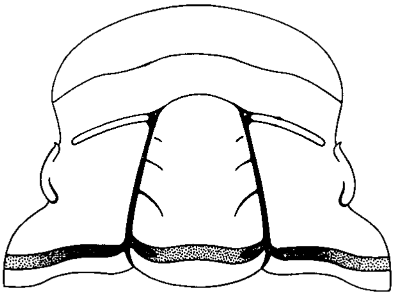

Fig. 3. *Gunnia convexa* **sp. nov., cranidium.**

Diagnosis

A *Gunnia* with a convex cranidium and a rim one-third of glabellar length and three-quarters of brim width (sagittally). Anterior marginal furrow shallowest on axial line. Glabella tapering and almost straight-sided. Anterior facial sutures slightly divergent, strongly convergent over the rim. Ocular ridges very weak, apparently only a step down in front of interocular cheeks. Fulcral points farther apart by one-third at the posterior margin than facial sutures at anterior margin.

Thorax and pygidium unknown.

Differential Diagnosis

G. convexa differs from *G. lutea* in the almost straight-sided glabella, the relative widths of the interocular cheeks, and the shape of the rim.

Genus PROBOWMANIA Kobayashi, 1935

PROBOWMANIA? FORTIS sp. nov.

(Pl. 7, figs 1a, 1b, 1c; text-fig. 4.)

Discussion of genus

Probowmania? fortis resembles *Probowmania* Kobayashi, 1935 (type species *Ptychoparia ligea* Walcott, 1913) in all respects except the proportions of some variable features: the rim is wider and flatter and the front of the glabella more truncate.

According to A. A. Öpik (in press) *Probowmania* belongs to the Ptychopariacea or even Ptychopariidae.

Material

Several cranidia preserved in a ferruginous sandstone. Holotype CPC 6819, Plate 7, figure 1a. A free cheek, CPC 6820, and a pygidium, CPC 6821, have been assigned to the species.

Description

Cranidium (length 8 mm) wider than long (length: width is 6 : 7)

Glabella almost half length of cranidium, subparallel sides, truncate in front. No glabellar furrows visible; about one-seventh of glabella lies in front of ocular ridges. Brim slightly downsloping and one-third of glabellar length inside (sagittally). Interocular cheeks slightly convex, almost horizontal, three-quarters width of glabella. Palpebral lobes three-sevenths of glabella long; anterior ends pointed and midway along cranidium; posterior end bluntly rounded. Palpebral furrow distinct except for shallow central portion. Posterolateral limbs broad-winglike, adaxial half parallel-sided, tips bluntly triangular. Ocular ridge weak, forming a step-down in front of interocular cheeks, not reaching axial furrow, slightly curved and forming angle of 118° to axis. Anterior facial sutures diverge 30°, converge over rim. Anterior marginal furrow a change of slope, axial furrow shallow but distinct at sides, only a change of slope at front. Occipital ring missing. Posterior marginal furrow wide, shallow, and directed backwards abaxially from fulcral points.

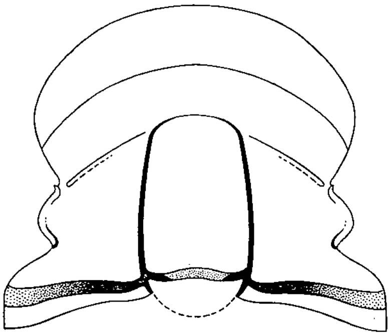

Fig. 4. *Probowmania fortis* **sp. nov., cranidium**

The free cheek CPC 6820 has been assigned to this species; it is the longest in the collections, and as far as can be ascertained the proportions of eye-length and facial suture are comparable with those of the cranidium.

The large pygidium CPC 6821 is of general ptychopariid design except that it is almost parallel-sided and the terminal piece truncated. The pygidium is transverse with a broad flat flange and an articulating half-ring present.

Diagnosis

Glabella almost parallel-sided; wide blunt posterolateral limb; wide flat brim, eyes less than half glabellar length.

Differential Diagnosis

Probowmania(?) fortis sp. nov. is a new species which is tentatively placed within the genus *Probowmania* Kobayashi 1935 by reason of its proportions and shapes of features. It differs from *P. ligea* (Walcott, 1913) in the wide flat rim and truncate glabellar front.

Discussion

P.(?) fortis occurs at locality NT7; it is therefore of early Middle Cambrian age, which is not inconsistent with the age of the genotype in China.

Genus ELLOTIA nov.

ELLOTIA DIMOTA sp. nov.

(Pl. 6, fig. 2a, 2b; text-fig. 5.)

Material

Three cranidia, the most complete of which has been selected as the holotype (CPC 6816, Pl. 6, fig. 2a).

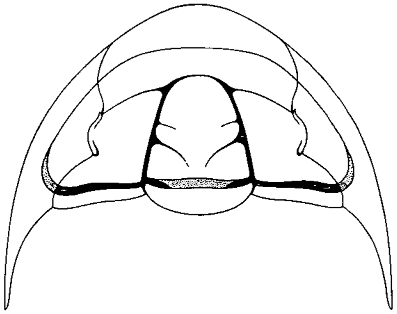

Fig. 5. *Ellotia dimota* **gen. nov. et sp. nov., cranidium**

Description

Cranidium convex, width three-quarters of length.

Glabella tapering, half as long as cranidium, sides slightly convex, front rounded. Glabella furrows very weak. Brim one-quarter of glabellar length, downsloping, convex. Rim half as wide again as brim, tapering laterally almost to nothing. Anterior margin of cranidium circular in plan. Interocular cheeks convex, rising slightly to palpebral lobes, three-quarters of glabellar width. Anterior end of palpebral lobe midway along cranidium, peaked, posterior end rounded; lobe half as long as glabella. Posterolateral limbs blunt, wing-like, base equal to half glabellar length. Very weak ocular ridges, a step-down in front of the interocular cheeks, slightly curved, not crossing axial furrow, form angles of 106° to axis. Anterior sutures diverge 20° from axial trace. At rim suture tends towards axis but remains almost parallel to glabellar side. Anterior marginal furrow a change of slope, almost straight in front of glabella, strongly curved at outer ends. Occipital ring a flat triangle with no apparent node; neck furrow wide, shallow, slightly deeper at sides. Posterior marginal furrow wide, of moderate depth, parallel to margin. Fulcral points just adaxial to eyes; facial sutures cut anterior margin well inside this position.

Thorax and pygidium missing.

Diagnosis

Cranidial width three-quarters of length; glabellar front rounded. Brim one-quarter of glabellar length. Rim half as wide as brim, laterally tapering to almost nothing. Anterior margin circular in plan. Ocular ridges form angles of 106° to axis.

Differential Diagnosis

Gunnia and *Ellotia* are closely similar. They differ in the degree of convexity, divergence of the anterior sutures, shape of rim and anterior margin.

Family PTYCHOPARIIDAE Matthew, 1887

Genus PIAZIELLA Lochman, 1947

The genus *Piaziella* Lochman, 1947 (*Piazella* of some later authors) was proposed to accommodate *Ptychoparia pia* Walcott, 1917; by Lochman's analysis it is a new genus. Walcott's original material was derived from the Mount Whyte Formation, Mount Stephen, Alberta, Canada; it is of Lower Cambrian age (Walcott, 1917). Rasetti (1951) figured another specimen of this species and also proposed a new species, *P. tuberculata,* based on the ornamentation of the cranidium.

The fauna at NT7 includes a trilobite cranidium which, by measurement and comparison, cannot reasonably be separated from the genus *Piaziella.*

PIAZIELLA CHERRIA sp. nov.

(Pl. 7, fig. 2; text-fig. 6.)

Material

One undistorted cranidium, holotype CPC 6921, Plate 7, figure 2, text-fig. 6.

Description and differential diagnosis

Piaziella cherria sp. nov. belongs to the genus *Piaziella* Lochman, 1947, by virtue of the relative proportions of glabella, interocular cheeks, rim, brim, and posterolateral limbs.

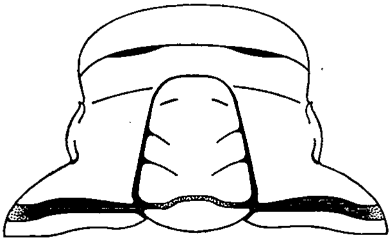

Fig. 6. *Piaziella cherria* **sp. nov., cranidium**

It differs from *P. pia* (Walcott, 1917) and *P. tuberculata* Rasetti, 1951, in the following details: anterior end of palpebral lobe opposite a point one-third of glabellar length from front of that unit; palpebral lobe almost half as long as glabella and slightly curved; brim proportionately narrower, rim flat; anterior facial sutures only slightly divergent.

P. pia has anterior ends of palpebral lobes opposite midpoint of cranidium; ocular ridges reach glabella one-third of length from front of glabella; brim wide, rim may be slightly convex, anterior sutures strongly divergent; eyes small.

P. tuberculata is strongly ornamented; the surface of *P. cherria* is unknown.

GLOSSARY OF TERMS

Cherria — Cherria (Gr.) waste or barren land, the nature of the country of the Litchfield area.

Convexa — Convexus (L.) convex.

Dimota — Dimotus (Gr.) rounded, alludes to rounded anterior margin.

Ellotia — (f) Elliot Creek, anagram of the name Elliot.

Fortis — Fortis (L.) chance, luck, no particular allusion.

Gunnia — (f) after Mrs Aeneas Gunn, who was a well-known figure in the north-western Northern Territory.

Lutea — Luteus (L.) meaning yellowish, the colour of the Elliot Creek Formation.

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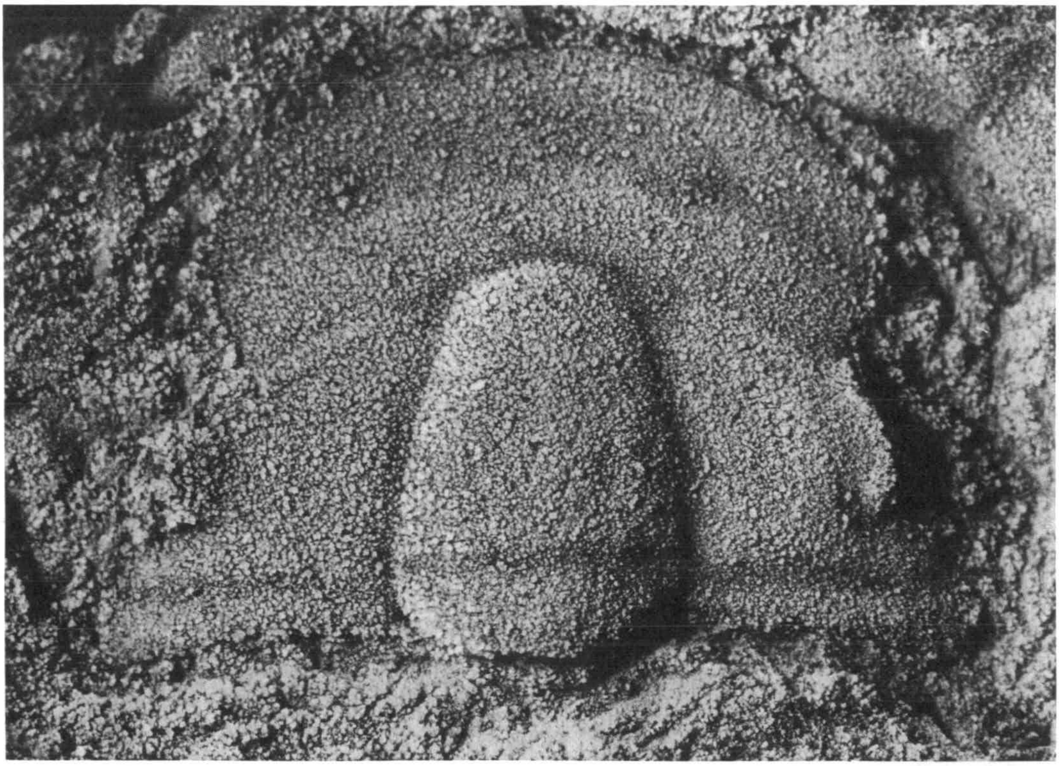
PLATE 5

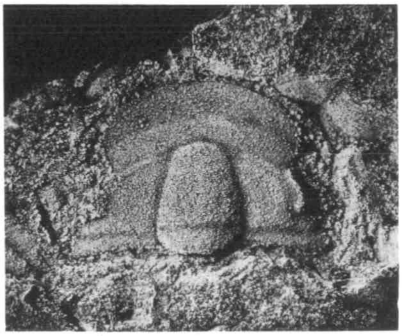
Figure 1a, b. — *Gunnia lutea,* gen. et sp. nov. top view.

Holotype cranidium CPC 6813. 1a x 10, 1b x 3.

2a, b, c. *Gunnia lutea,* another cranidium CPC 6814, 2a. top view, 2b. left lateral view, 2c. front view.

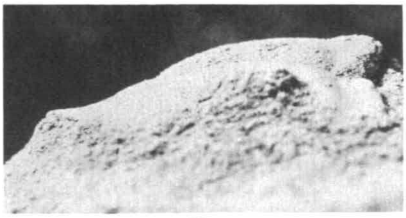


1a

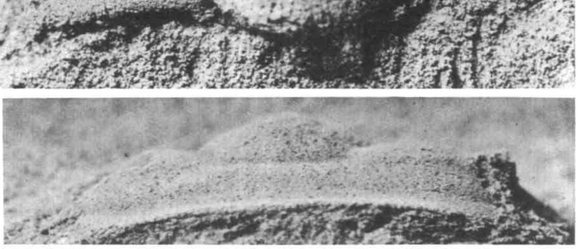


1b

2a



2b



2c

Gunnia lutea

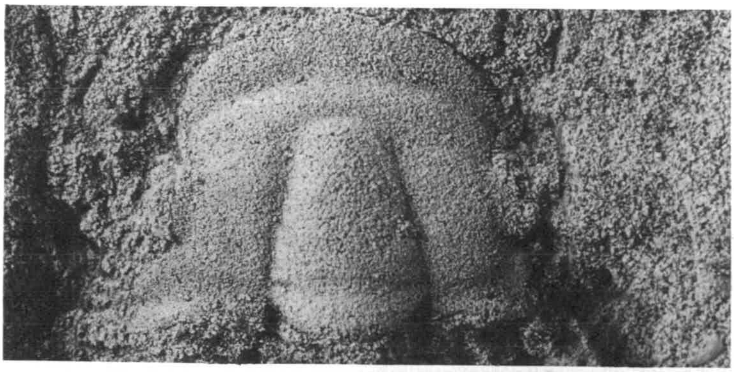
PLATE 6

Figure 1 — *Gunnia convexa,* sp. nov., top view cranidium.
Holotype CPC 6815, x 7.

2a. *Ellotia dimota* gen. et sp. nov., top view cranidium.
Holotype CPC 6816.

2b. *Ellotia dimota,* right free cheek, CPC 6817, ventral view.

3. *Redlichia* sp. right free cheek, CPC 6818, ventral view, x 4.



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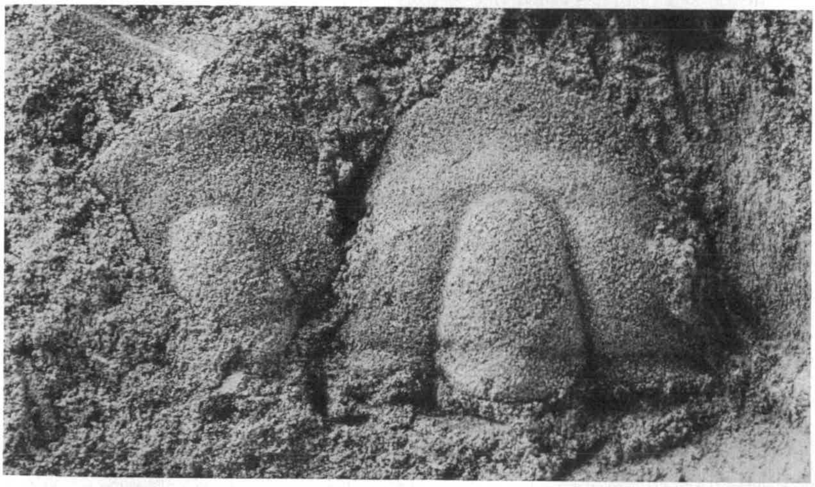
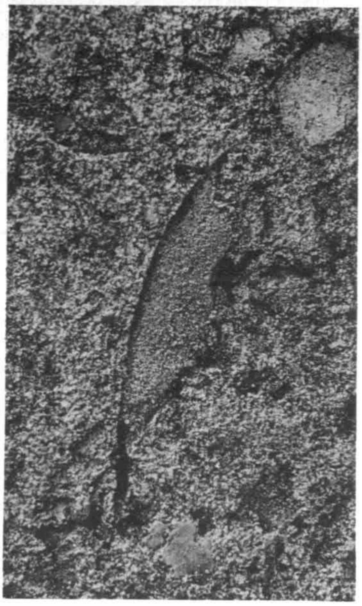


2a

3



2b

Gunnia, *Ellotia*, *Redlichia*

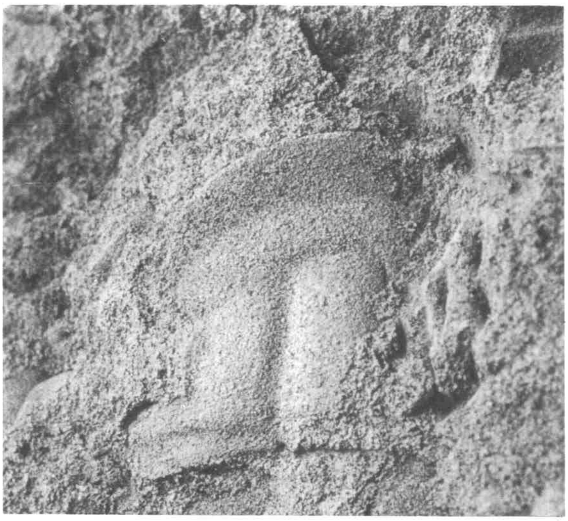
PLATE 7

Figure 1a. *Probowmania(?) fortis* gen. et sp. nov., top view cranidium.
Holotype CPC 6819, x 5.

1b. Left cheek CPC 6820 assigned to *P.(?) fortis,* x 3.

1c. Pygidium CPC 6821 assigned to *P.(?) fortis,* stereoscopic view, x 6.

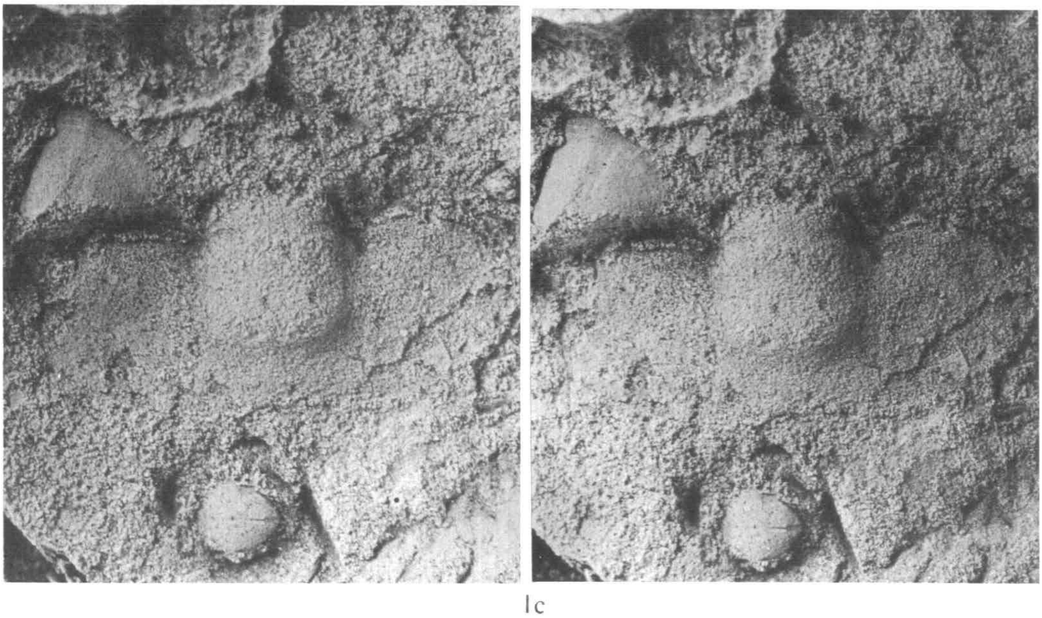
2. *Piaziella cherria* sp. nov. Top view cranidium.
Holotype CPC 6921, x 6.



1a

2

1b



1c

?Probowmania, Piaziella

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DEVONIAN SPORES FROM THE PERTNJARA FORMATION, AMADEUS BASIN, NORTHERN TERRITORY

by E. A. Hodgson

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SUMMARY

A spore assemblage from a cuttings sample of the Pertnjara Formation in Exoil Mereenie Water Bore No. 2 is described. It consists of only a few spores, but they include *Geminospora lemurata, Radiaspora* sp., and *Ancyrospora* spp., which are diagnostic of the Devonian. The spores are compared with similar forms from Australia and overseas and are of considerable value in determining the position of the sample in relation to the standard Devonian succession.

INTRODUCTION

Two bores were drilled in search of water for use in drilling Exoil Mereenie No. 1 Well, Amadeus Basin, Northern Territory. The second bore was drilled at latitude 23°59′25″S, longitude 131°33′06″E, to a total depth of 720 feet. The bore started in a siltstone in the lower part of the Pertnjara Formation and finished in a waterbearing sandstone, thought to be the sandstone that contains Middle or Upper Devonian *Bothriolepis* remains (J. G. Tomlinson, this Vol.) in outcrop above the Mereenie Sandstone.

OBSERVATIONS

All the cuttings from the Mereenie Water Bore No. 2, except one, were too oxidized to contain palynomorphs. The few spores in the cuttings from 680-700 feet, however, although carbonized, were well preserved. The forms recorded in the sample include:

Leiotriletes liebigensis sp. nov.

Geminospora lemurata Balme (relatively abundant).

Radiaspora darensis sp. nov. (rare).

Lophozonotriletes sp. (rare).

Auroraspora cf. *A. micromanifestus* (Hacquebard) Richardson (rare).

Ancyrospora parke sp. nov.

Ancyrospora amadei sp. nov.

Ancyrospora cf. *A. simplex* Guennel.

SYSTEMATIC DESCRIPTIONS

The spores described below are referred to the classification established by Potonié (1956; 1958; 1960). Most of the descriptive terminology is derived from these publications and from Potonié & Kremp (1955), Couper (1958), and Richardson (1960; 1962).

The specimens shown in Plate 8 occur in two permanent slides (MFP 3128.1 and MFP 3128.2) of the BMR palynology slide collection. Their position in the slides is given, in tenths of a millimetre, relative to a zero mark on the slide, according to the method outlined by Traverse (1958).

Anteturma SPORITES H. Potonié, 1893

Turma TRILETES Reinsch, 1881, Potonié & Kremp, 1954

Subturma AZONOTRILETES Luber, 1935

Infraturma LAEVIGATI (Bennie & Kidston, 1886) Potonié, 1956

Genus LEIOTRILETES (Naumova) Potonié & Kremp, 1954

Type species

Leiotriletes sphaerotriangulus (Loose); Bismark Seam, Ruhr, West Germany; Upper Carboniferous (Westphalian B).

LEIOTRILETES LIEBIGENSIS sp. nov.

(Pl. 8, fig. 1)

Description (based on eight specimens)

Spore semiangular to circular in polar view. Contact areas are relatively flat and give the proximal face a slightly pyramidal shape, distal face slightly convex. The Y-mark, 1.5-2 μ wide, has labra and is surrounded by a darkened area which narrows gradually towards the equator. Exine psilate, but under oil immersion fine concentric lines can be seen on the proximal surface.

Dimensions (eight specimens) Diameter 28-50 μ.

Holotype

Plate 8, figure 1, 34 μ diameter. Slide MFP 3128.1/158.161. Exoil Mereenie Water Bore No. 2, 680-700 feet.

Derivation of name

From Mount Liebig. The bore from which the sample was collected is located in the south-eastern corner of the Mount Liebig 1 : 250,000 Sheet area.

Genus GEMINOSPORA Balme, 1960

Type species

Geminospora lemurata Balme; Core between 2174 feet and 2186 feet, Pelican Hill Borehole, Gneudna Formation, Carnarvon Basin, Western Australia; Upper Devonian (Frasnian).

GEMINOSPORA LEMURATA Balme, 1960

(Pl. 8, figs 2, 3)

Geminospora lemurata Balme, 1960, *Palaeobotanist,* 9(1), 4-5, pl. 1, figs. 5-10

Description (based on eleven specimens):

Outline semiangular to circular in polar view, proximal face pyramidal, distal face slightly convex. The spore consists of a 3-5 μ exoexine enclosing a smooth, thin-walled (1 μ thick) mesosporoid of circular outline in polar view. The Y-mark is of uniform thickness of about 1 μ; it has weak labra and extends almost to the equator of the mesosporoid. In some specimens the exoexine is clearly made up of two layers of comparable thickness; a light inner layer and a darker outer one which on the distal surface is ornamented with irregularly shaped granules less than 1 μ high and up to 1 μ wide. Figure 3 shows a specimen in which the exoexine is partially separated from the mesosporoid and which has a darkening of the exoexine above the Y-mark. A similar darkening of the exoexine is shown in Figure 2, but in this specimen it is confined to the immediate vicinity of the distal pole.

Dimensions (eleven specimens): Diameter 39-66 μ.

Figured specimens

Plate 8, Figures 2 and 3. Slides MFP 3128.2/140.150, MFP 3128.1/124.086. Exoil Mereenie Water Bore No. 2, 680-700 feet.

Infraturma MURORNATI Potonié & Kremp, 1954

Genus RADIASPORA Hoffmeister, Staplin, & Malloy, 1955

Type species

Radiaspora sp. H.S. & M., 1955; Stanley Formation, Texas, Oklahoma, U.S.A.; Carboniferous.

RADIASPORA DARENSIS sp. nov.

(Pl. 8, fig. 5)

Description (based on four specimens)

In polar view the spore has a rounded triangular outline, the distal face is slightly convex, and the proximal face pyramidal. The Y-mark is about 1 μ wide at the proximal pole and tapers slightly towards its termination just short of the equator. On the distal surface the exine forms radial thickenings which originate at the equator, where they are 2-5 μ apart and 1-2 μ wide, and taper to a width of about 1 μ halfway along the radius of the spore. From this point most of the ribs continue, less strongly, to the distal pole.

Dimensions (four specimens): Diameter 28-31 μ.

Holotype: Plate 8, figure 5. Size 28 μ, 15 radial ribs. Slide MFP 3128. 1/112, 119. Exoil Mereenie Water Bore No. 2, 680-700 feet.

Derivation of Name: After Dare Plain.

Comments

Radiaspora darensis is similar to *Radiaspora* sp. A, Balme, 1960, except that its radial ribs, in conformity with the generic diagnosis, are located on the distal surface. Because the specimens were compressed, Balme (1960) was uncertain of the exact position of the radial ribs of his *Radiaspora* sp. A from the Gneudna Formation of the Carnarvon Basin, Western Australia, but concluded that they were proximal. He suggested that *Radiaspora* sp. A should accordingly be placed in *Emphanisporites* McGregor, 1960.

Discussion

The name *Radiaspora* was informally introduced by Hoffmeister, Staplin, & Malloy (1955), who noted 'an unpublished genus of Stanley age is "Radiaspora", a circular trilete spore with numerous radial ribs on the distal surface (pl. 3, fig. 7)'. R. Potonié (1956) commented on the invalidity of the genus and pointed out that no type species had been named and that the circular shape and numerous radial rays were not clearly shown in the original photograph. He made no attempt to validate the name *Radiaspora*.

Balme (1960) intended to validate *Radiaspora* on the basis of radially-ribbed specimens he obtained from the Gneudna Formation. However, after completing his original manuscript he learned of a paper being prepared by McGregor (published in 1961) in which the genus *Emphanisporites* was erected to receive radially ornamented spores which differ from *Radiaspora* in having proximal rather than distal ribs. Balme re-examined his strongly compressed specimens and decided that the radial ribs were probably proximal. However, he retained the informal name *Radiaspora,* 'in view of the controversy over the morphology of these radially ornamented forms and the absence of definitive specimens in the Australian material'.

In his reference to the validation of the name *Radiaspora,* McGregor (1961), quoting 'Balme, in press', was probably referring to the latter's original manuscript. He was apparently not aware of Balme's reconsideration of the Gneudna Formation specimens and the possibility that these should be referred to *Emphanisporites* rather than *Radiaspora.* McGregor recognized the uncertainty under which many radially-ribbed spores, especially compressed ones, had been assigned to either *Radiaspora* or *Emphanisporites,* and pointed out how correct interpretation of some specimens would necessitate modification of the life-range of the genus. If Balme's specimens do belong to *Emphanisporites,* the life-range McGregor suggested for the genus, 'the equivalent of parts of the Emsian and Eifelian stages of Europe', must be modified.

Reference of Balme's radially-ribbed specimens to *Emphanisporites* rather than *Radiaspora* reduces the number of well authenticated occurrences of spores with distal radial ribs. It also eliminates some of the data on which estimations of the life-range of the genus have been based. McGregor's (1961) suggestion that *Radiaspora* is an Upper Devonian genus may have been influenced by his belief, at the time, that Balme's specimens had proximal ribbing.

Turma ZONALES (Bennie & Kidston, 1886) Potonié, 1956 Subturma

Subturma ZONOTRILETES Waltz, 1935

Infraturma CINGULATI Potonié & Klaus, 1954

Genus LOPHOZONOTRILETES (Naumova, 1953) Potonié, 1958

Type species

Lophozonotriletes lebedianensis Naumova, 1953; Orlow, Mitsensk, Lebedian area, U.S.S.R.; Famennian.

LOPHOZONOTRILETES sp.

(Pl. 8, fig. 4)

Description (based on two specimens)

Shape circular in polar view, distal face convex. The strong concavity of the proximal face of the specimen illustrated in Plate 8, figure 4 may be an effect of preservation. Dehiscence is indistinct, but bounded by well defined, slightly sinuous, raised lips (2 μ high), which extend about two-thirds of the way along the radius of the spore. The spore has a dense cingulum 4-7 μ thick.

Ornamentation of the proximal face consists of fine (less than 0.5 μ) granules, which are concentrated on the cingulum and give it a dark appearance when the spore is examined with a low magnification objective. The distal face is ornamented with granules 4-6 μ across and 1.5-3 μ high, which are between 3 and 6 μ apart, have irregular bases, and are frequently mamillate.

Dimensions (two specimens): Overall diameter 50, 56 μ.

Figured specimen

Pl. 8, figure 4, Slide MFP 3128. 1/112.131. Exoil Mereenie Water Bore No. 2, 680-700 feet.

Anteturma POLLENITES R. Potonié, 1931

Turma SACCITES Erdtman, 1947

Subturma MONOSACCITES (Chitaley, 1951) Potonié & Kremp, 1954

Infraturma TRILETESACCITI Leschik, 1955

Genus AURORASPORA Hoffmeister, Staplin, & Malloy, 1955

Type species

Auroraspora solisortus H.S. & M, 1955; Hardisburg Formation, U.S.A.; Mississippian.

AURORASPORA cf. A. MICROMANIFESTUS (Hacquebard, 1957) Richardson, 1960

(Pl. 8, fig. 6)

Endosporites micromanifestus Hacquebard, 1957, *Micropaleontology,* 3, 317, pl. 3, fig. 16.

Auroraspora micromanifestus Richardson, 1960, *Palaeontology,* 3(1), 51.

Description (based on two specimens)

Body outline subtriangular with strongly convex sides. Central body is dark and dense and is completely enclosed within a delicate transparent bladder which has an irregular subtriangular outline in polar view. The body wall is 2-3 μ thick, and the bladder, which has no limbus, is 5-7 μ thick. The Y-mark is thin (about 1 μ) and extends to the equator of the spore body. On the bladder a slightly sinuous dark ridge runs parallel to the Y-mark and extends to the proximodistal margin of the bladder.

Dimensions (two specimens): Overall diameter 42, 52 μ, body diameter 28, 30 μ.

Figured specimen

Plate 8, figure 6, Slide MFP 3128.2/099.154. Exoil Mereenie Water Bore No. 2, 680-700 feet.

Comments

The genus *Auroraspora* Hoffmeister, Staplin, & Malloy, 1955, includes spores with a dark subtriangular to subcircular central body completely enclosed in a delicate transparent bladder. *Auroraspora* is readily distinguishable from *Endosporites,* since the latter has a limbus and a central body which is about as thick as the bladder. *Cosmosporites* is similar to *Auroraspora,* but is ornamented with small cones or spines. The Mereenie Water Bore specimens conform to the diagnosis of *Auroraspora.* They are structurally very similar to *A. macromanifestus* (Hacquebard) Richardson, which includes Type A of Lang (1925), but are smaller, having a diameter of only 52 μ, compared with the 102-254 μ of *A. macromanifestus.* They are therefore referred to as *Auroraspora* cf. *A. micromanifestus* (Hacquebard) Richardson.

INCERTAE SEDIS

Genus ANCYROSPORA Richardson, 1960, emend. Richardson, 1962

Type species

Ancyrospora grandispinosa Richardson, 1960; Cromarty nodule beds, Middle Old Red Sandstone, Navity shore, Scotland; Lower Givetian.

Comments

Lang (1925) recorded as Type G spores with anchor-shaped spines in the Old Red Sandstone at Cromarty, Scotland. Spores with anchor-shaped processes have subsequently been recorded in Devonian deposits in Spitzbergen (Hoeg, 1942), Germany (Eisenack, 1944), the USA (Arnold, 1936), the USSR (Naumova, 1953), Canada (McGregor, 1960), Scotland (Richardson, 1960), Australia (Balme, 1960), and France (Taugourdeau-Lantz, 1960).

The spores with anchor-shaped processes from the Mereenie Water Bore are included in the genus *Ancyrospora* Richardson because they are radial, trilete, and have a flange or pseudoflange and a circular, subcircular, or subtriangular equatorial outline.

ANCYROSPORA PARKE sp. nov.

(Pl. 8, fig. 7)

Description (based on one specimen)

Rounded triangular equatorial outline, proximal face flat, distal face convex.

The Y-mark is clearly defined, straight, and thin, and tapers slightly towards the equator. It has low lips, but the intexine of the central body is not folded back from it as in *Ancyrospora* cf. *A. simplex* Guennel. On the psilate proximal face of the exoexine a Y-shaped ridge lies above the Y-mark of the central body. The intexine is 1.5 μ thick and the exoexine 3-5 μ thick. The exoexine on the distal surface is finely pitted and bears a number of 7-15 μ spines, approximately 7-15 μ apart with bases 7-15 μ wide, which taper to 2-3 μ wide at about half or two-thirds of the length of the spine and thence continue parallel-sided to terminate in anchor-shaped processes. The heads of the anchors are about 5-6 μ wide. Some spines taper sharply at the base and therefore have a longer parallel-sided section.

Dimensions (one specimen): Overall diameter 77 μ, diameter of central body 50 μ.

Holotype

Plate 8, figure 7. Diameter 77 μ, nineteen equatorial spines. Slide MFP 3128.1/053.141. Exoil Mereenie Water Bore No. 2. 680-700 feet.

Derivation of name

After Parke Creek.

Comparison

This species is distinguished from *Ancyrospora amadei* and *A.* cf. *A. simplex* by the large size of its central body relative to overall diameter, by the relative abundance of its spines, most of which bifurcate and have broad bases and only a relatively short parallel-sided section, and by the fact that the intexine of the central body is not folded back from the Y-mark. It is similar in appearance to Lang's Type G (fig. 13) but is very much smaller.

ANCYROSPORA AMADEI sp. nov.

(Pl. 8, fig. 8)

Description (based on three specimens)

Body circular to rounded triangular in polar view, distal face slightly convex, proximal face pyramidal, Y-mark indistinct. The exine has two layers, an intexine 1.5-3 μ thick and an exoexine 4-7 μ thick. The exoexine extends equatorially as a flange 7-15 μ wide, and on the distal surface, where it is finely pitted, forms spines 10-35 μ long. The spines have broad bases (7-10 μ wide), taper sharply to a parallel-sided midsection 3-4 μ wide, and terminate in an anchor-shaped process 5-8 μ wide. Some specimens have open-ended conical processes which apparently are the bases of bifurcating spines from which the ends have been broken. These open-ended spines indicate that the bifurcating types are at least partly hollow, although the relatively high refractive index of most of the anchor-shaped terminations indicates that this part of the spine is solid.

Dimensions (three specimens): Overall diameter 80-135 μ, central body diameter 42-55 μ.

Holotype

Plate 8, figure 8. Maximum overall diameter 135 μ, thirteen equatorial spines. Slide MFP 3128.1/111 072. Exoil Mereenie Water Bore No. 2, 680-700 feet.

Derivation of name

After Lake Amadeus.

Comparison

Ancyrospora amadei differs from *Ancyrospora parke* and *A.* cf. *A. simplex* Guennel in its large overall size (greater than 100 μ), its indistinct Y-mark, its possession of an equatorial flange rather than a pseudoflange, and its very long spines, most of which terminate in anchor-shaped processes. It is also distinguished from *A. parke* and *A.* cf. *A. simplex* by its lack of a proximal exoexine ridge. *A. amadei* resembles both the the 'new genus' and *'Grandispora(?)'* of Hoffmeister et al. (1955, pl. 1, figs 6 and 10 respectively), but is smaller and has fewer spines than either of these.

ANCYROSPORA cf. A. SIMPLEX Guennel, 1963

(Pl. 8, figs 9, 10, 11; text-fig. 1)

Ancyrospora simplex Guennel, 1963, *Grana Palyn.*, 4(2), 257, fig. 10.

Description (based on twenty-two specimens)

Outline of exoexine, excluding spines, circular to rounded triangular, body outline circular. The spore consists of a psilate central body enclosed in a pitted exoexine which equatorially and distally develops broad-based spines. Many specimens have the intexine of the central body folded back from the Y-mark to produce a light coloured triangular area. Figures 9, 10, and 11 illustrate various degrees of development of this condition. Above the straight Y-mark (1-1.5 μ wide) the exoexine forms a sinuous Y-shaped ridge which runs parallel to the Y-mark and terminates in three darkened, thickened areas at the angles. No equatorial extension of the exoexine is present, but a pseudoflange (5-10 μ wide) is formed by the union at the equator of the broad bases of the spines. The spores shown in Figures 9, 10, and 11 have only a few bifurcating spines, but most of their other spines seem to have open ends, which indicate that their terminations, perhaps bifurcating, have been broken off. Text-figure 1 shows a hypothetical reconstruction of *Ancyrospora* cf. *A. simplex* Guennel.

Dimensions (twenty-two specimens): Overall diameter 63(69)90 μ, body diameter 35(38)42 μ.

Figured specimens

Plate 1, figures 9, 10, and 11. Overall diameters 76 μ, 74 μ and 50 μ. Slide MFP 3128.1/102.137, 090.121 and 084.144 respectively. Exoil Mereenie Water Bore No. 2, 680-700 feet.

Comparison

Ancyrospora cf. *A. simplex* Guennel is distinguished from *Ancyrospora parke* and *A. amadei* by the triangular area which is formed by the folding back of the intexine of the central body from the Y-mark and by the strong sinuous ridge of exoexine which, on the proximal side, runs parallel to the Y-mark of the central body. This species has only rare anchor-shaped spines, but has many other spines which, although blunt, appear as though their possibly anchor-shaped ends have been broken off.

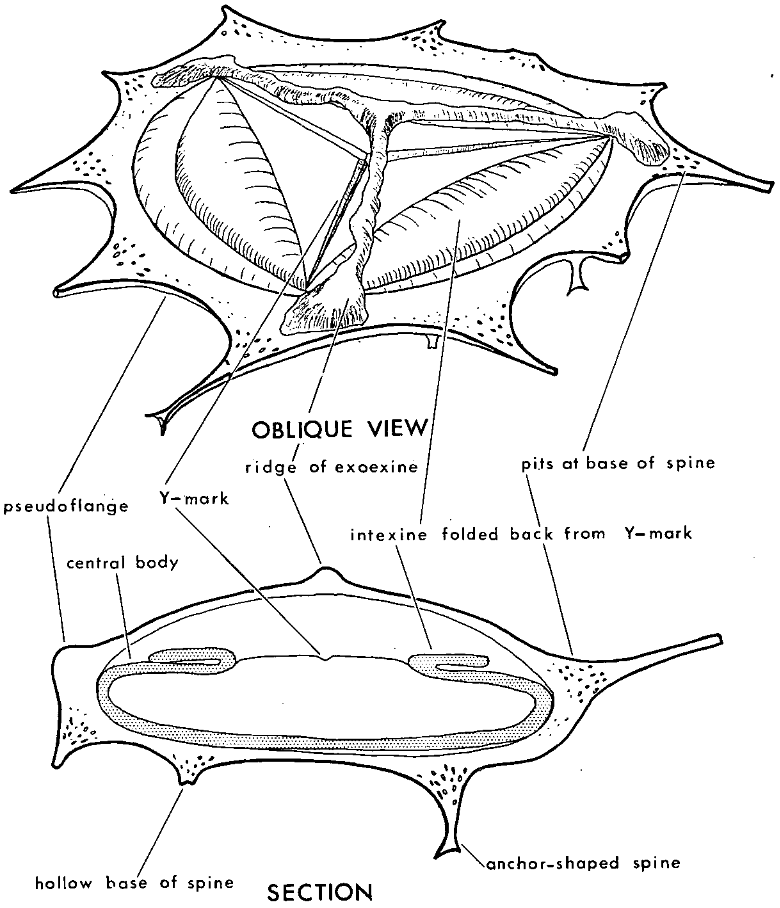

Fig. 1. ***Ancyrospora*** **cf.** ***A. simplex*** **Guennel: reconstruction**

TABLE 1: Summarized Characteristics of *Ancyrospora parke* sp. nov., *A. amadei* sp. nov. and *A.* cf. *A. simplex* Guennel

	Ancyrospora parke sp. nov.	*Ancyrospora amadei* sp. nov.		*Ancyrospora* cf. *A. simplex* Guennel		
Location	MFP 3128 1/053. 141	MFP 3128. 1/111. 072	MFP 3128. 2/142. 149	MFP 3128. 1/102. 137	MFP 3128. 1/090. 121	MFP 3128. 1/084. 144
Plate 8 Figure	7	8	not figured	9	10	11
Body shape	Rounded triangular	Rounded triangular	Rounded triangular	Rounded triangular	Rounded triangular	Subcircular
Overall diameter	77 μ	135 μ	112 μ	85 μ	89 μ	63 μ
Body diameter	50 μ	55 μ	55 μ	39 μ	40 μ	35 μ
Y-mark	distinct	indistinct	indistinct	distinct	distinct	distinct
Proximal face	flat	pyramidal	slightly pyramidal	flat	flat	slightly pyramidal
Distal face	convex	slightly convex	slightly convex	flat	slightly convex	convex
Intexine thickness	1.5 μ	1.5-3 μ	1.5-3 μ	1.5-3 μ	1.5-3 μ	1.5-2 μ
Exoexine thickness	3.5 μ	4-7 μ	4-5 μ	5-6 μ	5-6 μ	3-5 μ
Flange	none	10-15 μ	7-10 μ	none	none	none
Pseudoflange	less than 5 μ	none	none	5-10 μ	7-10 μ	?5-7 μ
Spine length	7-15 μ	10-35 μ	10-25 μ	5-15 μ	7-20 μ	5-7 μ
Spine shape	Most broad-based with anchor-shaped tips, some narrow-based with parallel sides and anchor-shaped tips	All with anchor-shaped tips	Most with anchor-shaped tips, some spines with tips (?) broken off	Most spines have tips (?) broken off, a few have anchor-shaped tips	Most blunt and with broad bases, a few narrow with anchor-shaped tips	Most blunt and with broad bases. Two with bifurcating tips
Proximal exoexine ridge	slight	absent	absent	well developed	well developed	well developed
Proximal intexine	not folded at Y-mark	not folded at Y-mark	slightly folded back from Y-mark	slightly folded back from Y-mark	folded back from Y-mark	folded back from Y-mark

Comments

Guennel (1963) believed that the spore which he nominated *Ancyrospora simplex* was 'unquestionably related' to the genotype *Ancyrospora grandispinosa,* even though it is only half the size and lacks the bifurcating spines which Richardson set down as a diagnostic feature of the genus. The Mereenie Water Bore specimens illustrated in Figures 9, 10, and 11 are of comparable size to *Ancyrospora simplex* Guennel and, since they have rare bifurcating spines, they conform to Richardson's generic diagnosis.

AGE OF THE MICROFLORA

Of the few well preserved spore assemblages which have been described from Australian Devonian sediments not many are from strata which can be reliably dated by marine faunas.

In the Great Artesian Basin, sediments containing Devonian microfloras have been encountered in several wells, including Phillips-Sunray Etonvale No. 1 and S.P.L. No. 1 (Birkhead). De Jersey (1962) ascribed Etonvale No. 1 Cores 12 (6955 feet) to 15 (7548 feet) and Birkhead Core 5 (5136-5141 feet) to the Middle Devonian, because they contained several diagnostic forms, including *Radiaspora* sp. The section of Etonvale No. 1 between Cores 12 and 15 is now believed to be a correlate of Phillips Sunray Quilberry No. 1 Cores 8, 9, and 10, in which McKellar (1965) recorded coral and brachiopod faunas of probable Givetian age. At the time of writing no palynological data on these cores from Quilberry were available. However, de Jersey (personal communication) has examined Devonian microfloras from several other recently drilled wells in the Adavale Basin, and has also made a further study of the Devonian microfloras of Birkhead and Etonvale. He believes that the microflora of the upper part of the Adavale Basin Devonian sequence is of Givetian age, and suggests that although it contains *Geminospora lemurata* and *Ancyrospora* cf. *A. simplex* it is of older aspect than the assemblage from the Pertnjara Formation.

McGregor (1961) suggested that *Radiaspora* is an Upper Devonian genus and *Emphanisporites* a Lower to Middle Devonian one. He noted how the name *Radiaspora* had previously been applied, often rather freely, to spores with radial ribs, even where the exact position of the ribs was not determinable. In drawing attention to the two groups of radially ornamented spores and the stratigraphic importance of correct determination of the position of the radial ribs, McGregor initiated a reconsideration of some specimens. As a result the life-ranges he suggested for *Radiaspora* and *Emphanisporites* may require substantial modification, since Balme's Frasnian specimens, originally thought to belong to *Radiaspora,* should probably be referred to *Emphanisporites.* The life-range of *Radiaspora* remains uncertain, and its presence in the Mereenie Water Bore sample cannot, at present, help to define the position of the sample within the Devonian succession.

Balme (1960) described spore assemblages from the Frasnian Gneudna Formation of the Carnarvon Basin and (1962) from the Famennian of the Fitzroy Basin. The assemblages from the Gneudna Formation are characterized by *Geminospora lemurata,* cf. *Ancyrospora* spp., and radially ribbed spores which Balme referred to *Radiaspora* but which should probably be placed in *Emphanisporites*. The Fitzroy Basin assemblages are completely different. Balme recorded only one species, *Retusotriletes* cf. *R. pyjchovii,* common to both the Gneudna and the Fitzroy Basin assemblages, but noted that many of the species which occur in the Fitzroy Basin Famennian range into the Lower Carboniferous.

The Mereenie Water-Bore assemblage is compared with that from the Gneudna Formation since it contains abundant *Geminospora lemurata* and *Ancyrospora* spp. It also contains spores with radial ribs which belong to *Radiaspora,* but which differ from Balme's *'Radiaspora'* in that their ribs are distally located.

Spores like *Geminospora lemurata,* which have a thick exoexine enclosing a mesosporoid, have been described from the USSR by Naumova (1953), who reported them to be most abundant in the Givetian and Lower Frasnian and rare in the Famennian. Balme cited the abundance of *Geminospora lemurata* in the Gneudna Formation as confirmatory evidence of the Frasnian age given to the formation by Glenister (1956) on the basis of its spiriferid brachiopods. The relative abundance of *Geminospora lemurata* in the sample from the Pertnjara Formation may similarly indicate an early Upper Devonian age.

The abundance of *Ancyrospora* spp. is the most distinctive feature of the Mereenie Water-Bore sample. Spores of a wide variety of morphological types having spines with anchor-shaped terminations have been reported from Australia, Canada, France, Germany, Scotland, Spitzbergen, USA, and USSR. They appear to be confined to the Devonian and have not been reported in well-dated sediments older than the early Middle Devonian. Naumova reported that these spores first appear in the Givetian of the USSR, reach their acme in the Frasnian, and decline in abundance in the Famennian. This agrees with Richardson's (1962) observations on the stratigraphical distribution of several genera with bifurcating processes. Richardson reported that the acme of *Ancyrospora* was in the late Middle to early Upper Devonian. The apparent absence of *Ancyrospora* and other forms with bifurcating anchor-shaped processes in the Upper Devonian of the Fitzroy Basin suggests that the life range of these fossils may be similarly constricted in Australia. If this is so, the abundance of *Ancyrospora* spp. in the Mereenie Water-Bore sample supports the conclusion, based on the abundance of *Geminospora lemurata,* that the sample is of late Middle or early Upper Devonian age.

Additional evidence for the Middle or Upper Devonian age of the basal part of the Pertnjara Formation comes from a vertebrate fossil (Tomlinson, this Vol., p. 189).

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PLATE 8

All magnifications x 750

Leiotriletes liebigensis sp. nov.
Fig. 1, MFP 3128.1/158.161 P-20

Geminospora lemurata Balme (sp. 169)
Fig. 2, MFP 3128.2/140.150

Fig. 3, MFP 3128.1/124.086

Lophozonotriletes sp.
Fig. 4, MFP 3128.1/112.131

Radiaspora darensis sp. nov.
Fig. 5, MFP 3128.1/112.119

Auroraspora cf. *A. micromanifestus*
(Hacquebard) Richardson
Fig. 6, MFP 3128.2/099.154

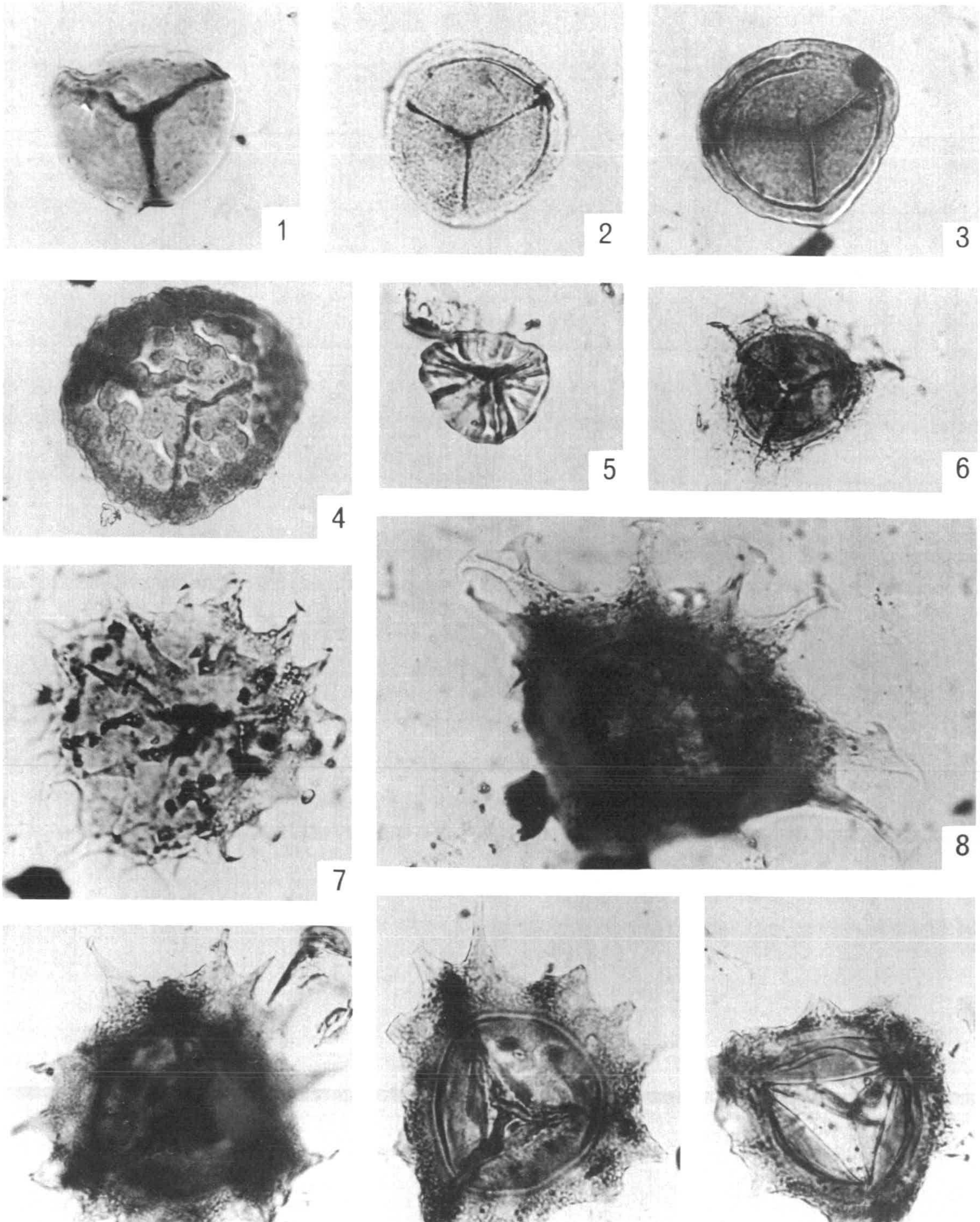
Ancyrospora parke sp. nov.
Fig. 7, MFP 3128.1/053.141

Ancyrospora amadei sp. nov.
Fig. 8, MFP 3128.1/111.072

Ancyrospora cf. *A. simplex* Guennel
Fig. 9, MFP 3128.1/102.137

Fig. 10, MFP 3128.1/090.121

Fig. 11, MFP 3128.1/084.144



Devonian spores

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POSSIBLE MIOCENE MARINE TRANSGRESSION IN NORTHERN AUSTRALIA

by A. R. Lloyd

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SUMMARY

The foraminifer *Ammonia beccarii* (Linné) is associated with freshwater molluscs, ostracodes, and algae in the Brunette Limestone near Rockhampton Downs on the Barkly Tableland in the Northern Territory of Australia; in the White Mountain Formation at White Mountain in the East Kimberley District of Western Australia; and in the Austral Downs Limestone near Roxborough Downs in Western Queensland. *Ammonia beccarii* is found in nearshore open ocean, coastal lagoonal, and deltaic environments today (Phleger, 1960a, b) and an explanation is therefore sought for the occurrence of this Miocene or younger foraminifer at the three localities so far inland from the present coastline and well away from indisputable Miocene or younger marine sediments.

It is believed that the foraminifers were introduced into these areas by a marine incursion during the Miocene. Subsequent uplift of the land caused the sea to retreat and brought about the present elevations.

INTRODUCTION

The 'Tertiary' deposits of Northern Australia have long been considered to be entirely non-marine. Foraminifers have been known in thin sections from the White Mountain Formation (Chapman, 1937) and from the Austral Downs Limestone (Paten, 1960, 1964). Chapman recorded *Globigerina* sp. near *bulloides* d'Orb., cf. *Discorbis, Trochammina* sp., and *Spiroplectammina* sp., associated with freshwater gastropods, including *'Planorbis hardmani'*, and ostracodes in a chert of the White Mountain Formation at Hill J40, White Mountain, in the eastern Kimberley District of Western Australia. Chapman thought the sediment was lacustrine and that the foraminifers were introduced into it by the wind from a nearby shoreline when the coast in the vicinity of the Ord River extended farther inland in early Pleistocene times. Subsequent workers disregarded the presence of the foraminifers and considered the deposits to be lacustrine.

Paten (1960, 1964) recorded 'Globigerine and Rotaline' foraminifers (identified by Dr I. Crespin), freshwater ostracodes, and charophyte algae from the Austral Downs Limestone, near Roxborough Downs in Western Queensland. Paten (1960, p. 392) stated that it was not known whether the foraminifers were derived from older rocks or indicate a marine incursion during deposition, but in 1964 he thought that the association of these forms indicated a brackish, continental environment of deposition for the Austral Downs Limestone.

The recent discovery of free well-preserved specimens of *Ammonia beccarii* in the Brunette Limestone near Rockhampton Downs on the Barkly Tableland in the Northern Territory (Lloyd, 1963a) reopened the question of their provenance at all three localities. Chapman and Paten's slides, together with thin sections of new material collected by J. J. Veevers, J. Roberts, and J. A. Kaulback from the White Mountain Formation in 1963, were re-examined, and found also to contain *A. beccarii.* The presence of this Miocene or younger species proved that the foraminifers in the Austral Downs Limestone could not be derived from older rocks as suggested by Paten (1960), as the only foraminiferal rocks in the general area are Lower Cretaceous. That the foraminifers were introduced by birds or wind into a brackish lake is most unlikely; it is very much more probable that the sea had direct access to the areas of deposition.

GEOLOGY

White Mountain, situated in the White Mountain Range, Ord River area, Western Australia, on the Northern Territory border, is about 900 feet above sea level and about 160 miles inland from Cambridge Gulf. It rises 340 feet above the surrounding plain and 600 feet above the river bed. The geology of the White Mountain area is mentioned by Wade (1924, p. 29); Matheson & Teichert (1948 pp. 15, 16); Traves (1955 pp. 84, 85, 94); McWhae et al. (1958 p. 122); and Dow & Gemuts (1964). Matheson & Teichert measured two sections, one at Trigonometrical Station J40, where 85 feet of siltstone and glauconitic and quartz sandstone are overlain by 10 feet of fossiliferous chert containing *'Planorbis hardmani'*, ostracodes, and foraminifers; the second to the south-west of J40, where 365 feet of marl, siltstone, and chert are overlain by a 5-foot capping of fossiliferous chert. Both sections lie unconformably on Cambrian Sandstone. The White Mountain Formation has been tilted and dips 25° north-east.

Glauconite, if present as recorded by Matheson & Teichert, is indicative of a marine environment, but this was not considered by them. However, an examination of new material by J. J. Veevers (pers. comm.) failed to reveal any glauconite. If it is present in the sediments below the fossiliferous chert, the bulk of the formation would be undoubtedly marine.

The White Mountain Formation sediments are thought to have been raised to their present height by a fault which was mapped along the northern side of the mountain (Dow & Gemuts, 1964), and by subsequent uplift. Chapman (1937) suggested a Pleistocene age for the Formation; Matheson & Teichert (1948) and Singleton (1939) suggested a Pliocene age; and Traves (1955) suggested a Tertiary age, but added that Pleistocene is not inconceivable; all suggested a lacustrine environment of deposition.

The Rockhampton Downs deposit is about 150 miles inland from the Gulf of Carpentaria and 720 feet above sea level. The Brunette Limestone occurs along watercourses in the centre of the Barkly Tableland as thin sheets and scattered boulders of white to brown fine-grained to coarsely crystalline siliceous limestone and dolomite up to 60 feet thick and unconformably overlying Lower Palaeozoic carbonates (Noakes & Traves, 1954; Randal & Brown, 1962a,b; Randal & Nichols, 1963; and Nichols, 1963). Until *Ammonia beccarii* was discovered the Brunette Limestone had been considered to be entirely lacustrine (Lloyd, 1963a; Randal & Nichols, 1963, p. 19; and Nichols, 1963, p. 20). Lloyd (op. cit.) stated that it was not older than middle Miocene and possibly not younger than Pliocene.

The Roxborough Downs deposit is situated about 350 miles inland from the Gulf of Carpentaria, and is less than 500 feet above sea level. The Austral Downs Limestone is a sequence consisting of an upper chalcedonic cap overlying grey, cream, or white limestone, which overlies a zone rich in ferruginous detritus, up to 30 feet thick. It crops out as small hills, ridges, and plateaux up to 12 miles wide along the Georgina River and Pituri Creek in western Queensland and in the Northern Territory, and as isolated boulders on the Sandover River 1 : 250,000 Sheet area (Whitehouse, 1940; Noakes & Traves, 1954; Noakes, Carter, & Öpik, 1959; Smith & Vine, 1960; Paten, 1960, 1964; Randal & Brown, 1962b; and Nichols, 1964). Paten recorded algae and ostracodes in a hard manganiferous limestone breccia at the junction of Manners Creek and the Georgina River on Roxborough Downs in Western Queensland. All workers placed it in the Tertiary, and with the exception of Whitehouse (1940), who thought it was a completely unfossiliferous surface-soil limestone, they all believed it to be lacustrine in origin.

OBSERVATIONS

Chapman's *'Globigerina'*, gastropods, and ostracodes were recognized in his thin sections from the White Mountain Formation, but the other fossils that he recorded could not be recognized. Thin sections of new material contain a number of very small random sections of foraminifers, which appear to belong to the rotaline species *Ammonia beccarii* (Pl. 9, figs 7-11). Chapman's *'Globigerina'* appears to be three chambers of this species.

In Paten's original slides from the Austral Downs Limestone near Roxborough Downs only one species of rotaline foraminifer was present, which is also thought to be *Ammonia beccarii* (Pl. 9, figs 12-16).

Numerous small free specimens of *Ammonia beccarii* (the largest being 0.3 mm in diameter) (Pl. 9, figs 1-6) have been found in association with three species of gastropods, one species of pelecypod, and one species of ostracode in a sample of conglomeratic gastropod calcirudite (coquina) which was collected from an isolated outcrop by M. A. Randal and R. A. H. Nichols in 1962 (Lloyd, 1963a). The outcrop is two miles north-east of Bore No. 18 Rockhampton Downs, and 28.5 miles north of Rockhampton Downs homestead on the road to Anthony Lagoon homestead. It occurs with rocks of the Brunette Limestone and may be in sequence with this formation (Randal & Nichols, 1936, p. 20; Nichols, 1963, p. 21).* Lloyd, Nichols, and Randal suggested that the limestone conglomerate was deposited in an estuarine or nearshore lagoonal environment. McMichael (this Vol., p. 133) identified all the molluscs as freshwater species.

AGE OF THE DEPOSITS

Ammonia beccarii has been recorded from the base of the middle Miocene to the Recent in Italy (Agip Mineraria, 1957, Table 41); from the upper Miocene in Indonesia (LeRoy, 1941, p. 117); from the Miocene and the Recent at Bikini Atoll (Todd, 1958, p. 278); from the lower Miocene in New Britain (Lloyd, 1963b); and from lower Miocene to Pliocene in Papua (Belford, 1965). *A. beccarii* therefore has a recorded range from lower Miocene to Recent, and it is considered that the rocks from the Barkly Tableland, White Mountain, and Roxborough Downs cannot be older than lower Miocene. Lloyd (this Vol., p. 126) suggests a general Miocene age for the Tertiary fossiliferous deposits of northern Australia, which include the Barkly Tableland and White Mountain deposits, on the basis of vertebrates, gastropods, and foraminifers.

SIGNIFICANCE OF AMMONIA BECCARII

Gauthier-Lièvre (1935) recorded foraminifers, both calcareous and agglutinated, living in inland saline waters of the Algerian Sahara Desert. Arnal (1961) described calcareous and agglutinated species of foraminifers living in the Salton Sea, Colorado Desert, California, where they were accidentally introduced, presumably by seaplanes. The foraminiferal species present can tolerate a wide range of salinity, pH, and temperature, and thus are able to survive. They include a form close to *Ammonia beccarii.*

Glaessner (1945, pp. 190-191) says 'The overwhelming majority of foraminifera are adapted to normal salinity, and cannot exist under conditions of a higher or lower salt-content in the sea water. One of the most common brackish water species, which, however, is not restricted to this environment, is *Rotalia beccarii* Linné.' He goes on to list recorded occurrences of foraminifers in non-marine environments, including that of Gauthier-Lièvre, and concludes by saying 'It is assumed that these faunas are survivors from the time when these areas were covered by the late Tertiary seas'. Cushman (1955, p. 46) similarly

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* *Ammonia beccarii* was found in association with a gastropod, *Plotiopsis* sp., in the Brunette Limestone from 0-5 feet in scout-hole H52, drilled 23½ miles W.S.W. of Eva Downs homestead by the Bureau of Mineral Resources in 1965. This proved that the previous fossiliferous occurrence is actually in sequence.

mentioned that these waters are supposed to be remnants of an old Miocene sea. Gauthier-Lièvre (1935) could not find a reason for the occurrence of foraminifers in inland saline waters, but discounted the possibility that birds were responsible for their introduction into these waters, because of desiccation en route. Cushman (1955, p. 46) quoted the report by Brodsky of foraminifers from springs in the desert of Kara-kum, Central Asia.

Bradshaw (1957), reporting on his studies of *Ammonia beccarii* in cultures in the laboratory, found that the species had normal growth and reproduction in salinities between 20 0/00 and 40 0/00. Above and below these limits growth and reproduction activity fell off until growth finally ceased at salinities higher than 67 0/00 or lower than 7 0/00. Reproduction occurred only at salinities between 13 0/00 and 46 0/00. The salinity of normal oceanic water is about 33 0/00 to 36 0/00 (Phleger, 1960a, p. 18). *A. beccarii* can therefore survive and reproduce in both brackish and saline waters as well as normal sea water.

Phleger (1960a) sets out many recorded occurrences of *A. beccarii* living in the nearshore open ocean as well as coastal lagoons and deltas whose salinities are higher or lower than normal sea water. In his discussion on the Mississippi Sound area, Phleger (1960a, p. 139) states that open-ocean benthonic foraminifers such as *A. beccarii* migrate into the Sound with the nearshore open-gulf water which invades the Sound, underriding the Mississippi Sound water. Where the open-gulf water is present in the Sound for a long time or at frequent intervals it provides an environment suitable for the open-ocean benthonic foraminifers which migrate into the Sound with it. He states that *Ammonia beccarii* and several species of *Elphidium* appear to tolerate considerable variation in their environment. In his discussion of coastal lagoonal foraminifers Phleger (1960b, pp. 275, 276) states that the fauna is divided into two elements, an indigenous and a nearshore open-ocean element. The nearshore element which invades the lagoon for at least a short distance includes *A. beccarii.* Todd (1958, p. 91) recorded *A. beccarii* from the Tanapaj Lagoon of Bikini Atoll, Western Pacific. Israelsky (1949) used *A. beccarii* as indicator of shallow-water marine to brackish-water environments in his study of depth oscillations in Miocene sediments penetrated in a well in Louisiana, USA.

The presence of only small specimens of one species in the three deposits may suggest an unfavourable environment, but Phleger (1960a, p. 272) says 'Experimental and field experience strongly indicate that small specimen size and few species are related to optimum conditions of the environment. Unusually large size appears to be characteristic of marginal environmental conditions'. Bradshaw (1957, p. 1140), in his experiments with cultures of *Ammonia beccarii,* showed that the organism can reproduce as soon as it has grown to a total of 13 chambers, and that reproduction typically terminates the life of the parent. On page 1145 Bradshaw goes on to say that 'reproduction is delayed by unfavourable temperatures and salinities, but growth and chamber addition may continue for a longer time if other conditions such as food are favourable'. The specimens may thus finally reproduce at a larger size and with a larger number of chambers than would be true under more favourable circumstances. Further, on page 1146, Bradshaw says that 'larger specimens of the same species would be expected in the unfavourable environments and the smaller specimens under the most favourable conditions'. Loeblich & Tappan (1964, p. 125) stated that 'concurrent rapid sedimentation might result in the accumulation of only a meagre population in the sediment'. If this is so, the conditions which permitted *A. beccarii* to migrate with the incoming oceanic waters into the lacustrine environments at White Mountain, Barkly Tableland and Roxborough Downs must have been optimum for this species only, excluding all other foraminiferal species.

PALAEOGEOGRAPHY

The present height of White Mountain (about 900 feet) above sea level can be attributed to faulting and uplift. The presence of 370 feet of Miocene sediments and the height of 600 feet above the bed of the Ord River gives some indication of the shift in base level that has taken place in the Ord River area during the late Tertiary or Pleistocene.

Some of the uplift that has occurred during the late Tertiary or Pleistocene in Western Australia is shown in the studies of Clarke & Phillips (1953), Fairbridge (1954, pp. 67-69), and Konecki, Dickins, & Quinlan (1958, p. 60). The effects of wave action have been observed at 750-800 feet, 500 feet, 200-250 feet, and 100 feet down to present sea level along the south coast of Western Australia (Clarke & Phillips, op. cit.). The Coastal Limestone, which extends for 2000 miles along the Western Australian coast, is partly marine and partly aeolian in origin, and is thought to be very late Pleistocene in age (Teichert, 1946, p. 112; and Fairbridge, loc. cit.). According to Konecki et al. (loc. cit.) it forms cliffs 120 feet high and reaches a maximum of 816 feet above sea level near the mouth of the Murchison River.

Noakes & Traves (1954, p. 51) stated that the recent cycle of erosion on the Barkly Tableland was initiated by gentle differential movements, mainly warping, which brought considerable topographical changes in the northern and eastern portions of the region with the sinking of the present Gulf of Carpentaria together with probable upwarping of land to the south. Differential movements which occurred possibly at the same time in South Australia affected the Barkly Tableland by inducing some rejuvenation of the internal drainage system of south-western Queensland, which eventually reached the upper Georgina River.

The Selwyn Range at the headwaters of the Burke River, a tributary of the Georgina River, is about 1200 feet above sea level, and was uplifted during the late Tertiary. This was recognized by the tilt of the Tertiary lake limestones along the Burke River (Öpik, 1961, p. 22). Twidale (1956, p. 2) described the uplift as 'the low Pleistocene Selwyn uplift'.

Mabbutt (1962, p. 167) mentioned that at the time of the subsidence of the Lake Eyre basin there was relative uptilting about the margin of the Barkly Tableland north-west of Alice Springs. He also stated that a regional fall to the south and east in the duricrusted cappings, the dissection of the weathered land surface, and the rejuvenation of the drainage system to the south-east of Alice Springs are attributable to the Lake Eyre subsidence.

The Tertiary limestones of the Barkly Tableland are 550 to 780 feet above sea level, and the rejuvenation of the Georgina River and its tributaries has been about 30 to 60 feet (Stewart, 1954, p. 51).

In Queensland, the Mulligan, Georgina and Diamantina Rivers and Cooper Creek traverse country composed largely of duricrusted Tertiary sandstone, claystone and conglomerate, which are now eroded into mesas to depths of 200 to 400 feet (David, 1950, 2, p. 13).

Ludbrook (1953, 1955) recorded freshwater or brackish water gastropods, freshwater and marine ostracodes, and the foraminifers *Ammonia beccarii, Cibicides refulgens, (?)Elphidium advenum,* and *(?)Nonion scapha* from 'Pleistocene to Recent' sediments from the south-eastern part of Lake Eyre North. Ludbrook (1953) was not sure of the origin of the foraminifers and the other marine forms, but thought that they could have lingered on in a Pleistocene lake from the Pliocene, as *A. beccarii* is the dominant foraminifer in Pliocene estuarine deposits in South Australia; or more probably they could have been introduced into the increasingly saline waters of Lake Eyre from Spencer Gulf via Lake Torrens by birds or some other agent of dispersal. Ludbrook (1955, p. 39) quoted Dr R. W. Fairbridge as saying that the microfaunal assemblage is one which would inhabit an extensive gulf or estuary reaching Lake Eyre through Lake Torrens from the head of Spencer Gulf during the high sea level phases of the Pleistocene.

Stirton, Tedford, & Miller (1961) in their studies of the Tirari Desert area east of Lake Eyre did not record any evidence of Tertiary marine rocks. Ludbrook (1963, p. 77), however, recorded the foraminifers *Triloculina tricarinata,* Miliolidae, *Elphidium advenum* var. *depressulum,* and unidentified species from the basal two feet of the Etadunna Formation penetrated in a bore drilled in the south-east part of Lake Eyre North. Stirton et al. (loc. cit.) suggested a possible Oligocene age for the Etadunna Formation, but Ludbrook (1963, p. 78) thinks it is not older than Miocene on the palynological evidence of Balme in an appendix to her report. The foraminifers identified by Ludbrook are not known from below the Miocene, and support her ideas on the possible age of the Etadunna Formation, although she does not mention this. Ludbrook stated that foraminifers can exist in seasonal salt lakes, and therefore indicate a saltwater lacustrine environment for the sediments. Whether by seasonal she meant an alternation between dry and salt water or between salt and fresh water through incursions of the sea, is not clear, but I cannot visualize any foraminifers existing under either condition from published data on their ecology and physiology.

The statement of Ludbrook (1965, p. 7) that foraminifers can be carried hundreds of miles by wind and by birds, and that they will survive if the salinity of the water into which they are introduced is favourable, implies that the foraminifers are adapted to the environments created by these methods of transportation and they will survive. There is no doubt in my mind that the foraminifers are not adapted to such methods of transportation, and they would quickly dry out and hence would not survive a flight of several hours or days over a distance of hundreds of miles. To my knowledge there have been no recorded occurrences of birds carrying live foraminifers and introducing them into inland waters.

Ludbrook (1965) stated that the discovery of *Ammonia beccarii* attached to a sample of Lower Cretaceous siltstone from a dam to the west of Lake Eyre and a report of Parr (1942, p. 4) of hundreds of specimens of a foraminiferal species attached to weeds from a salt lake in western Victoria were proof that foraminifers can survive in seasonal salt lakes. Parr's findings do not prove this. The foraminifer, he said, is usually found at the mouths of rivers where the influx of fresh water lowered the salinity of the seawater in the vicinity. Unfortunately he did not identify the species. Parr himself later visited the lake to see if the foraminifers were actually living in the lake, but it had dried up and he did not find the proof he was looking for. He was not sure if they could have been derived from the rocks nearby. It can be seen that Parr's report needed further investigation before it could be used as proof of foraminifers actually living in a seasonal lake. If they were dead or alive, I believe that they could have been remnants of the late Tertiary seas that covered the Murray Basin.

It is known that foraminifers can live in inland saline lakes, but until live foraminifers have been collected immediately before and after a period of drying-up it is considered that the evidence cited by Dr Ludbrook cannot be used as proof that foraminifers can survive in seasonal lakes.

Sprigg (1950) and Hossfeld (1950) record evidence of Pleistocene sea levels up to 240 feet above present sea level in the south-east of South Australia. Howchin (1901) discovered foraminifers belonging to the genus *Elphidium* associated with ostracodes and gastropods from the silt of the saline Yorktown Lagoon in South Australia. The forms were, he stated, characteristically estuarine or shallow-water marine in habitat in South Australia. Howchin thought that birds might have been responsible for the introduction of the marine fauna into these lakes, but went on to say that some of the scattered saline areas could be explained as remnants of a retreating sea because the land had risen several feet since the Tertiary. Ludbrook (1958, p. 134) recorded Pleistocene marine sediments 120 feet above sea level along the eastern fringe of the Eucla Basin in South Australia.

Lower and upper Miocene marine sediments occur widely throughout the Murray Basin (Ludbrook, 1958a, p. 111). D. J. Belford (pers. comm.) recently discovered lower Miocene foraminifers, including *Austrotrillina howchini* and *Sorites* sp., from samples collected by Hunt Oil Company at 29°50'S. 125°51'E. in the southern part of the Officer Basin in Western Australia. Tertiary rocks crop out widely in this area, and the previously known area of outcrop is extended much farther inland from the Great Australian Bight.

Carter (1963, p. 170) recorded *Discorbis dimidiatus* and two species of *Elphidium* in association with a sublittoral limpet. *Actinoleuca calamus,* two terrestrial, and five non-marine aquatic Recent species of molluscs from the Nelson Bay Formation in Victoria. He attributes the presence of the terrestrial and marine forms to wind action which blew them into a nearshore freshwater lake. Frankel (1964, p. 363) recorded the occurrence of foraminifers associated with terrestrial gastropods of possible Pliocene or Pleistocene age in a calcareous sandstone which is between 150 and 170 feet above present sea level and two miles inland, at Durban in South Africa. He thinks the marine forms would have been washed on to beaches from where they were blown with the sand on to nearby sand dunes where the gastropods were living. The same gastropod species are living on dunes along the Natal coast at the present time. The occurrence of these mixed faunas is easily explained because of the proximity of the deposits to the present oceans.

CONCLUSIONS

Ammonia beccarii is an open ocean nearshore species which is tolerant to salinities both higher and lower than normal seawater; and when favourable oceanic currents invade coastal lagoons or deltaic areas, it is able to migrate along with the currents and survive. The molluscs, ostracodes, and algae in the deposits under discussion indicate that the sediments are freshwater at least in part. The presence of the foraminifers seems therefore to be explicable only by a marine incursion into freshwater lakes which were present in the three areas.

A brief marine transgression is therefore postulated across what is now the Ord River area in Western Australia and the Northern Territory; and across the Barkly Tableland and the upper reaches of the Georgina River in the Northern Territory and Western Queensland some time during the Miocene or Pliocene or possibly the Pleistocene.*

The transgression of the Ord River area no doubt originated from Cambridge Gulf, but the evidence does not allow one to be sure of the place of origin and lateral extent of the Barkly Tableland and Georgina River transgressions: it may have been an extension of the Ord River transgression, it may have been separate in space and time, and originated from the Gulf of Carpentaria; or

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* Fairbridge (1953, p. X1/40) stated that during the lower Miocene and Pliocene the seas were generally transgressive, and during the upper Miocene the seas were generally regressive in Australia; in view of this, the brief transgression in Northern Australia could have occurred during the lower Miocene.

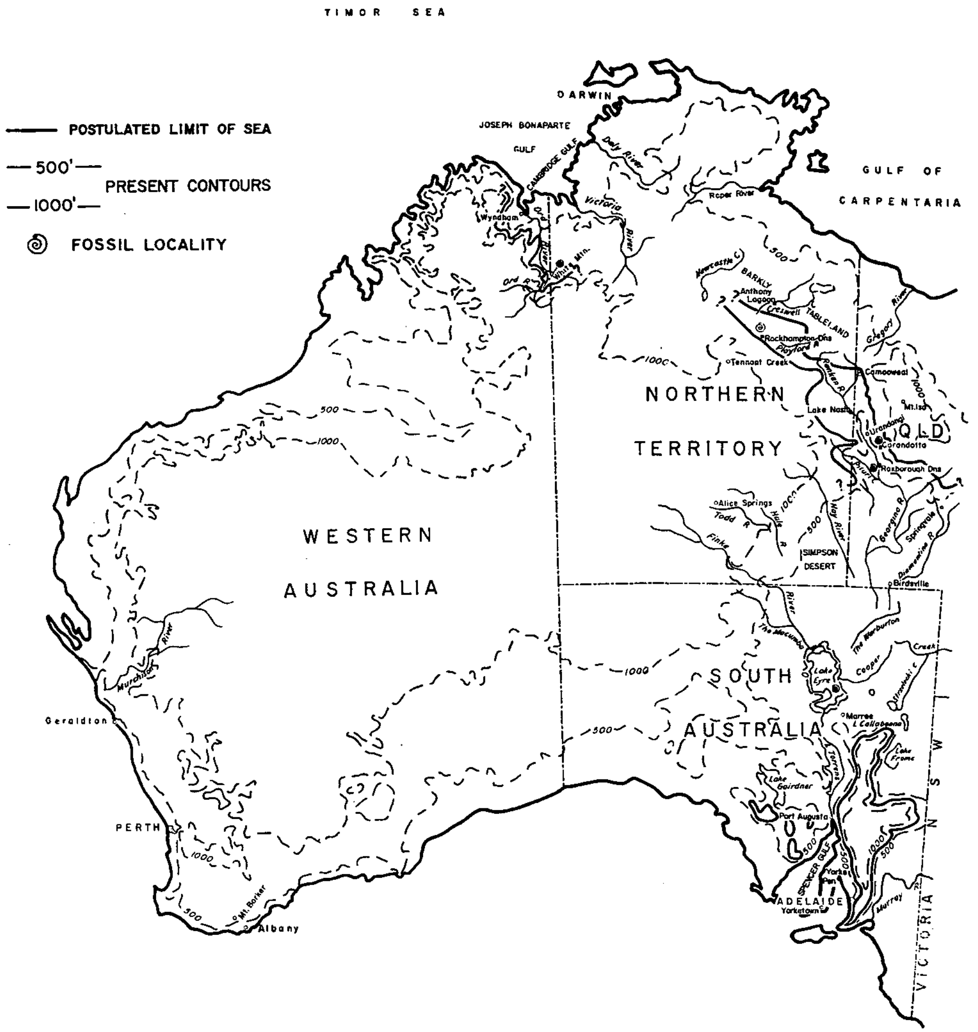

Fig. 1. Postulated extent of the Miocene marine transgression

it may have been an extension of the transgression that undoubtedly reached the south-eastern part of Lake Eyre North as envisaged by Fairbridge. The lower Miocene seas that covered the Eucla Basin and a part of the Officer Basin or the Miocene seas that covered the Murray Basin may have extended to Lake Eyre, and through the upper reaches of the Georgina River on to the Barkly Tableland. Still further, the seas may have briefly covered the area from the Great Australian Bight, Spencer Gulf, and Murray Basin in Southern Australia to Lake Eyre and along the Georgina River to the Gulf of Carpentaria and across the Barkly Tableland to Joseph Bonaparte Gulf. There has been considerable movement of the land in South Australia and in central and northern Australia in the late Tertiary or Pleistocene, and the uplift has been sufficient to lead to a retreat of the sea and account for the present elevations.

The White Mountain Formation is either a small isolated deposit or a remnant of a more extensive deposit. The presence of Miocene marine organisms at two localities does not support the statements of Noakes & Traves (1954, p. 39) and Noakes et al. (1959, p. 5) that the sea did not encroach on the Barkly Tableland and the upper reaches of the Georgina River after the retreat of the Lower Cretaceous sea. The new evidence indicates that the sea encroached on these areas briefly some time during the Miocene. The observation of Carroll (1944, p. 56) that the quartz grains of the Simpson Desert sand are not more worn than those in many beach sands or beach dune sands seems rather interesting; the degree of roundness may not be good evidence, but some of the Simpson Desert sand may be beach deposits.

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PLATE 9

Fig. 1-16 — *Ammonia beccarii* (Linn.).

Fig. 1-3 — CPC 6882, Brunette Limestone. 1. ventral view X100; 2. apertural view X100; 3. dorsal view X100.

Fig. 4-6 — CPC 6883, from section of Brunette Limestone. 4, X150 approx. 5, 6, X100.

Fig. 7 — CPC 6884, from section of White Mountain Formation. X250.

Fig. 8-11 — CPC 6885, from section of White Mountain Formation. 8, X200 approx. 9-11, X100 approx.

Fig. 12 — CPC 6886, from section of Austral Downs Limestone. X100 approx .

Fig. 13-14 — CPC 6887, from section of Austral Downs Limestone. X150.

Fig. 15-16 — CPC 6888, from section of Austral Downs Limestone. 15. X150 approx. 16. X120.


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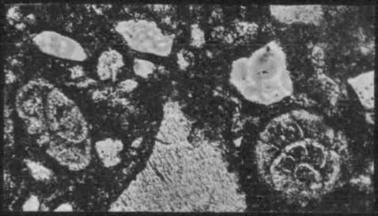
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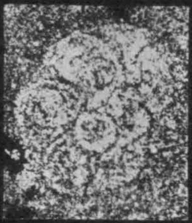
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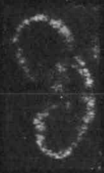
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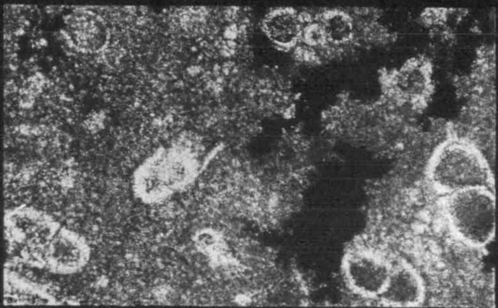
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Ammonia becearii (Linn.)

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OUTLINE OF THE TERTIARY GEOLOGY OF NORTHERN AUSTRALIA

by A. R. Lloyd

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SUMMARY

The Tertiary sediments of Northern Australia are widespread across the continent and consist mainly of hard unfossiliferous chalcedonic limestone with some clastic sediments and fossiliferous limestone, often silicified, containing freshwater and land gastropods, freshwater pelecypods, ostracodes, and algae: foraminifers at three localities and vertebrate remains also at three localities. Deposits are described from the Canning Basin and Eastern Kimberleys in Western Australia; eastern Arnhem Land, Barkly Tableland, Lander River/Alice Springs/Simpson Desert areas in the Northern Territory; and the Riversleigh, Georgina River, Pituri Creek, Boulia/Springvale/Winton, Mackay, and Ipswich areas in Queensland. The molluscs, ostracodes, and algae indicate a lacustrine environment and the foraminifers indicate a marine influence at the three localities. On the evidence of the foraminifers, gastropods, and vertebrates the age of the outcropping fossiliferous sediments is thought to be Miocene.

Pollens indicating a possible early Tertiary age are recorded from subsurface sections near Alice Springs and Mackay.

The sediments mapped as Mesozoic or Lower Cretaceous, with the exception of the fossiliferous Rumbalara Shale, in the Alice Springs region are considered to be early Tertiary in age.

INTRODUCTION

The Tectonic map of Australia shows the main outcrop areas of sediments which have been referred to the Tertiary in Northern Australia. They form two linear belts, one of which runs from the Canning Basin in Western Australia to the Alice Springs and Simpson Desert areas in the Northern Territory; and the second from the Barkly Tableland in the Northern Territory along the Georgina River and Pituri Creek to the Springvale area in Queensland. Recent mapping by the Bureau of Mineral Resources has extended this outcrop area south-east of Alice Springs; in the north-western and western parts of the Simpson Desert and the eastern part of Arnhem Land in the Northern Territory; in the Canning Basin of Western Australia; and in the Boulia-Winton area of Queensland.

This study was initiated by a search for Tertiary vertebrate fossils in the Amadeus and Georgina Basins in the Northern Territory and in the Springvale and Riversleigh areas of Queensland by Dr R. H. Tedford of the University of California and the writer in 1963. During this survey, extensive collections of fossil molluscs were made, which, together with collections made by other geological parties of the Bureau of Mineral Resources from the Alice Springs and Barkly Tabeland areas of the Northern Territory and the Ord River area

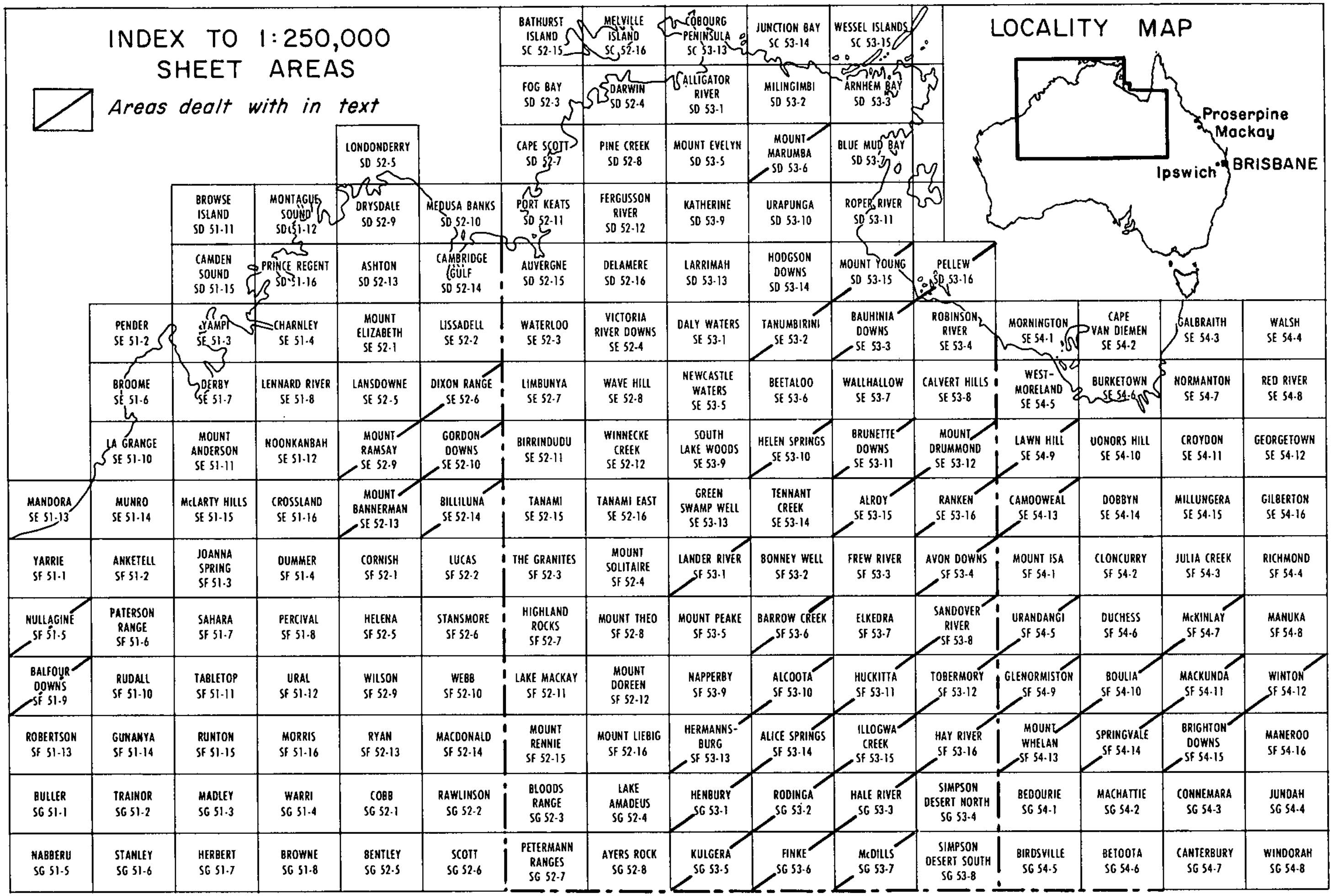

Fig. 1. Areas referred to in text

of Western Australia, formed the basis of the study by Dr D. F. McMichael of the Australian Museum, Sydney (this Vol., pp. 133-160). This paper gives the geological background to his paper, and emphasis is placed on the fossiliferous sediments. Whitehouse (1940), Paten (1960, 1964), and other authors listed in the references give a comprehensive account of the Queensland Tertiary. The rock-types, silicification, topographic expression, and nature of outcrop along present waterways are remarkably constant over such a vast area, and for this reason these sediments have long been regarded as Tertiary, although there was no direct evidence of age. The work on the foraminifers by Lloyd (this Vol.) and the molluscs by McMichael (this Vol.) and the studies on the vertebrate fossils by M. O. Woodburne (1967) and R. H. Tedford (1967, in press) at the University of California are giving a better understanding of the ages of the fossiliferous sediments.

ACKNOWLEDGMENTS

The contributions of Dr R. H. Tedford to the geological observations in the field in 1963, which are incorporated in this paper, are gratefully acknowledged. Thanks are also extended to Dr Tedford for reading the original manuscript, and for his valuable suggestions; to Dr D. F. McMichael for his stimulating discussions and suggestions; and to Professor D. Hill of the University of Queensland, and Dr M. O. Woodburne of the University of California for the loan of material.

OUTLINE OF GEOLOGY

Canning Basin, Western Australia

McWhae et al. (1958, pp. 122-124) describe most of the known and suspected Tertiary deposits of the Canning Basin area.

The Oakover Beds, named by Maitland in 1904, consist of chalcedony, common opal, silicified limestone, marl, white to brown limestone, and limestone breccia. The unit forms low mesas near the Oakover River and at the northern end of the Gregory Range in the Nullagine 1 : 250,000 Sheet area. It is about a hundred feet thick and unconformably overlies ?Permian tillite and Precambrian metamorphics. Traves, Casey, & Wells (1956, pp. 31, 32) consider the beds to be chemically deposited and lacustrine. They state that the mode of occurrence is similar to the Tertiary deposits of the East Kimberley Region and the Northern Territory, but do not attempt a correlation. Veevers & Wells (1961, p. 197) record undiagnostic ostracodes from the limestone of the Oakover Beds. On the Balfour Downs Sheet area, de la Hunty (1964, pp. 15, 16) recorded 100 feet of limestone with opaline silica which he placed in the Oakover Beds.

In the north-east of the Canning Basin, Casey & Wells (1964), Wells (1960, p. 9), and Veevers & Wells (1961, p. 199) describe the Lawford Beds, which consist of 100 feet of massive pisolitic and earthy marl and sandy limestone with a cap of opaline chalcedony, and fragments of ferruginous concretions and pisolitic ironstone at the base. They are similar to and possibly equivalent to the Oakover Beds. The Lawford Beds form mesas and buttes on the banks of Christmas, Lawford, and Wolf Creeks in the northern parts of the Mount Bannerman and Billiluna Sheet areas. Similar deposits recently mapped on the Mount Ramsay Sheet area are considered to be an extension of the Lawford Beds (H. G. Roberts, pers. comm.). Dow, Gemuts, Plumb, & Dunnet (1964, p. 93) extended the name Lawford Beds to cover similar sediments on the Gordon Downs Sheet area, where they crop out around Mount Timperley, in the Calico Creek area, and west of Douri Dam. The best outcrop is at Mount Timperley, where there is about 30 feet of white massive chalcedonic limestone, at the base of which is a poorly exposed leached rubbly white calcareous siltstone. No fossils have been found.

Lander River and Barrow Creek 1 : 250000 Sheet areas, Northern Territory

In the Lander River and Tilmouth/Central Mount Wedge areas there are extensive deposits of Tertiary lacustrine limestone up to 50 feet thick (A. D. M. Bell, pers. comm.).

Smith & Milligan (1964, p. 11 and Table 1) recorded a few outcrops of chalcedony and soft silty limestone in the western half of the Barrow Creek Sheet area, which are lithologically similar to rocks mapped as Tertiary on the Huckitta Sheet area. The sediments are unfossiliferous and are generally less than 20 feet thick, but 125 feet was logged as ?Tertiary in White Well on Stirling station, and Milligan (1963) logged 120 feet of ?Tertiary in BMR Grg 18 near Spinifex Bore on the Stuart Highway.

Alcoota 1 : 250000 Sheet area, Northern Territory

Newsome & Rochow (1964, p. 352) reported on the occurrence of late Tertiary vertebrate fossils 4 miles south of Alcoota homestead and about 100 miles north-east of Alice Springs. They described a section near the fossil occurrence, which, in descending order, is as follows:

5 feet chalcedonic limestone;

20 feet red-brown silty sandstone with lenses of conglomerate, ferruginized near the top;

30 feet green clay;

0-2 feet fossiliferous clay lenses.

Unknown thickness of clay resting on granite.

Fossil gastropods were found in the green 'clay' by M. O. Woodburne and J. E. Mawby of the University of California in 1963 while excavating for vertebrate fossils. Woodburne (1967) has described the stratigraphy and mammalian fauna from this area; he defined the succession as the Waite Formation and described the gastropod-bearing sequence as 2.5 feet of red sandy alluvium overlying 3½ feet of pale green and white to light grey siltstone the base of which was not reached. The gastropods occur immediately east of and lie stratigraphically just below the vertebrate horizon. Woodburne has tentatively assigned a late Miocene age to the vertebrate fauna, based on the stage of evolution.

Widespread mesas east of Alcoota station on the Alcoota Sheet area and around Swan homestead on the Huckitta Sheet area are capped by 3 to 4 feet of chalcedonic limestone. In some places, unfossiliferous sedimentary arenaceous limestone occurs beneath this caprock; in others the chalcedonic limestone rests directly on lateritized Archaean metamorphics.

Along the east-facing escarpment 15 miles east of Alcoota homestead red clastic sediments overlie a laterite profile developed on Archaean metamorphics. The clastic sediments are interbedded with and capped by chalcedonic limestone. They are lithologically similar to the sediments which conformably overlie the fossil vertebrate horizon 4 miles south of Alcoota homestead.

Alice Springs and Huckitta 1 : 250,000 Sheet areas, Northern Territory

Arltunga Beds

Madigan (1932b, p. 97) defined the Arltunga Beds as sands, gravels and limestones, unconsolidated except for the 'duricrust', forming flat-topped hills in the Todd, Paddys Hole, Hale, and Plenty plains. Singleton (1939, p. 52) referred to it as the Arltunga series. K. G. Smith (1964a, p. 56; 1964b, p. 12, table 1) renamed the unit the Arltunga Beds and extended it to cover ?Tertiary outcrops on the Huckitta Sheet area, which are composed of up to 90 feet of chalcedony with relict patches of silicified limestone in the cavities, crudely and massively bedded; the chalcedony grades downwards into limestone with layers, nodules, and veins of chalcedony and into grey or white travertinous limestone, which generally has a brecciated or pellety appearance, and incorporates ferruginous fragments from the underlying weathered surface. Madigan (loc. cit.) thought the deposits appeared to be remnants of valley fills in the present watercourses; Smith (loc. cit.) suggested that they might have been laid down in a lake or series of lakes along the older courses of present-day drainage.

Madigan recorded '*Planorbis*' shells (determined by Chapman) from limestone caps of mesas up to 50 feet high on Paddys Hole Plain, which he considered to be Pleistocene in age. At the Arltunga airstrip, which is on Paddys Hole Plain and is the type locality of Madigan's Arltunga Beds, 12 feet of arenaceous limestone containing gastropods, ostracodes, and charophytes was found overlying Precambrian basement. On a low mesa half a mile to the south, similar gastropods occur in a silicified limestone overlying silicified poorly sorted pebbly sandstone, which in turn overlies mottled Precambrian rocks.

Milligan (1963, p. 20, 21) extended the name to include sequences of Tertiary limestone, sandstone, claystone and chert penetrated between 126 and 206 feet and 125 and 220 feet in BMR Grg 3 and BMR Grg 3A respectively which were drilled 26 miles west of Annitowa homestead on the Elkedra 1 : 250,000 Sheet area.

It is considered that the name Arltunga Beds should be restricted to the outcrops in the vicinity of Arltunga airstrip. The all-embracing use of the name by Madigan, K. G. Smith (1964a, b), and Milligan (1963) to cover a wide variety of rock types over a wide area, because they are thought to be Tertiary, does not comply with the rules of stratigraphic nomenclature and detracts from the value of the name. Woodburne (1967) adopts the same view.

(i) *Hale Plain.* On the north side of the Hale River between Ambalindum and Claraville stations, Madigan (loc. cit.) recorded about 50 feet of very calcareous, arenaceous, and gritty clays with a travertine capping, in which he found stems of *Chara* and small bivalves, possibly *Corbicula* (determined by Chapman, who considered it to be Pleistocene in age). In 1963, a sequence of 75 feet or more of flat-lying white, green, and brown soft calcareous clastic sediments overlain by 15 feet of red-brown poorly sorted coarse sandstone and conglomerate capped by chalcedonic limestone was observed. These rocks presumably rest on Precambrian rocks. The fossils recorded by Madigan from these rocks were not seen in outcrops visited.

(ii) *Plenty Plain.* On the Plenty Plain, Madigan (1932b, p. 99) described a 90-foot section consisting of 50 feet of grey sandy clay, 15 feet of red ferruginous sandstone, and 25 feet of white chalcedony. In 1963, a mesa near the Plenty airstrip was visited and only 4 to 5 feet of chalcedonic limestone was observed, resting on a complete lateritic profile developed on Archaean metamorphics, and it is evident that Madigan included the products of deep weathering of the Archaean rocks in his 90-foot section, as suspected by K. G. Smith (1964, p. 57).

28 miles east of Alice Springs

An outcrop of cream gastropod-bearing limestone forms a prominent hill on the northern side of the Alice Springs/Loves Creek road 28 miles east of Alice Springs and 10 miles north-east of Undoolya Gap. The limestone is about 100 feet thick and unconformably overlies Lower Palaeozoic rocks. It dips 5° to the north.

Todd River homestead area

In 1964, R. D. Shaw (pers. comm.) mapped outcrops of gastropod-bearing limestone which forms mesas and ridges in the vicinity of Todd River homestead. At one locality 13 miles east-south-east of the homestead, orange-brown limestone with rare gastropods is interbedded with blue-grey or brown silicified limestone with numerous gastropods. Fifteen miles south-east of the homestead, pale brown, grey, and pale yellow gastropod-bearing limestone, silty in parts, overlies grey 'billy'. The limestone forms a 20 to 30-foot capping on the mesas and ridges, but the base is not exposed and it could be up to 70 feet thick. The beds dip up to 15° to the south-east and west, forming a basin-like structure.

Hermannsburg 1 : 250,000 Sheet area

Prichard & Quinlan (1962, p. 27) record chalcedonic limestone about 2 miles west of Hamilton Downs homestead, and about 30 feet of siliceous limestone in a scarp of a low mesa which is nearly 2 miles long and 1 mile wide above Burt Plain. The limestone is unfossiliferous and is thought to have formed in a Tertiary lake. Prichard & Quinlan correlated the limestone with the Arltunga Beds because of its lithology, topographic position, and postulated lacustrine origin. They also considered that gravel beds in the southern part of the Sheet area might be Tertiary, although M. A. Condon (footnote in Prichard & Quinlan) regards them as Pleistocene.

Madigan (1932a, p. 700) recorded abundant fossil wood in a conglomerate about 20 feet thick which occurs on the top of a low hill on the north side of the plain inside the Waterhouse Range. He thought it was Tertiary or Quaternary.

Henbury 1 : 250,000 Sheet area

On the Henbury Sheet area, Ranford, Cook, & Wells (1965) mapped sequences of ?Tertiary white, grey, and pale yellow limestones and chalcedonized limestone with interbeds of purple and green siltstone and sandy siltstone, and red-brown coarse-grained poorly sorted calcareous sandstone. The individual limestone beds are up to 6 feet thick and in places form prominent scarps and mesa-cappings. The maximum thickness of the unit is 100 feet near Maloney Bore on Henbury station. Other ?Tertiary deposits consisting of conglomerate and sequences of interbedded calcareous sandstone, siltstone, and sandy limestone form mesas up to 25 feet high near Chandlers Range on Henbury station. Poorly preserved planorbid gastropods were found in a cream silicified limestone 6 miles north-east, and abundant ostracodes in a limestone 4 miles north, of Henbury homestead. Ostracodes, planorbid gastropods, and oogonia of *Chara* were found in a highly silicified limestone which forms a hillock about 10 feet high 4 miles west of Running Waters Yard and 5 miles south-east of Mount Caldwell on Henbury station. All the sequences are unconformable on Lower Palaeozoic rocks.

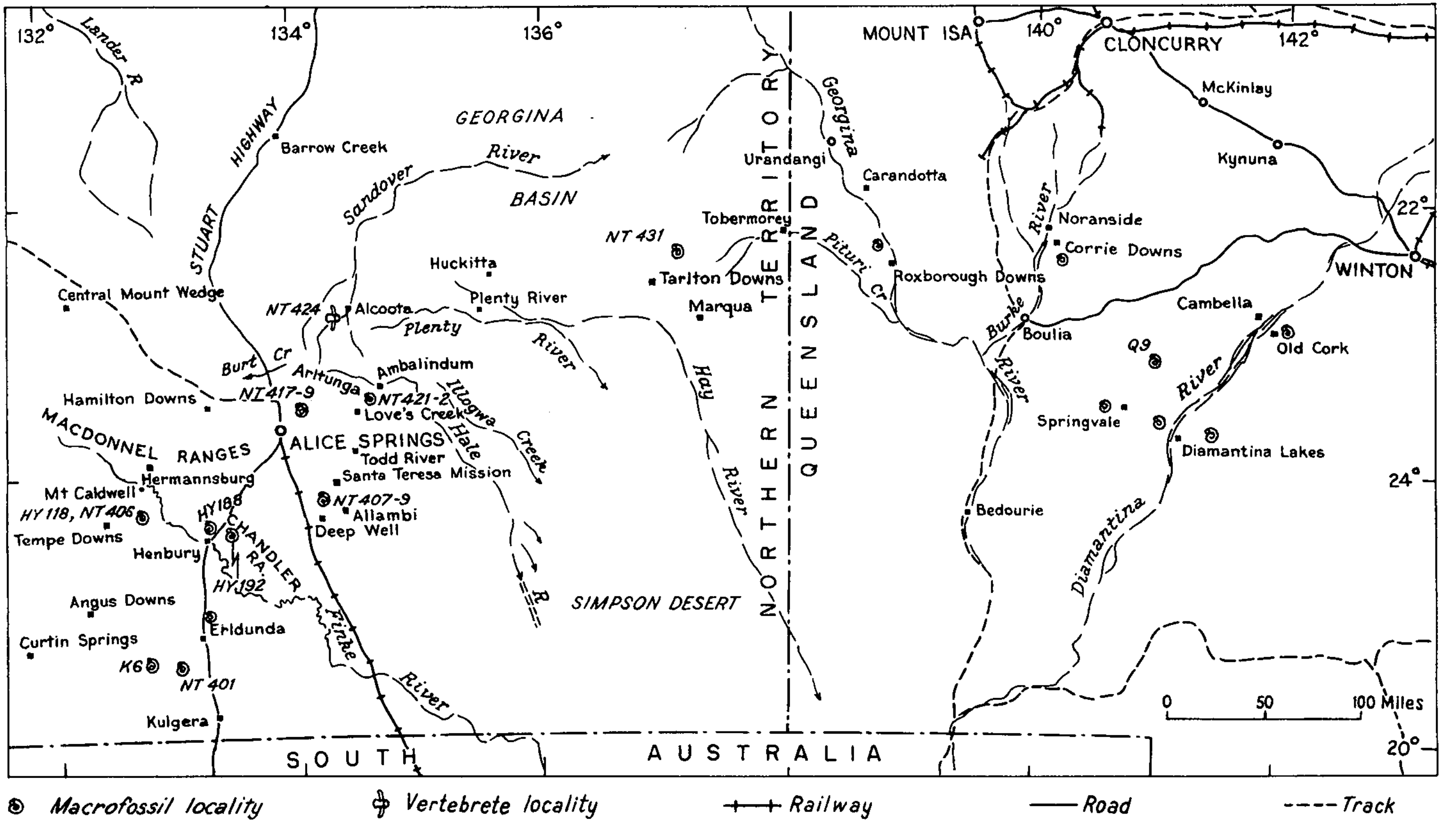

Fig. 2. Locality map, central Australia and western Queensland

Kulgera and Finke 1 : 250,000 Sheet areas

Wells, Stewart, & Skwarko (1966) record areas of grey billy, conglomerate, and highly silicified limestone in the Kulgera and Finke Sheet areas. Gastropods and pelecypods occur in a sequence of siltstone and sandstone with a chalcedonic capping ¾ mile south-east of Pulchera Well on Erldunda station, in the Kulgera Sheet area. In 1963 gastropods were discovered 4 miles west of Beefwood Bore on Erldunda station in a continuation of the same north-facing escarpment, which is a sequence of more than 35 feet of flat-lying green sandstone and gastropod-bearing arenaceous limestone. Oogonia of *Chara* and a poorly preserved ostracode have been found in a sample from 95 feet in a shothole 5 miles north of Erldunda homestead.

Some of the areas on the Kulgera Sheet and around Curtin Springs on the Ayers Rock Sheet which are shown as Tertiary limestone on the geological map of the Alice Springs region (Quinlan, 1962) were considered to be thin travertine.

A sequence of red poorly sorted sandstone and duricrust conglomerate up to 30 feet thick occurs at the top of the escarpments 2 miles north-east of Well 95 on Erldunda station in the Kulgera Sheet area, and makes up an east-facing escarpment near Karinga Dam just north of the Angas Downs/Erldunda road. No fossils were found in these 'post-duricrust' sediments.

Rodinga 1 : 250,000 Sheet area

Over 60 feet of gently west-dipping green to yellow arenaceous limestone bearing duricrust pebble lenses crops out as a long strike ridge along the western edge of Phillipson Pound from 2 miles north-east of Kangaroo Well north to Limestone Bore on Deep Well station in the Rodinga 1 : 250,000 Sheet area. Fossil gastropods and ostracodes occur widely in these sediments, and at one site 7 miles north-east of Deep Well homestead, fragmentary vertebrate remains were discovered with the gastropods in tough limestone in 1963. Crocodile and turtle remains are the most common, but bird bones and a single small kangaroo jaw were found. The kangaroo is very similar to a species from an undescribed fauna which lies stratigraphically between the Ngapakaldi and Palankarinna faunas in the Lake Eyre Basin (Stirton, Tedford, & Miller, 1961). According to the tentative time scale of those authors, the Deep Well jaw fragment would be approximately later Miocene (Stirton, Woodburne, & Plane, 1967). In 1964, L. C. Ranford and P. J. Cook (pers. comm.) mapped an extension of this outcrop which runs as a southerly and south-westerly ridge and small isolated mesas from 2 miles east of Kangaroo Well to 3 miles east of Deep Well homestead. Here it consists of fossiliferous white chalcedonic limestone and white calcareous claystone overlain by red-brown and pink-brown calcareous poorly sorted sandstone about 70 feet thick and unconformable on Lower Palaeozoic rocks.

Elsewhere on the Rodinga Sheet area and extending on to the Alice Springs Sheet area around the Ooraminna Anticline, L. C. Ranford, P. J. Cook, & R. D. Shaw (pers. comm.) have mapped as possible Tertiary sediments a sequence of sandstone, claystone, and chalcedonic limestone which lies above the Tertiary 'grey billy' (duricrust) horizon. The sediments occur in mesas scattered throughout Rodinga and the southern part of the Alice Springs Sheet areas; they are up to 50 feet thick and are characteristically capped by grey weathering chalcedonic limestone. The southernmost exposure of the post-billy sediments on the Rodinga Sheet area occurs 48 miles south-east of Deep Well Siding. This outcrop consists of low mounds of chalcedonic limestone, which is apparently unfossiliferous. Chalcedonic cappings, 10 to 15 feet thick, are found on the mesas and ridges overlying Lower Palaeozoic rocks in the vicinity of Santa Teresa Mission and on the Todd River Plain. Fossil gastropods were seen at the following localities on the Rodinga Sheet area during the 1964 field season, apart from the occurrences near Deep Well homestead (Ranford and Cook, pers. comm.). They are not well enough preserved to be described.

(1) 10 miles south-west of Santa Teresa Mission in white calcareous claystone, 2 feet thick.

(2) 30 miles east of Santa Teresa Mission in 30 feet of grey-green shale overlain by about 10 feet of white clayey chalcedonic limestone.

(3) 10 miles south of Allambi homestead in 25 feet of white chalcedonic limestone.

Post-laterite and post-duricrust coarse red clastic sediments occur widely around Santa Teresa Mission, where they are overlain by chalcedonic limestone. None of these rocks is fossiliferous.

L. C. Ranford (pers. comm.) considers that the 'pre-silcrete' sediments in the north-eastern part of the Amadeus Basin are equivalent to subsurface sediments encountered near Alice Springs in which Tertiary pollens were found. P. R. Evans (pers. comm.) states that 'The Alice Springs microflora was obtained from ditch samples from the Alice Springs Farm area bore W.R.B./Z.G. at depths of 929-959 feet, 997-1006 feet, and 1015-1038 feet. Each sample contained abundant triporate pollens, including forms similar to *Triorites harrisii* Couper (which Cookson & Pike, 1954, record from Australian Eocene-Pliocene deposits) in association with *Dacrydiumites* cf. *D. florinii* Cookson & Pike, which is known to range from Palaeocene to Pliocene in age (Cookson & Pike, 1953). Fairly common, but at present unidentifiable ?aquatic microorganisms, consisting of very thin psilate membranes fitting closely to inner and likewise thin sacs, occurred at 929-959 feet. The environmental significance of these assemblages is unknown. The lack of variety in the pollen assemblage as a whole is remarkable in view of other records of Australian Eocene-Pliocene floras, which always seem to include at least a *Nothofagus* and *Myrtaceidites* content (e.g., Balme & Churchill, 1959; Evans & Hodgson, 1963).'

Possible early Tertiary sequences of claystone, siltstone, sandstone, and conglomerate form isolated outcrops near the MacDonnell and Ferguson Ranges, in the ranges south-east of Ringwood homestead, near Phillips bore in the Phillipson Pound, and south of the James Range near Gum Tree Creek, on the Alice Springs and Rodinga 1 : 250,000 Sheet areas. They form mesas with silcrete capping (L. C. Ranford, pers. comm.).

Illogwa Creek 1 : 250,000 Sheet area

D. R. Woolley (pers. comm.) has recorded a maximum thickness of 100 feet of poorly bedded cream argillaceous limestone with well bedded brown limestone, overlain by a hard chalcedonic cap, on the Illogwa Creek Sheet area. E. N. Milligan (pers. comm.) reports that these outcrops are commonly about 20 miles wide and 60 miles long, trending south-east from the north-central sector of the Sheet area. They thin rapidly on to Archaean basement to the south-west and north-east. The base of Tertiary outcrop (40 feet thick) is known to be approximately 1000 feet above sea level at one point in the central sector. In line with a point 4 miles north-east of this D. R. Woolley has identified 180 feet in subsurface. In the central area Tertiary sediments lie on laterite and soil developed on both Archaean and ?Cretaceous rocks.

Simpson Desert area, Northern Territory

Pebble conglomerate, claystone, and sandstone are distributed widely about the margins of the Simpson Desert in the Northern Territory as veneers. They are 30 to 40 feet thick near the South Australian border (Sprigg, 1963, p. 50).

A. J. Stewart (pers. comm.) mapped a thin sequence of unfossiliferous sandstone and siltstone with lenses of conglomerate in the southern half of Hale River 1 : 250,000 Sheet area around Andado homestead and north-east and south-east from there on McDills Sheet area. The unit is capped by about 5 feet of silcrete and is unconformable on the Rumbalara Shale. It has an average thickness of 15 feet and a maximum of 40 feet. It is considered to be equivalent to a sandstone sequence in the north of South Australia which contains Tertiary non-marine gastropods and lies unconformably on an equivalent of the Rumbalara Shale.

White Mountain Formation, White Mountain, East Kimberley District, Western Australia

The first discovery of non-marine fossiliferous Tertiary sediments in Northern Australia was by Hardman (1885), who recorded freshwater gastropods in a chert at the summit of hill J40 in the White Mountain Range in the Eastern Kimberley district of Western Australia. Hardman recorded that McCoy named the gastropod *Planorbis hardmani,* but McCoy did not publish the name. Wade

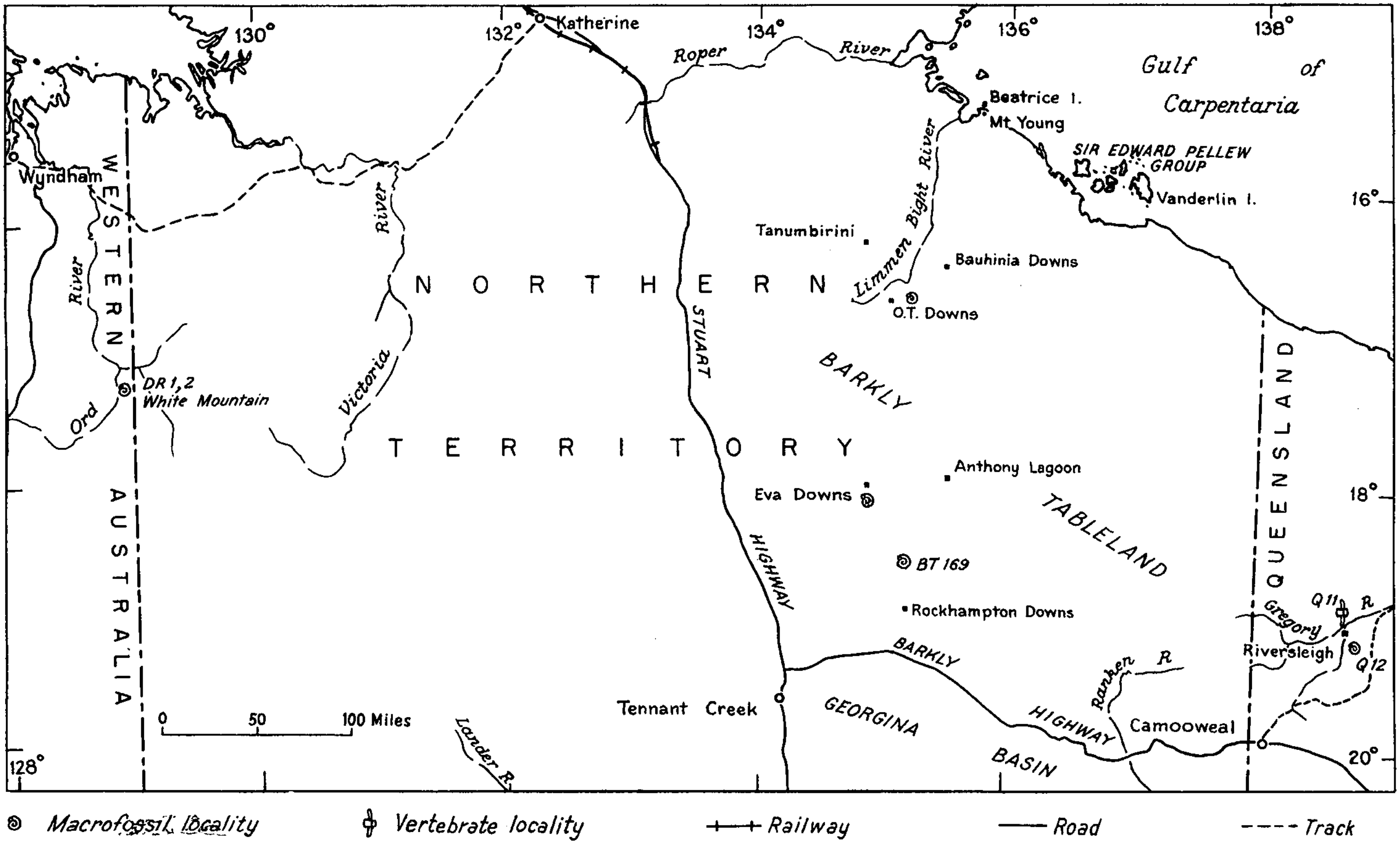

Fig. 3. Locality map, northern Northern Territory

(1924, p. 29) briefly mentioned these sediments and figured *P. hardmani* for the first time. Chapman (1937) was the first to describe *P. hardmani* and the lithology of the chert. He also reproduced one of Wade's figures and recorded ostracodes, two other species of gastropod, foraminifers, and insect, plant, and sponge fragments. The White Mountain Formation consists of up to 370 feet of fossiliferous chert, siltstone, and marl unconformable on the Cambrian Elder Sandstone. The age of the formation has been considered to be Pleistocene, Pliocene, or simply Tertiary (Singleton, 1939, p. 52; Matheson & Teichert, 1948, p. 15; Traves, 1955, pp. 84, 85, 90; McWhae et al., 1958, p. 122; Dow, Gemuts, Plumb, & Dunnet, 1964, p. 93; and Dow & Gemuts, 1964). Material collected by D. M. Traves, J. J. Veevers, J. Roberts, and J. A. Kaulback includes free specimens of ostracodes and *'Planorbis' hardmani,* as well as thin sections of *P. hardmani,* ostracodes, and the foraminifer *Ammonia beccarii. Ammonia beccarii* ranges from lower Miocene to Recent, and the age of the sediments is thought to be Miocene (this Vol., p. 95).

Brunette Limestone, Barkly Tableland, Northern Territory

The Brunette Limestone occurs as thin sheets and scattered boulders of white to brown fine-grained to coarsely crystalline limestone and dolomite along watercourses in the centre of the Barkly Tableland, Northern Territory (Noakes & Traves, 1954, p. 40; Randal & Brown, 1962a,b; Randal & Nichols, 1963; and Nichols, 1963). Nichols (1963, p. 18) recorded algae from the Brunette Limestone, and Lloyd (this Vol., p. 89) recorded the foraminifer *Ammonia beccarii* (Linn.), three species of gastropods, a pelecypod, and an ostracode from an isolated outcrop which is thought to be in sequence with the Brunette Limestone. It was considered to be a lacustrine deposit of late Tertiary age, but the discovery of *A. beccarii* showed that there was a marine influence in the area and that the age of the deposit is probably Miocene.

Austral Downs Limestone, Queensland and Northern Territory

The Austral Downs Limestone occurs as small plateaux, ridges, and hills, in linear belts up to 12 miles wide along the Georgina River and Pituri Creek in western Queensland and the eastern part of the Northern Territory, and as scattered outcrops in the Sandover River 1 : 250,000 Sheet area (Whitehouse, 1940, p. 31; Noakes & Traves, 1954, p. 40; Noakes, Carter, & Öpik, 1959, p. 11 and table 1; Smith & Vine, 1960; Randal & Brown, 1962b; Nichols, 1964; Reynolds & Pritchard, 1964; and Paten, 1960, 1964). It consists of ferruginous detritus at the base, overlain by grey, cream, or white limestone with an upper chalcedonic cap, and is unconformable on Lower Palaeozoic limestone and dolomite. Whitehouse could not find any fossils in these sediments and therefore thought they were probably surface soil limestones. Noakes & Traves and the other workers considered that they were lacustrine. Paten recorded charophyte and other algal remains, plant tissue, ostracodes, and foraminifers in the Austral Downs Limestone, which he thought indicated a continental brackish-water lake deposit, but Lloyd (this Vol., p. 89) identified the foraminifer as *Ammonia beccarii* and considers that foraminifers indicate a marine influence.

K. G. Smith (1963, p. 12 and table 1) recorded 10 to 15 feet of impure limestone and chalcedony, forming several small mesas in the north-east part of the Hay River 1 : 250,000 Sheet area, which is an extension of the Austral Downs Limestone. It is unconformable on Precambrian and Palaeozoic rocks.

Milligan (1963, p. 19) recorded 41 feet of white-grey limestone in BMR Grg 9A drilled at Lake Marion on the Georgina River 6 miles south of Urandangi, which he placed in the Austral Downs Limestone. It overlies 53 feet of soft brown siltstone whose base is green and calcareous, which in turn unconformably overlies ?Lower-Middle Cambrian Camooweal Dolomite. Milligan considers the siltstone to be Tertiary. Poorly preserved planorbid gastropods, ostracodes, and oogonia of the alga *Chara* were discovered in 1963 in an isolated outcrop of the Austral Downs Limestone forming a small hill alongside the Alice Springs/Tobermory/Queensland road near the Tarlton Downs/Marqua boundary. These sediments have been considered to be late Tertiary in age by Whitehouse and subsequent workers; Lloyd (this Vol., p. 97) considers them to be Miocene.

Springvale-Boulia-Winton-Bedourie areas, Western Queensland

Carter & Öpik (1963, table 2) recorded up to 30 feet of chalcedony and limestone along the Burke River north of Boulia on the Duchess 1 : 250,000 Sheet area. Paten (1960, 1964) recorded ostracodes, the gastropod *?Bulinella* sp., and diatoms from 1-4 miles west of 6 miles Bore on Corrie Downs in the Noranside Limestone (a sequence comparable with the Austral Downs Limestone), which crops out in the Burke River valley on the Boulia Sheet area. Whitehouse (1940, p. 26) and Paten (1960, p. 392) describe similar outcrops of limestone near Bedourie, which are unfossiliferous.

The Horse Creek Formation forms cappings on small hills and plateaux in the Springvale area. It consists of up to 35 feet of cherty limestone with a few green clay bands, unconformably overlying the late Cretaceous or Tertiary Springvale Formation. It contains ostracodes, charophyte algae, and two species of gastropods — a low-spired form and a thin-shelled high-spired form. A late Tertiary or Quaternary age was suggested (Paten, op. cit.). Jauncey (1964, table 1) recorded 0-40 feet of brown and grey fine-grained limestone containing ostracodes, charophytes, and faecal pellets in the Goyder and Hamilton Ranges, and north-west and south-east of Hunters Gorge on Brighton Downs Sheet area. He placed the sequence in the Horse Creek Formation. P. J. Jones (pers. comm.) found small ostracodes, charophytes, and thin worm burrows in a limestone from Horn Creek, 8 miles north-east of Hunters Gorge.

The Springvale Formation forms low hills and underlies the plateaux capped by the Horse Creek Formation. It consists of up to 70 feet of clayey sandstone, swelling clay, and calcareous lenses and nodules of lacustrine origin, all of which have been partly ferruginized and indurated. Small faults and warpings are present within the formation. Thin-shelled plane-spired gastropods occur in silicified limestone and hard limestone about 12 miles south of Springvale homestead. Other thin-shelled fragmentary molluscan remains occur in grey limestone about 16 miles south-south-east of the homestead (Paten, 1960, 1964). Jauncey (1964, table 1) described 0-70 feet of similar sediments on the Brighton Downs Sheet area, which he placed in the Springvale Formation. They lie unconformably on the Moses Sandstone.

Vine (1964b, table 1; 1964c, p. 470) and Jauncey (1964, table 1) describe the Moses Sandstone as 0-10 feet of unfossiliferous fine-grained sandstone, in part calcareous, but mainly strongly silicified by weathering, with sandy ironstone at the base. It crops out in the Mackunda, Hamilton, and Goyder Ranges in the Brighton Downs Sheet area, and is unconformable on the Mackunda Beds and the Winton Formation. The dips are mainly horizontal, but local warping has produced dips up to 2° in the Goyder Range and 8° in the southernmost outcrop. The unit is thought to be a Tertiary fluviatile deposit.

The Mueller Sandstone was described by Vine (1964b, table 1; 1964c, p. 474) as a 5 to 30-foot sequence of brown, white, and red fine-grained breccia which forms the plateau of the Mueller Range on the Mackunda Sheet area. It is flat-lying except near the Cork Fault, where it has low dips. The unit is unfossiliferous and is unconformable on the Old Cork Beds.

The Old Cork Beds on the Mackunda 1 : 250,000 Sheet area were described by Vine (1964b, table 1; 1964c, p. 470) as a sequence of up to 300 feet of white, grey, and green claystone, sandy siltstone, limestone, sandstone, conglomeratic sandstone, and ?algal beds around the junction of Middleton Creek and the Diamantina River. They cover about 800 square miles and form flat plains ending in low scarps. The unit overlies the Winton Formation unconformably and is similar to the Tertiary rocks of the Springvale area. P. J. Jones (pers. comm.) identified abundant cyprid ostracodes in a specimen from 7 miles north of Cambula homestead; and planorbid gastropods and cyprid ostracodes in a green-grey porous limestone 1 mile south-east of Old Cork homestead. Jauncey (1964, table 1) recorded 0-65 feet of similar sediments overlying the Horse Creek Formation on the Brighton Downs Sheet area, which he placed in the Old Cork Beds.

Vine (1964a, table 1; 1964c, p. 474) defined the Edkins Formation as a sequence of 0-23 feet of thin-bedded cross-laminated and interlaminated sandstone and siltstone, thin-bedded to massive sandy siltstone, and conglomerate. It contains reworked lateritized sediments, but is strongly silicified in parts. The formation forms flat cappings on mesas in the vicinity of Kynuna on the McKinley Sheet area and is unconformable on the Winton Formation. Fossils have not been found in the formation, but it is thought to be Tertiary in age.

In the Winton Sheet area the Werite Beds form the Forsyth Range and cap lower hills to the north-west of the Forsyth Range, Allens Range, and a part of Corys Range. The unit is composed dominantly of unfossiliferous silty sandstone with locally conglomeratic sandstone, quartz sandstone, and mudstone. It is commonly strongly leached and silicified. A maximum of 145 feet is exposed. The Werite Beds lie unconformably on the Winton Formation and are thought to be Tertiary in age (Vine, 1964c, p. 474).

Paten (1960, 1964) described the Marion Formation as about 25 feet of silicified sandstone or silty sandstone which extends an unknown distance south from Noranside on the Boulia Sheet area. Conifer wood is the only known fossil. The formation lies unconformably on the Winton Formation, and is thought to be Miocene-Pliocene in age.

Eastern Arnhem Land, Northern Territory

The Annie Creek Limestone is exposed in small areas along the north-eastern part of the Mount Marumba 1 : 250,000 Sheet area. It consists of unfossiliferous massive buff to grey limestone with a characteristic fluted weathering habit. It lies unconformably on the Upper? Proterozoic Mainoru Formation and appears to postdate the Lower Cretaceous strata. By analogy with similar deposits elsewhere in the Carpentaria region the limestone is tentatively regarded as Tertiary (Roberts & Plumb, 1963, p. 12).

The Kulampirri Beds consist of widespread massive travertine associated with black soil, and are exposed on the coastal plain between the Yiyintyi Range and the Nathan River, on the Mount Young 1 : 250,000 Sheet area. The travertine may be a Tertiary lake deposit, as similar deposits in the Carpentaria Region are fossiliferous (Plumb & Paine, 1964, p. 13, table 1).

The Beatrice Island Limestone is a massive buff oolitic limestone which is 30 feet thick and unconformably overlies rocks of the Upper Proterozoic Tawallah Group. It lies horizontally and forms the main outcrop on Beatrice Island. Fossil gastropods and pelecypods are present in the limestone, but the samples could not be located for restudy. They were thought to indicate a sub-Recent age and a shallow marine environment of deposition (Plumb & Vine, 1964, p. 13, table 1). Because of the uncertainty of their age and the possibility that it could be Tertiary the unit is included here.

The Vanderlin Limestone crops out only in the Sir Edward Pellew Group, mainly on Vanderlin Island and small islands east of Vanderlin Island. It consists of light yellow to white coarsely cross-bedded limestone with tabular cross-beds up to 15 feet thick. The topset beds consist mainly of flaggy shelly limestone containing gastropods, and the foresets and bottomsets consist of unfossiliferous finely oolitic limestone. There are a few thin bands of quartz sandstone in the foreset beds. The limestone appears to be marine, but it may have been formed by the cementation of sand dunes. If it is marine its present height of 130 feet above sea level may have been brought about partly by emergence and partly by eustatic changes in sea level (J. W. Smith, 1963, p. 5). Plumb & Paine (1964) correlated the Beatrice Island Limestone with the Vanderlin Limestone. The age of the Vanderlin Limestone is also uncertain and may be Tertiary or younger. J. W. Smith (loc. cit.) simply placed it in the Cainozoic.

In the Bauhinia Downs 1 : 250,000 Sheet area J. W. Smith (1964, p. 15) described the Golliger Beds, which crop out poorly in the Golliger Creek area between O.T. homestead and Three Knobs and north-west of Bauhinia Downs homestead near the Limmen Bight River. The unit is a massive white to yellow lacustrine limestone containing gastropods, and is compared with the Carl Creek Limestone near Riversleigh homestead in Queensland. Paine (1963, p. 11 and table 1) described small outcrops of grey sandy limestone which are thought to be equivalent to the Golliger Beds in the Tanumbirini Sheet area. They occur at plain level in the Younger Gulf Fall physiographic division, 12 miles west-south-west of Tanumbirini homestead and between Two Mile and Lagoon Creeks. The limestone is about 10 feet thick and contains abundant gastropods and plant remains, but the fossils could not be located for restudy. The gastropods have been found 9 and 10½ miles east and 13 miles north-east of O.T. Downs homestead.

In the Mount Drummond Sheet area, Smith & Roberts (1963, p. 12 and table 1) described the Cleanskin Beds, which they considered might be Tertiary in age. The unit consists of poorly outcropping unfossiliferous limestone which is commonly chalcedonic with a skeletal appearance. It occurs in the headwaters of Cleanskin Creek and in the Fish Hole Creek area. The Cleanskin Beds are similar to the Brunette and Austral Downs Limestones to the south and the Golliger Beds to the north.

Carl Creek Limestone, Riversleigh, North-west Queensland

The Carl Creek Limestone was named by Jack (1895). Cameron (1901, p. 190) first recorded freshwater and land gastropods, mammalian and reptile remains from the Carl Creek Limestone, near Riversleigh homestead, in north-west Queensland. Cameron wrote that R. Etheridge Junior identified the gastropods as *Helix* and *Isidora,* but Rands, in a footnote to Cameron's report, stated that Etheridge identified the gastropods as *Therrites forsteriana* and *Isidora* near *I. pectorosa.* Whitehouse (1940, p. 24) referred to them as *Thersites* and *Chlorites.* David (1914, p. 255) suggested the name Helicidae Limestone. The Carl Creek Limestone forms a capping on or abuts against the Cambrian Thorntonia Limestone or Precambrian shales, and consists of up to 140 feet of massive and irregularly bedded white to grey limestone, with conglomerate up to 25 feet thick at the base containing abundant chert, pebbles derived from the underlying Thorntonia Limestone (Whitehouse, 1940, p. 24; Bryan & Jones, 1946, p. 77; Noakes & Traves, 1954, p. 40; Paten, 1960, p. 393; and Carter & Öpik, 1961,

p. 12 and table 1). It was observed that the basal conglomerate of the Carl Creek Limestone also contains quartzite clasts resembling duricrust, and locally it rests on ironstone or ferruginized basement. Noakes & Traves (loc. cit.) referred to it as the Verdon Limestone, and suggested a Cretaceous or Tertiary age. Cameron (1901) suggested a post-Tertiary age; Whitehouse (1940) a Pliocene age; Bryan & Jones (1946) a Pleistocene age; and Öpik (in Carter & Öpik, 1961) said the age was not conclusive and could be Tertiary or Upper Cretaceous. Vertebrate fossils collected in 1963 from the cliff 1 mile south of Verdon Creek (locality M103 on Lawn Hill 1 : 250,000 Geological map) included large ground birds, crocodile and turtle remains, and a poorly represented mammal fauna consisting of a possible kangaroo and two species of diprotodonts. The Carl Creek diprotodonts are very similar to species from the Ngapakaldi fauna of the Lake Eyre basin (Stirton, Tedford, & Miller, 1961), and both have been assigned to the late Oligocene or possibly early Miocene (Stirton, Woodburne, & Plane, 1967; Tedford, in press), although Ludbrook (1963) and Lloyd (this Vol.) consider the Ngapakaldi fauna to be no older than Miocene on the evidence of spores and foraminifers respectively which occur stratigraphically below the vertebrates.

Ipswich area, south-east Queensland

Jones (1927, pp. 28-30), Whitehouse (1940, pp. 34-36), and Staines (1960, pp. 346-348) described the Tertiary sediments of the Ipswich area. The Silkstone Formation is described as a sequence of clay, fissile shale, sandstone, dolomitic limestone, and basalt up to 910 feet thick, developed around Ipswich. Some of the limestone is chalky, but much is highly silicified, being completely replaced at times by chalcedony, and contains Planorbid gastropods. The beds are horizontal in parts and folded in parts. Whitehouse considered them to be Miocene in age, but Bryan & Jones (1946) and Staines assigned them to the Oligocene.

The Redbank Plains Formation conformably underlies the Silkstone Formation and in turn unconformably overlies both the Ipswich Coal Measures and the Bundamba Group. It is composed of mudstone, clay, fissile shale, and soft sandstone, and is 100 to 420 feet thick. The faunal assemblage includes fish, ostracodes, insects, a pelecypod, fragmentary bones, and reptilian skin impressions. Dicotyledonous leaf impressions are also present. It is thought to be Eocene or Oligocene (Staines, 1960, p. 346, 347).

Cape Hillsborough, Proserpine 1 : 250,000 Sheet area, Queensland

Jensen (1963, pp. 11-13) described Tertiary strata at Cape Hillsborough, 19 miles north of Mackay on the Proserpine 1 : 250,000 Sheet area in Northern Queensland. It consists of rhyolite, rhyolitic agglomerate, and conglomerate underlain by shale and sandstone; it dips 10-15° south. On the northern side of Cape Hillsborough, soft brown carbonaceous shale with plant debris and current bedded friable quartz sandstone crops out. He recorded dicotyledonous leaves and gastropods in the shale and stated that in 1939 F. W. Whitehouse identified the gastropod as being similar to *Sigaretus*. Samples of the shale were examined and found to be made up almost entirely of ostracodes, with rare fish bones and numerous poorly preserved gastropods. P. R. Jones (pers. comm.) considered that the ostracodes were indicative of an estuarine environment. D. F. McMichael (pers. comm.) examined the gastropods and considered that though they were too poorly preserved for positive identification, some small discoidal shells could be planorbids and that one sinistral shell could be related to *Physastra*. He was inclined to believe that they indicated a freshwater deposit, but would not place any reliance on the molluscs in this regard.

Jensen (1963) also recorded that Mackay Oil Prospecting Syndicate (MOPS) Bore No. 4 located immediately south of Cape Hillsborough drilled through 303 feet of soft shale and mudstone, and finished in hard silicified sandstone. MOPS No. 5 Bore, also near Cape Hillsborough, passed through 195 feet of shale (from 30 feet to 225 feet), and then passed through 500 feet of sandstone, tuffaceous in part, from 225 feet to 725 feet before entering andesitic tuff which probably belonged to the Carboniferous Campwyn Beds. Jensen estimated that the Tertiary sequence is of the order of 1600 feet thick at Cape Hillsborough and about 300 feet south-west of Calen.

E. A. Hodgson (in an appendix to Jensen, 1963) examined three samples from MOPS 4 and 5 for spores and recorded the following results:

'The sample from Bore No. 4 (235-300 feet) produced a good yield of well-preserved pollen, among which triporate species including *Triorites harrisii* were relatively abundant. Rare specimens of *Nothofagus* cf. *deminuta* were recorded. The remainder of the assemblage was made up of *Inaperturopollenites* sp., podocarpaceous species and unidentified pollens, including an intersemi-angular form. This sample is of Tertiary (probably Lower Tertiary) age.

The samples from Bore No. 5 from 40 feet and from 660-665 feet failed to produce a microflora.'

From the fossil evidence I consider that the Cape Hillsborough deposits are freshwater or estuarine.

Flat-lying sandstone which is unconformable on the Campwyn Beds on Newy, Outer Newey, and Mausoleum Islands is correlated with the sandstone at Cape Hillsborough and on lithology considered to be Tertiary by Jensen (1963). Fossil wood has been found in this sandstone. Jensen also recorded that two bores drilled on Newy Island in 1912, and logged by W. E. Cameron, encountered 85 feet of soft sandstone, pebbly conglomerate and shale.

AGES OF THE DEPOSITS

Although the foraminifer *Ammonia beccarii* (Linn.) is present in the White Mountain Formation, Brunette Limestone, and Austral Downs Limestone (Lloyd, this Vol.), it is not a reliable index fossil and does not permit a correlation. *A. beccarii* does, however, indicate that these sediments are not older than lower Miocene. The gastropods identified by McMichael (1965) are all extinct species and their distribution suggests that they are more or less the same age. The association of *Syrioplanorbis hardmani, Physastra rodingae,* and *Gyraulus chapmani* with *Ammonia beccarii* in the White Mountain Formation and *Syrioplanorbis hardmani* with *A. beccarii* in the Brunette Limestone suggests that these gastropods may not be older than lower Miocene.

Tedford (in press) tentatively places the vertebrate fauna in the Carl Creek Limestone in the late Oligocene or early Miocene, and the vertebrate fauna near Deep Well tentatively in the later Miocene, and Woodburne (1967) tentatively places the Alcoota vertebrate fauna in the late Miocene or early Pliocene on the basis of a comparison with the vertebrate faunas in the Etadunna Formation near Lake Eyre in South Australia, to which Stirton, Tedford, & Miller (1961) tentatively assigned an Oligocene age, and Stirton, Woodburne, & Plane (1967) a late Oligocene or early Miocene. Ludbrook (1963) and Lloyd (this Vol.), however, on the basis of spores and foraminifers respectively which occur stratigraphically just below the vertebrates, stated that the Etadunna Formation was not older than Miocene. The presence of *Bothriembryon praecursor* in the Etadunna Formation and Deep Well sediments and *Meracomelon lloydi* in the Etadunna Formation, Deep Well sediments, and Carl Creek Limestone suggests that these gastropods are also Miocene species.

From the evidence of the gastropods, foraminifers, and vertebrates it is therefore considered that the White Mountain Formation, Brunette Limestone, Austral Downs Limestone, Carl Creek Limestone, Horse Creek Formation, Arltunga Beds, the deposits 28 miles east of Alice Springs at Alcoota, and near Henbury and Todd River homesteads, and the Etadunna Formation are all Miocene, but are not necessarily correlates. The other fossiliferous sequences such as those near Erldunda, the Old Cork Beds, Silkstone Formation, and Golliger Beds, which have either not been examined or contain gastropods which are not present in the other sediments, may also be Miocene. The age of the unfossiliferous deposits cannot be ascertained, but in the Alice Springs area, by virtue of their geological setting, the 'post-duricrust' sediments may be Miocene or younger and the 'pre-duricrust' sediments may be Eocene to Miocene.

ENVIRONMENT OF DEPOSITION

McMichael (this Vol.) shows that the molluscan faunas indicate a lacustrine environment, but they could have lived in nearshore freshwater lagoons. The foraminifers in the White Mountain Formation, Brunette Limestone, and Austral

Downs Limestone (Lloyd, this Vol.) indicate a marine incursion in these areas. Nichols (1963) suggested as a result of petrological study that the fossiliferous sequence in the Brunette Limestone was laid down in a nearshore lagoon. It is therefore considered that the fossiliferous sediments of Northern Australia were laid down in lakes some of which were not far removed from the ocean, and that the White Mountain Formation, Brunette Limestone, and Austral Downs Limestone were actually subjected to a brief marine incursion.

The unfossiliferous sediments were also possibly laid down in lakes or along watercourses, and any fossils that were present would have been destroyed through diagenetic processes.

'MESOZOIC' SEDIMENTS IN THE ALICE SPRINGS REGION

With the exception of the Rumbalara Shale in the south-east part of the Alice Springs region, which is indisputably Lower Cretaceous in age on fossil evidence, it is considered that the mapping of sediments as Mesozoic or Lower Cretaceous in the Alice Springs region has been based on unsound evidence.

On the Hermannsburg Sheet Prichard & Quinlan (1962, p. 26) mapped, as Lower Cretaceous, sequences of unfossiliferous siltstone with pebbly and silty sandstone at the base in places, which form low mesas on the plain along Arumbera Creek, towards the Finke River, and on Missionary Plain east of the Hugh River. The siltstone is up to 40 feet thick and contains beds of sand up to an inch thick; it occurs below the leached and partly silicified cap of the mesas. The sediments are not folded and are unconformable on Precambrian and Palaeozoic rocks. Similar sediments occur on the plain from Mount Sonder westward along Arumbera Creek towards Burt Plain; on the divide between the Finke drainage and Arumbera Creek; and as scattered outcrops down the valley of Arumbera Creek until near Burt Plain. They appear to be continuous with beds under the Burt Plain which have been encountered in waterbores.

Quinlan (1962, p. 143) thought that sediments cropping out at Barrow Creek and encountered in bores on Willowra, Pine Hill, Bond Springs, and Mount Riddock stations were possibly of Mesozoic age. Quinlan goes on to say 'The Mesozoic or pre-laterite sediments cannot always be distinguished in bore-hole samples from the unconformably overlying Tertiary to Quaternary alluvium'. He also shows 'undifferentiated Mesozoic' on his map in the south-eastern part of the Amadeus Basin. The Mesozoic or Lower Cretaceous ages of these sediments are based on unpublished reports by Dr I. Crespin which have been partly quoted in Joklik (1955, p. 35), Prichard & Quinlan (1962), and Quinlan (1962). Crespin (1948) recorded spherical siliceous tests of radiolaria belonging to the group Spumellaria from a sample from 200-250 feet in a waterbore on Bond Springs about 16 miles west of the 16-mile Government waterbore north of Alice Springs. Samples from other bores on Bond Springs station were unfossiliferous. Crespin (1950) reported that samples, mainly siltstone, from

580-590, 600 and 640 feet from the 16-mile Government bore north (not west as stated by Dr Crespin) of Alice Springs, were unfossiliferous. From a miscellaneous sample she recorded lignite and from 'chips of strata from various depths, accumulated by driller on top of 44 gallon drum at bore' she recorded 'fragments of gypsum, dark grey siltstone and numerous spherical bodies referred to radiolaria, fragments of molluscan shells and an ostracod'. Crespin (1951) described a sample from a bore on Froud Creek (not Freud River as stated by Dr Crespin), 80-90 miles south-west of Alice Springs, as containing lignite, fine angular quartz grains, and a fragment of dark grey rock crowded with radiolaria similar to the samples from the 16-mile bore and Bond Springs Bore.

The specimens unfortunately could not be found and therefore could not be re-examined. However, the original samples from the Bond Springs and 16-mile bores were located and examined. The Bond Springs sample from 200 to 250 feet and the sample of 'dark grey siltstone' from the top of the 44-gallon drum at the 16-mile bore were found to be calcareous pebbly siltstones. The spherical objects that were identified as Radiolaria were found to be trapezohedral analcite crystals on examination by I. R. Pontifex. No ostracodes or molluscs were observed, and it is thought that fragments of calcite veins from the rock are what was recorded as fragments of molluscs. There is, therefore, no evidence for Lower Cretaceous rocks in these bores, nor on which to base a Mesozoic age for the sediments mapped by Prichard & Quinlan (1962) and Quinlan (1962) in the Alice Springs area and Amadeus Basin.

E. N. Milligan (pers. comm.) also considers that the sediments shown as Mesozoic in the Arltunga/The Gardens area on the geological map of the Alice Springs area by Quinlan (1962) are Tertiary.

From a study of the limestone and chalcedonic limestone outcrops in 1963, Dr Tedford and I considered that the chalcedonic limestones closely resembled caliche or kunkar, and were formed by pedocal soil processes. Woodburne (1967) reaches the same conclusion for the Alcoota area.

LOCALITIES, LITHOLOGY, AND FAUNAS OF SAMPLES EXAMINED BY DR D. F. McMICHAEL (THIS VOL.)

Sample No.	*Locality*	*Lithology*	*Formation*	*Fossils*
NT401	4 miles west of Beefwood Bore, Erldunda, N.T.	Limestone, light green, amorphous, soft, sandy, vuggy.		Gastropod *(Gabbia* sp.)
K6	¾ mile S.E. of Pulchera Well, Erldunda, N.T.	Limestone as in NT401.		Gastropod (*Gabbia* sp.) *pelecypod (Corbiculana* sp.) ostracodes; oogonia
HY116 NT406	4 miles west of Running Waters Yard or 5 miles south of Mt Caldwell, Henbury.	Silicified limestone, brown, red and yellow, hard; ferruginous, sandy in parts.		of *Chara;* gastropod *(Syrioplanorbis hardmani).*
NT407	7 miles N.E. Deep Well homestead, N.T.	Limestone, light brown, microcrystalline, hard; vuggy, veined by coarse calcite mosaic; manganese dendrites; brecciated in parts.		Ostracodes; vertebrate remains; gastropods *(Meracomelon lloydi, Physastra rodingae).*
NT408	1 mile north of NT407.	Limestone, cream to white, microcrystalline, hard; manganese dendrites; brecciated in parts.		Gastropods *(Meracomelon lloydi).*
NT409	3 miles north of NT407.	Limestone breccia, cream to white, hard; veined by coarse calcite mosaic.		Gastropods *(Meracomelon lloydi, Bothriembryon praecursor, Syrioplanorbis hardmani).*
Rd21	4 miles E.N.E. of Deep Well homestead.	Limestone as in NT407.		Gastropods *(Potamopyrgus* sp., *Bothriembryon praecursor, meracomelon lloydi).*
NT417	10 miles north of Undoolya Gap or 28 miles east of Alice Springs on road to Loves Creek.	Limestone, yellow and cream, amorphous, hard; small vugs; ferruginous in parts.		Ostracodes; oogonia of *Chara;* gastropods (*Syrioplanorbis hardmani*).
NT422	2 miles S.W. of Arltunga airstrip, N T.	Silicified limestone, white to grey, red, hard; arenaceous, vuggy; ferruginous in parts.	Arltunga Beds	Ostracodes; oogonia of *Chara;* gastropods *(Syrioplanorbis hardmani).*
NT423	Arltunga airstrip, N.T.	Silicified limestone, red, hard; arenaceous.	Arltunga Beds	Gastropods *(Syrioplanorbis hardmani, Gyraulus chapmani, Anisus arltungae).*
AS234	15 miles S.E. of Todd River homestead, N.T.	Silicified limestone, pale brown, grey, pale yellow, hard; silty in parts.		Ostracodes; abundant algal stems; gastropods (*Potamopyrgus* sp., *Syrioplanorbis hardmani, Gyraulus chapmani).*
AS235	13 miles E.S.E. of Todd River homestead, N.T.	Silicified limestone, orange-brown, blue-grey, brown, hard.		Ostracodes; gastropods *(Potamopyrgus* sp., *Syrioplanorbis hardmani, Gyraulus chapmani).*
NT424	4 miles south of Alcoota homestead, N.T.	Clay, green.	Waite Formation	Vertebrate remains; gastropods *(Isidorella* sp., *Physastra rodingae*).
Q9	16 miles S.E. of Springvale homestead, Qld; locality S123 on Springvale Sheet.*	Silicified limestone, red-brown, hard.	Horse Creek Formation	Ostracodes: oogonia of *Chara;* gastropods *(Potamopyrgus* sp., *Syrioplanorbis hardmani).*
Q11	1 mile south of Verdon Creek or 5 miles north of Riversleigh homestead, Qld. Locality 103 on Lawn Hill Sheet.*	Limestone, brown, microcrystalline, hard; veined by coarse calcite mosaic.	Carl Creek Limestone	Ostracodes; vertebrate remains; gastropods *(Physastra rodingae, Meracomelon lloydi).*
Q12	1 mile S.E. of Riversleigh homestead, Qld; locality 90 on Camooweal Sheet.*	Limestone, white, microcrystalline, hard; veined by coarse calcite mosaic.	Carl Creek Limestone	As in Q11.
BT169	28.5 miles north of Rockhampton Downs homestead, N.T.	Conglomeratic gastropod calcirudite (coquina); limestone, light grey, brown, microcrystalline, hard; subrounded fragments of limestone 2 mm to 2 cm; abundant gastropods.	Brunette Limestone	Ostracodes; foraminifer (*Ammonia beccarii*); *pelecypod (Corbiculina* sp.); gastropods (*Plotiopsis* sp., *Syrioplanorbis hardmani*).
DR1	Hill J40, White Mountain, East Kimberley District, W.A.	Silicified limestone, light brown, microcrystalline, hard.	White Mountain Formation	Ostracodes; gastropods *(Syrioplanorbis hardmani, Gyraulus chapmani, Physastra rodingae*); foraminifer (*Ammonia beccarii*).
DR2	,, ,,	,, ,,	,,	Ostracodes; gastropod (*Syrioplanorbis hardmani).*
DR4/4	,, ,,	,, ,,	,,	Ostracodes; gastropods *(Syrioplanorbis hardmani, Gyraulus chapmani,*
—	Tirari Desert, east of Lake Eyre, South Australia.	Limestone	Etadunna Formation	*Syrioplanorbis hardmani, Meracomelon lloydi, Bothriembryon praecursor*).

* i.e. 1 : 250,000 geological map.

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NON-MARINE MOLLUSCA FROM TERTIARY ROCKS IN NORTHERN AUSTRALIA

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SUMMARY

The non-marine Mollusca from Tertiary rocks of northern Australia are reviewed systematically. Species described or recorded by earlier workers, together with new material from the Bureau of Mineral Resources collection, yield ten species of gastropods and one bivalve. Of these, only six gastropods are sufficiently well preserved to allow specific description. The molluscs are all characteristically land and freshwater species and it is suggested that the deposits were laid down in a lake.

INTRODUCTION

Lloyd (this Vol.) has given an account of the Tertiary geology of northern Australia. He has mentioned a number of fossil land and freshwater molluscs from widely separated localities, but only one species has been adequately described: the freshwater pulmonate gastropod from the White Mountain Range in the Kimberley District of Western Australia, which was named *Planorbis hardmani* and subsequently described in detail by Chapman (1937). Older publications include references to *Planorbis* from other localities, including the eastern MacDonnell Ranges (Madigan, 1932) and Ipswich, Queensland (Whitehouse, 1940); to *Corbicula,* a bivalve, from the eastern MacDonnell Ranges (Madigan, 1932); and to land snails from the Carl Creek Limestone, north-west Queensland, tentatively identified as *Therrites* [sic.] (=*Thersites*) *forsteriana,* and a freshwater pulmonate from the same formation, tentatively identified as *Isidora* near *I. pectorosa* (Cameron, 1901).

Since these accounts were published, geological work in northern Australia has resulted in the accumulation of much additional material. Preliminary reports on some of this material have been available in the mimeographed Records of the Bureau of Mineral Resources, but the present account is an attempt to bring together all the available material for comparative study in the light of many advances which have been made in recent years in knowledge of the systematics of living non-marine molluscs.

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SYSTEMATIC DESCRIPTIONS

Class GASTROPODA

The classification of the non-marine gastropods has undergone many changes in recent years. For more than a century after Linnaeus, the classification of species into genera and genera into higher groups was based almost entirely on the shape and sculptural detail of the shell. During the latter part of the nineteenth and the first half of the twentieth centuries, the study of the anatomy of the animals and of the structure of their radulae revealed that classifications based on shell morphology were completely misleading. The gastropod shell, being fundamentally a simple coiled tube, has only a few really basic shapes, though these shapes are subject to almost infinite variation in detail. Consequently the shape of the shell has been duplicated over and over again by groups of widely diverse origins, even to the extent of convergences in sculptural detail. It is generally true that these convergences exist between species from different zoological regions, whereas within the one region genera can usually be recognized on shell characters; nevertheless, it is not possible from a study of the shells alone to be certain of the correct family allocation.

In studying Tertiary non-marine molluscs one is handicapped by a twofold disadvantage. First, the anatomical characters are irretrievably lost, and, second, the details of sculpture are seldom preserved sufficiently well to permit certainty regarding generic allocation. Thus the decisions made will usually be based on (1) a knowledge of the Recent fauna and thus the probable family groups represented among the fossils, and (2) the gross shell morphology coupled with what sculptural details are available, which will permit the making of comparisons with known members of the Recent fauna. Both criteria are potential sources of error, since families may have been represented in the fossil record which are no longer part of the Recent fauna and since convergence in shell morphology between fossil forms and Recent species which are only distantly or not at all related obviously must have occurred.

If these difficulties are borne in mind, the systematic arrangement adopted here will be seen in its proper perspective and no undue conclusions will be drawn on the basis of this taxonomy.

Subclass PROSOBRANCHIA

Order MESOGASTROPODA

Family HYDROBIIDAE

Genus POTAMOPYRGUS Stimpson *sensu lato*

Potamopyrgus Stimpson, 1865, *Amer. J. Conch.*, 1, p. 53. Type species by original designation, *Amnicola corolla* Gould.

Remarks: The genus *Potamopyrgus* is based on a New Zealand species which is known to be quite variable in details of shell morphology. A large number of forms closely related to *Potamopyrgus* are known from Australia, which have been split up into a number of generic units by Cotton (1943) and Iredale (1943); at least some of these probably represent valid genera. However, since many of them are based on such features as the radula formula and the structure of the operculum, precise allocation of the fossils described here is impossible, and they are referred to *Potamopyrgus* s.l.

POTAMOPYRGUS sp.

(Pl. 10, fig. 1)

Remarks: In samples AS234 and AS235, from 15 miles south-east and 13 miles east-south-east of Todd River homestead, approximately 50 miles east of Alice Springs, Northern Territory, the exposed weathered surface of a series of richly fossiliferous silicified limestone consists almost entirely of several pulmonate genera (*Gyraulus, Physastra, Syrioplanorbis*) and a small high-spired gastropod which appears to be referable to *Potamopyrgus* s.l. There is no trace of an operculum in the material available, but in general appearance the shells are similar to the living species of *Potamopyrgus*, such as *P. antipodum* (Gray) from New Zealand (Pl. 10, fig. 2). They are larger than any of the Recent Australian species, but otherwise similar in general shape to such species as *niger* Quoy & Gaimard from Tasmania and *buccinoides* Quoy & Gaimard from Victoria. Carter (1963, p. 170) has recorded the latter species under the genus *Austropyrgus* Cotton, from the lower Pleistocene Nelson Bay Formation, near Portland, Victoria, but the specimens were all very small, reaching a maximum length of 2.2 mm. It will be seen by comparison with Carter's figures that the sutures of *buccinoides* are much more strongly impressed than in the present species.

Similar shells are found in samples RD21, from 4 miles east-north-east of Deep Well station (about 30 miles south-west of AS234 and AS235) and Q9, from 18 miles south-east of Springvale homestead, north-west of the Diamantina River in Queensland, but neither of these localities is so rich in other species.

Unfortunately the details which can be seen in the available material are insufficient to permit the description of a new species, or identification with any known species.

Descriptions: Shells large for the genus, maximum length greater than 5 mm, maximum width of body whorl 2½ to 3 mm. Spire elevated, shell consisting of 5½ whorls, regularly increasing in size; whorls flattened, sutures weakly impressed, without spiral ribs or spines on early whorls; body whorl with a weak peripheral keel.

Family BITHYNIIDAE

Genus GABBIA Tryon, 1865

Gabbia Tryon, 1865, *Amer. J. Conch.*, 1, p. 220. Type species by monotypy, *Gabbia australia* Tryon.

GABBIA sp.

(Pl. 10, figs 3, 4)

Remarks: In sample K6 from ¾ miles south-east of Pulchera Well, Erldunda, Northern Territory, are some ill-defined impressions of a small turbinate gastropod which differs in shape from those referred above to *Potamopyrgus*. This locality is close to NT401, 4 miles west of Beefwood Bore, Erldunda, where similar impressions are found, but in neither case are any sufficiently clear or well preserved to permit adequate study and determination. The largest example is part of a mould, approximately 10 mm in length and 7 mm at its broadest part. A few small partly exposed casts show a shell with a broad, rounded body whorl, comparatively low spire, and not differing greatly in shell morphology from Recent species of *Gabbia,* a genus which is widespread in Australia today. However, these specimens are not sufficient to justify a formal description.

Ludbrook (1953, p. 108) recorded the Recent species *Coxiella gilesi* (Angas) from sub-Recent limestones at Lake Eyre, South Australia. This species is very similar in form to species of *Gabbia,* but *Coxiella* is normally an inhabitant of salt lakes, and there is no evidence of a saline environment in the two samples studied here.

Family THIARIDAE

Genus PLOTIOPSIS Brot, 1874

Melania (*Plotiopsis*) Brot, 1874, *Syst. Conch.-Cab.* (*Martini-Chemnitz*), Bd. 1, Abth. 24, p. 7. Type species by original designation, *Melania balonnensis* Conrad.

Remarks: The family Thiaridae, formerly known as Melaniidae, includes many genera of tropical freshwater snails, which in recent years have been redefined in anatomical terms. Although there is some similarity in shell morphology between genera, those groups which occur in Australia at the present time are relatively distinctive, and among them, the high-spired *Plotiopsis,* strongly sculptured with axial ribs and spiral striae, is easily recognized.

PLOTIOPSIS sp.

(Pl. 10, fig. 5)

Remarks: In sample BT169 from 28½ miles north of Rockhampton Downs homestead on the Rockhampton Downs to Anthony Lagoon Road, Northern Territory, are many fossils of a high-spired gastropod. The rock is a soft limestone and the fossils are for the most part poorly preserved. Occasional specimens retain some sculpture, which shows them to be very similar to Recent species of *Plotiopsis.* Several species of this genus are living today in the inland and coastal rivers and lakes of eastern and northern Australia, but the state of preservation of the fossils does not permit a more precise identification.

Subclass PULMONATA

Order BASOMMATOPHORA

Family PLANORBIDAE

Subfamily PLANORBINAE

The family Planorbidae was for many years used to include all the flat-coiled freshwater pulmonates, but recent work, especially that of Baker (1945) and Hubendick (1948, 1955), has clearly demonstrated that shell shape has little meaning in allocating species to groups above the level of genus. The important characters determining tribe and subfamily classification are the anatomical features of the male genitalia, which may result in very similar shells being placed in different subfamilies. Even at the generic level, the shape of the shell can vary, but in general the shells of species in a particular genus are reasonably consistent in shape. Unfortunately for the palaeontologist very similar shell shapes have evolved on a number of occasions, so that a particular fossil species could be equally well referred to one of several genera.

The size and shape of the large species discussed below, *'Planorbis' hardmani,* suggest that it might be included in one of four genera adopted by Zilch (1959, based largely on Wenz's unpublished manuscripts and Hubendick's recent studies): *Indoplanorbis* Annandale & Prashad, 1920; *Syrioplanorbis* Baker, 1945; *Australorbis* Pilsbry, 1934; or *Planorbarius* Froriep, 1806. (H. B. Baker (1963, p. 34) has suggested that the name *Planorbarius* should be considered a synonym of *Planorbis* s.s. and that *Coretus* Gray, 1847, should be used for the group usually so named.) Of these genera, *Indoplanorbis* falls into the subfamily Bulininae, *Syrioplanorbis* and *Australorbis* into the subfamily Planorbinae, tribe Biomphalariae, and *Planorbarius* into the subfamily Planorbinae, tribe Helisomateae.

With one exception, each of these genera is listed by Zilch as having a long fossil history. *Indoplanorbis* is known only as a Recent genus, but is widespread through India and Ceylon. *Syrioplanorbis* is said to range from the upper Oligocene of Europe, and is found fossil through Asia, but only occurs in the Recent as a single Syrian species. *Australorbis* is said to range from the Upper Cretaceous to the upper Oligocene of Europe, and is also known fossil from China and North America. Recent species, however, are restricted to South America and the West Indies, though some authors regard the African *Biomphalaria* as being the same genus. *Planorbarius* is said to range from the upper Eocene of Europe, North Africa, and Asia Minor, and lives today in Europe and Northern Asia.

Taking zoogeography into consideration, one is forced to conclude that any of the above genera could have extended its range to Australia during the middle and late Tertiary, though on distributional grounds *Syrioplanorbis* and *Planorbarius* seem most likely to have done so. A detailed comparison of the fossils with Recent shells indicates that their characters are closest to Recent *Syrioplanorbis* as described by Zilch (1959, p. 117). Hubendick (1955) regards this genus as identical with *Biomphalaria* on anatomical grounds, but there are significant differences in shell shape. In an attempt to compare the Australian fossils with other fossil *Syrioplanorbis,* I inquired from Dr A. Zilch of the Senckenburg Museum, Frankfurt-am-Main, about the known fossil occurrences of *Syrioplanorbis*. However, he informs me that these geological distribution data were given on the authority of the late Dr W. Wenz's unpublished manuscripts and that he does not know exact details of species and horizons. A search of the available geological literature by Mr A. Lloyd for fossil *Syrioplanorbis* from Asia has been unproductive, so the comparison must await further information.

These facts indicate the difficulties of classification in this family, and should be borne in mind when inferences about the evolution and origin of the Australian Planorbidae are being made.

Genus SYRIOPLANORBIS F. C. Baker, 1945

Syrioplanorbis F. C. Baker, 1945, *The Molluscan Family Planorbidae,* p. 88. New Name for *Heterodiscus* Westerlund, 1902, not *Heterodiscus* Sharp, 1886. Type species by original designation, *Planorbis libanicus* Westerlund.

Diagnosis (after Zilch): Shell moderately large, solid, flat discoidal; upper and lower side* slightly (and almost symmetrically) depressed; 5 to 6 whorls, completely rounded; body whorl nearly cylindrical; aperture rounded; basal margin strongly produced.

SYRIOPLANORBIS HARDMANI (Wade, 1924)

(Pl. 10, figs 6-8)

Planorbis hardmani Wade, 1924, *Comm. parl. Pap.* 142, 29, pl. 1.

Planorbis hardmani Wade, Chapman, 1937, *Proc. Roy. Soc. Vic.,* N.S., 50, 61-62, pl. 6, figs 1, 2.

Remarks: Although the species was first discovered by Hardman, who published McCoy's manuscript name (Hardman, 1885, p. 7) no description or illustration was given until 1924, when Wade adopted the name and used it in association with photographs of the fossils, thus making it available. (Wade incorrectly cited Foord as the authority for the name, probably a lapsus for McCoy.) Chapman (1937) was the first to describe and illustrate the species, and he correctly cited Wade as author and selected a lectotype and paralectotypes from the syntypes.

The range of specimens now available is quite large, but most specimens are poorly preserved, yielding little useful taxonomic information. A few, however, show details of sculpture and others reach a very large size.

Description: Shell sinistral, discoidal, upper surface deeply concave; lower surface shallowly concave, broadly umbilicate. Shell of 5½ whorls, regularly increasing; whorls rounded, with a slight angulation at the dorsal curvature and another at the lateroventral curvature, the base of the whorls being relatively flattened; sutures deeply impressed. Shell surface with fine spiral, slightly granulose ribs on the apical whorls, crossed by fine lines of growth; adult whorls relatively smooth, with fine oblique growth-lines only. Body whorl sometimes with a slight expansion and subsequent contraction just posterior to the aperture (Pl. 10, figs 6, 7). Aperture oblique, not especially broadened.

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* Although planorbids are frequently drawn as dextral shells, with the aperture on the right when facing the observer, the anatomy of the animals proves them to be sinistral with the aperture on the left of the shell when facing the observer. The terms upper and lower sides should be interpreted accordingly in the present account.

Dimensions (in mm):

	Maximum diameter	*Maximum height*
Lectotype, CPC105	20.50	7.00+
Paralectotype, CPC106	17.00	?
Paralectotype, CPC190	14.00	?
NT406, CPC6893	18.00	7.00
NT406, CPC6917	22.00	?

Types and Type Locality: Although Chapman indicated that the location of the lectotype was uncertain, it is now in the Commonwealth Palaeontological Collection, CPC105, together with two paralectotypes, CPC106 and 190. The specimens are all steinkerns, preserved in a reddish cream siliceous chert from the White Mountain Formation, Hill J.40, White Mountain Range (= Mount Elder), Kimberley District, Western Australia.

Occurrence: NT406, five miles south of Mount Caldwell, Henbury, N.T.; NT409, 11 miles north-east of Deep Well homestead, N.T.; NT417, 28 miles east of Alice Springs on road to Loves Creek, N.T.; NT422, 2 miles south-west of Arltunga airstrip, N.T.; NT423, Arltunga airstrip, N.T.; AS234, 15 miles south-east of Todd River homestead, N.T.; AS235, 13 miles east-south-east of Todd River homestead, N.T.; Q9, 16 miles south-east of Springvale homestead, Qld; BT169, 28½ miles north of Rockhampton Downs homestead, N.T.; DR1, DR2 and DR4/4, all Hill J.40, White Mountain Range, east Kimberley District, W.A.; also from the Etadunna Formation, north of Billa Kalina station, S.A.

Additional Remarks: The localities listed show that the species has a wide geographic range, from north Western Australia and western Queensland through the lower part of the Northern Territory into South Australia, but its geological range is not known. There are no Recent species of *Syrioplanorbis* in Australia, nor any genus remotely resembling it. All Recent Australian discoid planorbids are small, with a maximum diameter of 7 or 8 mm, and are discussed more fully below.

Genus GYRAULUS Charpentier, 1837

Gyraulus Charpentier, 1837, *N. Denkschr. schweiz. Ges. Naturw.*, 1, 21. Type species by subsequent designation (Dall, 1870, *Ann. Lyc. nat. Hist. N.Y.*, 9, p. 351), *Planorbis albus* Müller.

Diagnosis (after Zilch): Shell small, flat, discoidal; upper side almost flat or shallowly dished concave; lower side more or less distinctly, evenly umbilicate in the centre; few rapidly enlarging whorls, the body whorl especially strongly enlarged, flattened, outer part rounded, with fine growth-lines only or cancellated by these and fine spiral striae; aperture relatively broad, basal margin produced.

Remarks: Small planorbids in the Recent Australian fauna have been allocated to several genera by Cotton & Godfrey (1938) and Iredale (1943). These authors proposed five new generic names for Australian groups on the basis of differences in shell morphology: *Segnitila* Cotton & Godfrey, *Pygmanisus* Iredale, *Plananisus* Iredale, *Glyptanisus* Iredale, and *Glacidorbis* Iredale. The validity of these genera can only be determined by anatomical examination, and Zilch (1959) treated them as *genera inquirenda,* doubtfully referring *Segnitila* to the synonymy of *Helicorbis* Benson and leaving the others unallocated. Although the genera may prove to be valid, they are disregarded for the present, and the small fossil planorbids of northern Australia are referred to two recognized genera, *Gyraulus* Charpentier and *Anisus* Studer. The former ranges from the Mesozoic to Recent and is widely distributed both as fossils and as living species. It includes a number of rather distinctive subgenera, but the fossil species here described seems closest to *Gyraulus* s.s., and is quite similar in general form to a number of members of the Recent Australian fauna.

GYRAULUS CHAPMANI sp. nov.

(Pl. 10, figs 9, 10, 13)

Planorbis cf. *essingtonensis* E. A. Smith, Chapman, 1937, *Proc. Roy. Soc. Vic.,* N.S., 50, 62-63.

Remarks: Chapman recorded a small species of planorbid from the same formation as that from which *Syrioplanorbis hardmani* (Wade) was originally described under the name *P.* cf. *essingtonensis* Smith. Specimens from the Bureau of Mineral Resources (Wade Collection) are apparently those studied by Chapman, and additional specimens are present in several samples among the material studied. More than one species is represented, but the commonest form is a small, relatively smooth species with the whorls increasing moderately rapidly in size, which appears to be referable to the genus *Gyraulus* s.s. It is not unlike several Recent Australian species, but the nearest is the South Australian form named *Plananisus isingi* (Cotton & Godfrey, 1932), specimens of which are illustrated on Plate 10, figures 11 & 12. It differs in being somewhat more tightly coiled and in lacking the sharp peripheral keel of *P. isingi.*

Description: Shell sinistral, small, maximum diameter 6 mm, maximum height approximately 1.5 mm. Upper side concave, deeply so towards the apex; lower side almost planate, not umbilicate; sutures moderately impressed. Surface sculptured with extremely fine spiral striae, crossed by fine growth-lines. Whorls 4½ in most specimens (but reaching 5½ in one large incomplete specimen), increasing moderately rapidly in size, body whorl not especially enlarged; whorls flattened above, with a rather sharp, square angulation of dorsolateral margin, lateral and ventral surfaces rounded; aperture oblique, basal margin produced.

Dimensions (in mm):

	Maximum diameter	*Maximum height*
Holotype (AS235, Specimen CPC6895) ..	4.50	?
Paratype (AS235, Specimen CPC6896) ..	1.50	?
Paratype (AS235, Specimen CPC6897) ..	3.50	?
Paratype (AS235, Specimen CPC6898, sec.)	4.00	1.50
AS234, Specimen CPC6899	6.00	?
DR4/4, Specimen CPC6916	3.00	0.75

Types and Type Locality: The holotype (CPC6895) is illustrated on Plate 10, figure 9. It and the paratypes (CPC6896-8) are from sample AS235, from 13 miles east-south-east of Todd River homestead, Northern Territory. The other specimens whose dimensions are given are not to be regarded as types, since their identity with the holotype is not absolutely certain.

Occurrence: Type locality, and from AS234, 15 miles south-east of Todd River homestead, N.T.; NT417, 28 miles east of Alice Springs on road to Loves Creek, N.T.; NT423, Arltunga Airstrip, N.T.; DR1, DR4/4, both Hill J.40, White Mountain Range, Kimberley District, W.A.

Additional Remarks: The species is named for F. Chapman, who first recognized its existence. Its geographical range is from north Western Australia to the Alice Springs district, but its geological range is unknown. The genus is probably well represented in the Recent Australian fauna, though this requires confirmation. Carter (1963, p. 171) recorded the species *Glyptanisus caroli* Iredale, 1943, from the lower Pleistocene Nelson Bay Formation, together with another planorbid species *Segnitila victoriae* (Smith). Through an unfortunate transposition of type lines the references on this page are all out of sequence. Both species are illustrated (pl. 29, figs 10-12, and pl. 28, figs 7-9 respectively) and appear to be very similar; both differ from the species described here in their more rapidly increasing whorl diameter and in being more strongly keeled at the periphery.

Genus ANISUS Studer, 1820

Anisus Studer, 1820, *Natur. Anz. allg. schweiz. Ges. gesamm. Naturwiss.*, 3(12), 91. Type species by subsequent designation (Gray, 1847, *Proc. geol. Soc. London,* p. 180), *Helix spirorbis* L.

Diagnosis (after Zilch): Shell small, flat discoidal, tightly coiled, shallowly concave on both sides, or almost flat above; numerous (6-9) slowly and regularly increasing whorls, rounded, often somewhat flattened or keeled above.

Remarks: Among the many specimens of small Planorbidae examined, one is quite distinct from all the others, and because of its tightly coiled whorls seems closest in shell morphology to the genus *Anisus* Studer, which ranges from the upper Miocene of Europe, Asia and North Africa, and is found living today in the same regions. There are no Recent species of *Anisus* from Australia and none of the Recent Australian planorbids is close in shell morphology to the species described here.

ANISUS ARLTUNGAE sp. nov.

(Pl. 11, fig. 1)

Remarks: Although based on a single specimen, the present form is so distinctive that I have no doubt of its validity.

Description: Shell sinistral, small, the maximum diameter 3½ mm, maximum height approximately 1 mm. Only ventral and lateral portions exposed, lower side shallowly concave, not notably umbilicate. Shell surface covered (where visible) with well developed spiral grooves, separating slightly nodulose spiral ribs, crossed by very fine growth-lines. Whorls 4¾ (specimen may not be adult) regularly rounded from the ventral to the dorsolateral area, remainder of whorls not visible; tightly coiled, increasing slowly in diameter, body whorl not enlarged.

Dimensions: The dimensions of the only known specimen are given above.

Type and Type Locality: The holotype and only specimen is CPC6900, from sample NT423, from the Arltunga Beds, Arltunga airstrip, near Alice Springs, Northern Territory.

Additional Remarks: The specific name is derived from the type locality and should be regarded as a noun in the genitive case. It is possible that some of the poorly preserved specimens in sample NT423 are also of this species, but others are definitely referable to *Gyraulus chapmani*. The same sample also contains specimens of *Syrioplanorbis hardmani*, so it appears that all three species lived sympatrically at least in this portion of their range.

'PLANORBIS sp.'

Planorbis sp., Whitehouse, 1940, *Pap. Dep. Geol. Univ. Qld*, N.S., 2, 35.

Remarks: Whitehouse recorded *Planorbis* from the Silkstone Series, Limestone Hill, Ipswich, Queensland, which he considered to be probably Miocene in age. Whitehouse commented that it was 'an undescribed species of *Planorbis* that I found in some abundance . . . . in 1922', but the specimens have never been described. The Geology Department, University of Queensland, has kindly made available material from the University's collection containing this species (specimens

F47284-47291), but it is in such a poor state of preservation that no determination is possible. Judging from the material available, however, it seems unlikely that it is identical with any of the species described here.

Genus PHYSASTRA Tapparone Canefri, 1883

Physa (Physastra) Tapparone Canefri, 1883, *Ann. Mus. Stor. nat. Genova,* 19, 243. Type species by monotypy, *Physa vestita* Tapparone Canefri.

Remarks: The genus *Physastra,* based on a Recent New Guinea species, is now used for many of the Recent Australian species formerly referred to genera such as *Lenameria* Iredale and, in the older literature, *Bullinus* Oken and *Physa* Draparnaud. It includes high-spired sinistral shells, with columella produced anteriorly, not truncate as in *Isidorella.*

PHYSASTRA RODINGAE sp. nov.

(Pl. 11, figs 2-5)

Bullinus sp., Chapman, 1937, *Proc. Roy. Soc. Vic.,* N.S., 50, 63.
Isidora, near *pectorosa,* Cameron, 1901, *Ann. Rep. geol. Surv. Qld,* 1900, 14.

Remarks: *P. rodingae* sp. nov. is represented in several samples by very large steinkerns, casts, and sections. Two kinds of shell are found, one with a relatively short spire and large body whorl, the other with a very tall spire, more loosely coiled, and with the body whorl relatively smaller. Although the two are rather dissimilar, it is well known that species of *Physastra* are exceedingly variable (e.g. Ivey, 1951) in response to both genetic and environmental differences, so that I prefer to consider all the specimens as variants of a single species. None of the available specimens is particularly well preserved; and although high-spired shells are commoner, the best preserved is a low-spired shell, and has been chosen as holotype.

Chapman (1937) referred to '*Bullinus* sp. nov.' from the White Mountain Formation when redescribing *Syrioplanorbis hardmani.* Examination of his material shows that only poorly defined moulds are present, but their general form suggests that the species is the same as that described here. Cameron (1901) recorded *Isidora* near *pectorosa* Conrad from the Carl Creek Limestone. '*I.*' *pectorosa* is a Recent species of *Physastra* from inland rivers of Queensland and New South Wales, and since *Physastra rodingae* is recorded here from Samples Q11 and Q12, both in Carl Creek Limestone, it seems probable that Cameron's record refers to this species also.

Description: Shells very large for the genus, the maximum height in excess of 33 mm, the maximum breadth greater than 14.5 mm. Spire usually elevated, sometimes relatively depressed; whorls 4 to 5, usually loosely coiled, body whorl enlarged, but occasional specimens with the body whorl relatively swollen, the whorls more tightly coiled. Aperture of partly grown shells relatively compressed laterally, produced anteriorly. Sculpture unknown.

Dimensions (in mm):

	Maximum height	*Maximum breadth*
Holotype CPC6901	24.00+	13.00+
Paratype 1, Q12, CPC6902	33.00	14.00+
Paratype 2, Q12, CPC6903	33.00+	14.50
Paratype 3, NT424, CPC6904	18.00	11.00

Types and Type Locality: The holotype is a partly isolated specimen, broken near the end of the body whorl, so that the aperture and terminal portion of the body whorl are embedded in the matrix. It comes from sample NT407, from 7 miles north-east of Deep Well homestead, Northern Territory.

Occurrence: Samples NT424, 4 miles south of Alcoota homestead, N.T.; Q12, 1 mile south-east of Riversleigh homestead, Qld; Q11, 5 miles north of Riversleigh homestead, Qld; DR1, Hill J.40, White Mountain Range, east Kimberley District, W.A.

Additional Remarks: The specific name is derived from the Rodinga 1 : 250,000 (4-mile) Sheet, on which the type locality, Deep Well station, is located, and should be regarded as a noun in the genitive case. The species has a geographical range from north Western Australia through the Alice Springs area and up into north-west Queensland. Its geological range is unknown. Carter (1963, p. 170) recorded *Lenameria acutispira* (Tryon) from the Lower Pleistocene Nelson Bay Formation, near Portland, Victoria. This species is common in the Recent fauna, and would now be referred to the genus *Physastra.* It differs from *P. rodingae* in its much smaller size.

Subfamily BULININAE

Remarks: As indicated in the remarks concerning the family, shell form cannot be taken as indicative of subfamily position in the Planorbidae. Originally the Bulininae (or Bulinidae = Bullinidae olim) were considered to be all high-spired shells, in contrast to the Planorbidae. However, Hubendick has shown that high-spired shells of the genus *Physastra* belong in the subfamily Planorbinae, whereas the high-spired shells of the genus *Isidorella* belong in the subfamily Bulininae.

Genus ISIDORELLA Tate, 1896

Isidorella Tate, 1896, *Rep. Horn sci. Exp. C. Aust.*, Pt 2, Zool., 212. Type species by original designation, *Physa newcombi* A. Adams & Angas.

Diagnosis (after Zilch): Shell moderately large, oval-conical to rounded-conical; spire short, sharp; whorls rounded, sutures deeply impressed; body whorl ventricosely swollen; aperture large, wide, broadly ovate.

Remarks: Zilch treats *Isidorella* as a subgenus of *Bulinus* Müller, but it is here regarded as a full genus. Zilch gives no geological range for it, recording it only from the Australian Recent, but *Bulinus* s.l. ranges back to the Mesozoic.

ISIDORELLA sp.

(Pl. 11, fig. 6)

Remarks: In sample NT424 from the Alcoota bone bed investigated by Woodburne et al., several poorly preserved freshwater physoid gastropods were collected. These have kindly been lent for study by Dr Woodburne. Among them were some relatively loosely coiled high-spired shells, which, although in poor condition, seem comparable with *Physastra rodingae* described above. However, six specimens differ in being low-spired, with swollen body whorls which are slightly laterally compressed when adult. The largest measures 18.5 mm in height and 15 mm in diameter. None of the specimens is really well preserved, except one juvenile, so that allocation to a particular species, or description as new, is not possible. The shells resemble most closely some Recent species of *Isidorella* and are provisionally referred to that genus.

As noted above, the species recorded by Cameron (1901) as *Isidora* near *pectorosa* is almost certainly the same as *Physastra rodingae*, and not the *Isidorella* recorded here.

Order STYLOMMATOPHORA

Family BULIMULIDAE

Remarks: The family Bulimulidae is used here for the shells often referred to in Australian literature as *Bothriembryonidae*. The latter family name, based on the Australian genus *Bothriembryon*, was used by Iredale and others, but Pilsbry has shown (1946, pp. 1-3) that the genus is closely allied to the South American genus *Bulimulus*, and must be placed in the same family.

Genus BOTHRIEMBRYON Pilsbry, 1894

Bothriembryon Pilsbry, 1894, *Nautilus,* 8, 36. Type species by original designation, *Bulimus melo* Quoy & Gaimard.

Diagnosis (after Zilch): Shell rather thin, rounded-ovate to elongate-ovate-conical; whorls somewhat arched, the 1½ to 2 embryonic whorls with straight or undulating axial striae or axial rows of punctate pits, the rest of the whorls mostly with simple growth striae or more-or-less strongly wrinkled striae and more-or-less distinct fine spiral grooves, also often granulated, usually striped or banded; body whorl large, umbilicate or imperforate; aperture ovate; apertural margins usually joined by a thin parietal callus; outer margin sharp; columellar margin expanded above and reflected, without teeth or folds.

Remarks: The genus includes many Recent species (at least nominal species) from south Western Australia, with a few additional species found in the Nullarbor Plain; Palm Valley, Central Australia; Eyre Peninsula and Port Lincoln District, South Australia; and Tasmania. For an account of the variation in shell morphology of this genus in Western Australia see Iredale (1939, pp. 15-36, pl. 2). The bulimiform shell has evolved on many occasions in the pulmonate land molluscs and, as in many freshwater species, shell shape is an unreliable guide to family classification. However, with only one or two minor exceptions, all the Recent Australian bulimiform shells are members of the genus *Bothriembryon* s.l., and on distributional grounds it seems likely that the shells described below belong there also.

BOTHRIEMBRYON PRAECURSOR sp. nov.

(Pl. 11, figs 7-9)

Remarks: In sample NT409 from 11 miles north of Deep Well station, Northern Territory, are a section of a bulimoid shell and a poorly exposed cast of what appears to be the same species. From sample Rd21, from the nearby locality 4 miles east-north-east of Deep Well station, comes a fossiliferous limestone containing an abundance of shell remains, principally helicoid land snails, but with a few bulimoid shells, apparently identical with those from NT409. Two of these have been isolated and another is almost free from its matrix. Additional specimens have been seen from the Etadunna Formation, north of Billa Kalina station, South Australia. These are all regarded as belonging to the one species of *Bothriembryon.*

Description: Shells medium size, maximum height approximately 21 mm, maximum diameter approximately 14 mm. Spire high, whorls, 4½ to 5, regularly increasing, body whorl not swollen. Shell imperforate. External sculpture not known, but steinkerns may show regular radial ridges, probably representing depressions on the internal whorl surfaces corresponding to growth ridges and rest marks externally.

Dimensions (in mm):

	Maximum height	*Maximum diameter*
Holotype, CPC6906	14.00	9.00
Paratype 1, Rd21, CPC6907	15.00	10.00
Paratype 2, Rd21, CPC6908	16.00+	10.50+
Paratype 3, NT409, CP6909	20.00+	14.00

Types and Type Locality: The holotype is an isolated steinkern of an immature shell, CPC6906, with paratypes in the same collection and in the Australian Museum. The type locality is 4 miles east-north-east of Deep Well homestead, near Alice Springs, N.T. (sample Rd21).

Additional Remarks: The fossils closely resemble in form several other species of *Bothriembryon,* including the Recent species *B. barretti* Iredale, which inhabits the Nullarbor Plain. However, *barretti* does not have the internal growth marks observed in *B. praecursor* and is considerably longer. Possibly *B. praecursor* is ancestral to *B. barretti,* but only a knowledge of its detailed external sculpture would enable its true affinity to be determined.

The occurrence of *Bothriembryon* in the Tertiary of Central Australia confirms the belief that this genus must have been more widespread in inland Australia than it is today. Such a past distribution has been suggested to account for the present distribution of the genus, especially the occurrence of one Recent species, *Bothriembryon spenceri* (Tate), in Palm Valley, Central Australia. The latter differs considerably in form from *B. praecursor,* hence is not considered to be a close relative.

One other fossil species has been described which may be referable to *Bothriembryon.* This is *Bulinus* (sic) *gunnii* Sowerby, 1845 (in Strzelecki, *Phys. Descr. New South Wales & Van Diemen's Land,* p. 298, pl. 19, fig. '5' (=6)), from Tertiary travertine near Hobart, Tasmania. The original description and illustration are insufficient to enable its determination, but Harris (1897, pp. 3-4) described the holotype in the British Museum as an internal cast, comparable with *'Liparus'* (=*Bothriembryon*) *leeuwinensis* from south Western Australia, and concluded that the two species must be congeneric and even closely allied specifically. Harris considered that the chief difference between the species was the more conical and tumid shape of the fossil, which was also not so elongate as *Bothriembryon kingi* (Gray), another south Western Australian species, while the lines of growth were more oblique. From this it appears that *Bothriembryon gunni* (Sowerby) is more high-spired than *B. praecursor.*

Family CAMAENIDAE

Remarks: The family name Camaenidae has not often been used by Australian malacologists, but it seems clear from anatomical comparisons that the bulk of the Australian helicoid land snails have their closest relationship with the camaenid snails of South East Asia. Iredale proposed a number of family groups, including Hadridae, Chloritidae, Xanthomelontidae, and Rhagadidae, for the Australian helicoids, some of which may represent at least valid subfamilies; but this can only be determined by adequate anatomical study.

Genus MERACOMELON Iredale, 1937

Meracomelon Iredale, 1933, *Rec. Aust. Mus.,* 19, 52 (nomen nudum).

Meracomelon Iredale, 1937, *S. Aust. Nat.,* 18, p. 30. Type species by original designation, *Helix rufofasciata* Brazier.

Remarks: Iredale first introduced the name *Meracomelon* in 1933.

Diagnosis (after Iredale): Shells medium sized, 15 to 30 mm in maximum diameter, flattened helicoid, with the periphery keeled sometimes in the juvenile but very rarely in the adult stage, texture thin, coloration generally banded, sculpture subgranulose, umbilicus small, open, columella reflected, outer lip usually thin.

MERACOMELON LLOYDI sp. nov.

(Pl. 11, figs 10-14)

?*Therrites* (sic) *forsteriana,* Cameron, 1901, *Ann. Rep. geol. Surv. Qld,* 1900, 14.

Thersites and *Chlorites* (sic), Whitehouse, 1940, *Pap. Dep. geol. Univ. Qld,* N.S., 2, 24.

Remarks: In samples NT407, NT409 and Rd21, from the general neighbourhood of Deep Well station, south-east of Alice Springs, and in Q12 from near Riversleigh, north-west Queensland, are found a series of quite well preserved helicoid land snails, most of which are represented by steinkerns and casts. They are comparable in shape with several Recent groups of land snails, but do not agree exactly with any; the genus *Meracomelon* is relatively close, and because of the fine granulose sculpture, they are tentatively placed there. The species is obviously different in shape from any known Recent species, and is therefore named as new.

Description: Shell of medium size, maximum height approximately 17 mm, maximum diameter 24 mm. Shape helicoid, spire relatively low, sutures scarcely impressed. Whorls 6½, tightly coiled, slowly increasing in size, body whorl not notably expanded, whorls slightly angled at the periphery. Shell narrowly umbilicate. Aperture of early whorls finely but irregularly granulose, with prominent rest marks, more or less regularly spaced on some specimens.

Dimensions (in mm):

	Maximum height	*Maximum diameter*
Holotype, CPC6910	13.00	17.00
Paratype 1, NT407, CPC6911	13.50	16.50
Paratype 2, Q12, CPC6912	14.50	21.00
Paratype 3, Q12, CPC6913	17.00+	23.00
Paratype 4, Q12, CPC6914	15.50	22.00
Paratype 5, Rd21, CPC6915	10.50	14.00

Types and Type Locality: The holotype (CPC6910) is from sample NT409, from 11 miles north-east of Deep Well homestead, Northern Territory.

Occurrence: Type locality and NT407, 7 miles north-east of Deep Well homestead, N.T.; NT408, 8 miles north-east of Deep Well homestead, N.T.; Rd 21, 4 miles east-north-east of Deep Well homestead, N.T.; Q11, 5 miles north of Riversleigh homestead, Qld; Q12, 1 mile south-east of Riversleigh homestead, Qld; and from the Etadunna Formation, north of Billa Kalina station, S.A.

Additional Remarks: In Cameron's (1901) report on the geology of north-west Queensland, fossil land snails from the Carl Creek Limestone were identified as *Therrites* (error = *Thersites*) *forsteriana,* now placed in the genus *Zyghelix.* The latter is a Recent species known only from eastern Queensland, from Cairns north to Cooktown and on the adjacent offshore islands. It seems likely that Cameron's species is the same as *M. lloydi,* since they are both from the Carl Creek Limestone, and if this is the case, then they differ decidedly from *Z. forsteriana* (Reeve), which is much more depressed, with strong, regular granular sculpture and strong radial growth ridges. Whitehouse (1940) referred to *Thersites* and *Chloritis* from the Carl Creek Limestone, but I do not know the source of his reference to *Chloritis.* The latter is a distinctive Recent group of camaenids, and no specimens have been seen which could be referred to it.

Only one other fossil land snail known from Australia is comparable with *M. lloydi.* This is *Helix tasmaniensis* Sowerby, 1845 (in Strzelecki, *Phys. Descr. New South Wales & Van Diemen's Land,* p. 298, pl. 19, fig. '6' (= 5)), from the Tertiary of Tasmania. The figure shows a normal helicoid shell, with the aperture concealed in the matrix. Several specimens are in the Australian Museum collection, and they differ in many ways from *M. lloydi,* especially in having a more depressed spire, with fewer whorls, increasing more rapidly in diameter, and do not appear to be closely related.

Class BIVALVIA

Family CORBICULIDAE

Genus CORBICULINA Dall, 1903

Corbiculina Dall, 1903, *Trans. Wagner Inst. Sci. Phila.*, 3, 1449.

Type species by original designation, *Corbicula angasi* Prime.

Remarks: In his account of the geology of the eastern MacDonnell Ranges, Madigan (1932, p. 98) mentions the occurrence of small bivalves, identified by Chapman as 'possibly *Corbicula*' in travertine from the north side of the Hale River between Ambalindum and Claraville stations. He regarded them as possibly Pleistocene. The genus *Corbiculina* is now generally used for those Australian shells formerly referred to *Corbicula,* although the differences between the two genera and their application to Australian species requires confirmation and study.

CORBICULINA sp.

Remarks: Two of the samples studied contain specimens referable to *Corbiculina.* In K6 from ¾ mile south-east of Pulchera Well, Erldunda, Northern Territory, near the South Australian border, one small rock shows two fragments of bivalve shells partly overlying each other. They may be two halves of the one valve or portions of different valves. Only a small portion of the external surface is revealed, without any indication of hinge structure or shell shape. However, the strong concentric ridge sculpture and approximate size are very similar to those of Recent species of *Corbiculina.* In BT169 from 28½ miles north of Rockhampton Downs, Northern Territory, another incomplete valve is found which is certainly referable to *Corbiculina* on the basis of its shape and surface sculpture. Unfortunately none of the specimens is adequate for specific determination or description.

ECOLOGY OF THE TERTIARY MOLLUSCS OF NORTHERN AUSTRALIA

The species described in the systematic account are separable into two series, the freshwater shells and the land snails. However, since in practically every case the land snails occur in association with freshwater shells, it can be assumed that the deposits were all laid down as sediments in an aqueous environment, and that they are not terrestrial or aeolian. It is probable that the land snails have been carried down into the freshwater environment either by being blown or, more probably, by being swept downstream during floods. The freshwater snail genera represented, with the possible exception of *Potamopyrgus* and *Plotiopsis,* are found today in purely freshwater habitats. By 'purely freshwater' I mean inland waters of low salinity, uncontaminated with seawater. Even *Plotiopsis* and *Potamopyrgus* are essentially freshwater genera, though the former is sometimes found in the lower reaches of tropical rivers, where water of slightly increased salinity may occur in areas under tidal influence, while the latter includes at least one estuarine species (*Potamopyrgus procinctus* Hedley) in eastern Australia. By analogy with these known habitats of Recent forms, it can be assumed that the environment in which the fossil species lived was a freshwater one, without any significant degree of contamination by the sea.

The presence of the land snails does not necessarily indicate well developed forest conditions. The genus *Meracomelon* is characteristically found in dry country today, while *Bothriembryon* inhabits desert areas such as the Nullarbor Plain as well as wet forest areas in south Western Australia. In the Central Australian area at the present time, thousands of dead shells of a variety of land-snail species can be found in certain places (such as the creek bed at Palm Valley, near Hermannsburg Mission, N.T.). In times of flood, large numbers of these shells must be carried downstream, and it is easy to imagine their accumulation in a lake alongside the shells of freshwater species actually living in the lake.

The probable depositional environment for these fossils appears then to have been a large lake or lagoon, of virtually pure freshwater, into which streams flowed from surrounding country, which may or may not have been forested. However, Lloyd (this Vol., p. 87) has shown that marine foraminifers occur in association with the molluscs in some localities, suggesting that there have been incursions of the sea into this lacustrine environment. If such incursions took place, they must have been of relatively short duration, since there is no evidence of the preservation of any other marine organisms, and in particular no estuarine molluscs, which might have been expected to occur had estuarine conditions lasted for any length of time. The lakes could well have been similar to some of the coastal lagoons which exist today along the eastern seaboard of Australia. These range from lagoons open permanently to the sea, which contain waters of medium to high salinity and which support an estuarine fauna, to those which are quite isolated from the sea by sand dune ridges and which contain low salinity water supporting true freshwater organisms. Lagoons of the latter type are occasionally broached by the sea during storms, allowing an influx of seawater. Such an influx might well cause the death of all the freshwater organisms living in the lake at the time, but if it is of brief duration, there will be a gradual return to low salinity conditions, followed by reinvasion of true freshwater organisms from surrounding refuge areas.

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PLATE 10

Figure 1. — *Potamopyrgus* sp. CPC6889, from AS234, 15 miles south-east of Todd River homestead, N.T., x8.

Figure 2. — *Potomopyrgus antipodum* (Gray). AMC64678. Recent, New Zealand. x7.

Figures 3-4. — *Gabbia* sp. CPC6890 & 6891, from K6, ¾ mile south-east of Pulchera Well, Erldunda, N.T. x4½ and x7 respectively.

Figure 5. — *Plotiopsis* sp. CPC6892, from BT169, 28 miles north of Rockhampton Downs homestead, on Rockhampton Downs to Anthony Lagoon Road, N.T. x5.

Figures 6-8. — *Syrioplanorbis hardmani* (Wade).

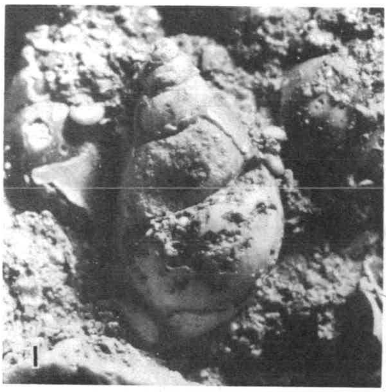
6. Lectotype, CPC105. Hill J40, White Mountain Range, Kimberley District, W.A. x1.
7. Figured specimen, CPC6893, from NT406, 5 miles south of Mt Caldwell, Henbury, N.T. x1½.
8. Figured specimen, CPC6894, from NT423, Arltunga airstrip, N.T. x7.

Figures 9-10. — *Gyraulus chapmani* sp. nov.

9. **Holotype** CPC6895 and paratypes, CPC6896 and 6897, from AS235, 13 miles east-south-east of Todd River homestead, N.T. x6.
10. Paratype CPC6898, AS235, as above. x8.

Figures 11-12. — *Plananisus isingi* (Cotton & Godfrey) AMC64679. Recent, Jaensch's Swamp, Tailem Bend, S.A. x4.

Figure 13. — *Gyraulus chapmani* sp. nov. CPC6899, from AS234, 15 miles south-east of Todd River homestead, N.T. x5.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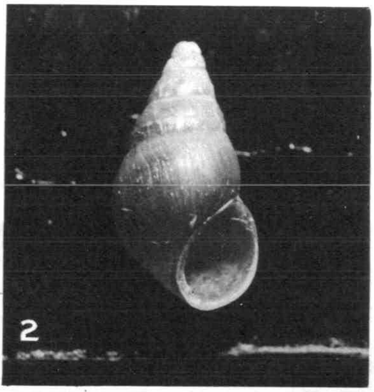
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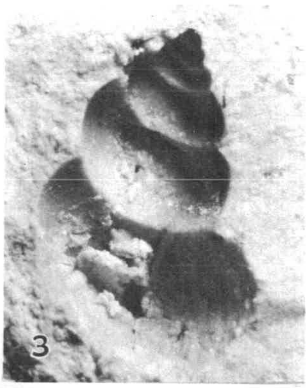
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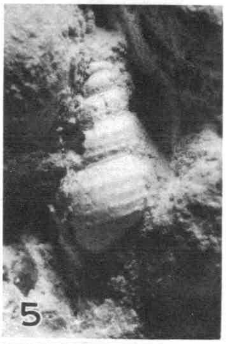
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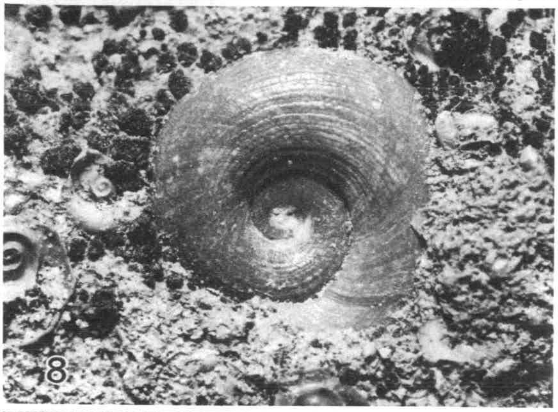
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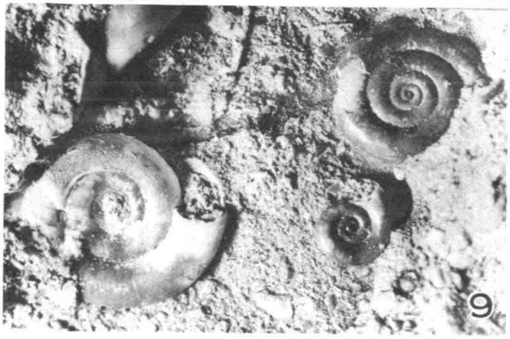
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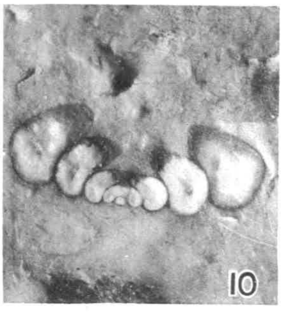
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Tertiary Mollusca

PLATE 11

Figure 1. — *Anisus arltungae* sp. nov. **Holotype**, CPC6900, from NT423, Arltunga airstrip, N.T. x10.

Figures 2-5. — *Physastra rodingae* sp. nov.

2. **Holotype**, CPC6901, including mould containing remainder of specimen, from NT407, 7 miles north-east of Deep Well homestead, N.T. x1½.
3. **Holotype**, CPC6901, isolated portion. x2½.
4. Paratype 1. CPC6902, from Q12, 1 mile south-east of Riversleigh homestead, Queensland. x1½.
5. Paratype 3. CPC6904, from NT424, 4 miles south of Alcoota homestead, N.T. x1¾.

Figure 6 — *Isidorella* sp. CPC6905, from NT424, 4 miles south of Alcoota homestead, N.T. x2.

Figures 7-9. — *Bothriembryon praecursor* sp. nov.

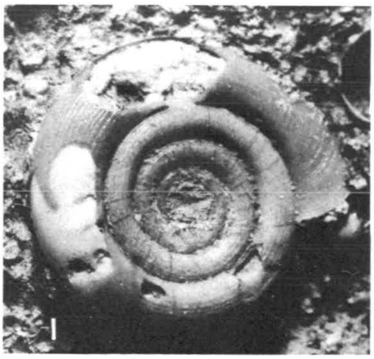
7. **Holotype**, CPC6906, from Rd21, 4 miles east-north-east of Deep Well homestead, N.T. x2½.
8. Paratype 2, CPC6908, from Rd21, as above. x1¾.
9. Paratype 3, CPC6909, from NT409, 11 miles north-east of Deep Well homestead, N.T. x2.

Figures 10-14. — *Meracomelon lloydi* sp. nov.

10. **Holotype**, CPC6910, from NT409, 11 miles north-east of Deep Well homestead, N.T. x4.

11-13. Paratype 2, CPC6912, from Q12, 1 mile south-east of Riversleigh homestead, Qld. x1½.

14. Paratype, CPC6915, from Rd21, 4 miles east-north-east of Deep Well homestead, N.T. x2½.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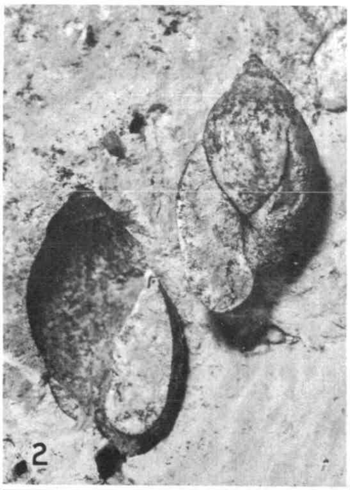
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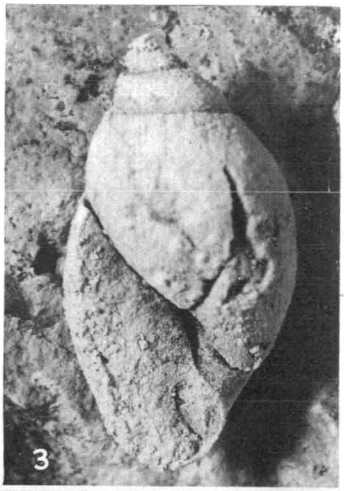
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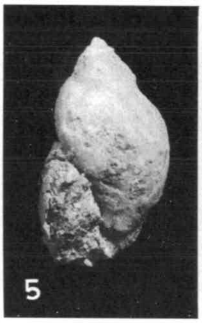
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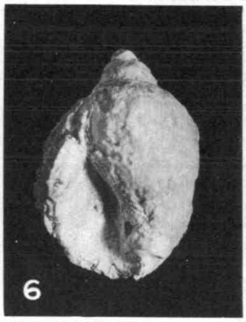
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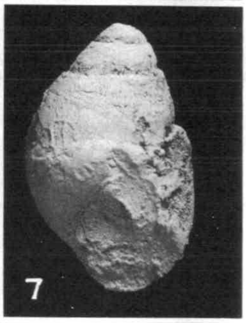
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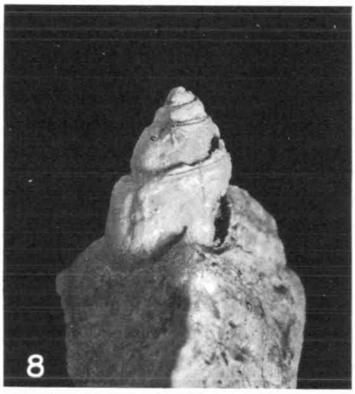
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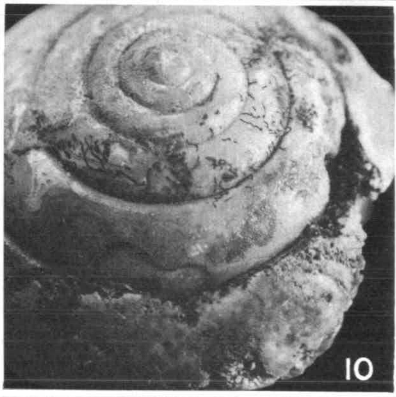
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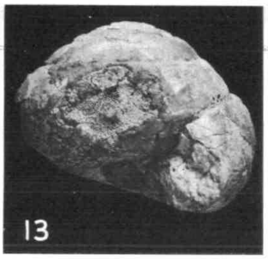
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Tertiary Mollusca

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EARLY ORDOVICIAN AT CLARAVALE IN THE FERGUSSON RIVER AREA, NORTHERN TERRITORY

by A. A. öpik

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SUMMARY

Fossils collected by the Australian Aquitaine Petroleum Pty Ltd at Claravale, Fergusson River area, Northern Territory, are Tremadocian in age; the possibility of a lower Tremadocian age is discussed.

According to P. J. Jones, the conodonts independently establish the Tremadocian age of the Claravale sequence, and contain species occurring in the Pander Greensand of the Joseph Bonaparte Gulf area, Western Australia, and the Ninmaroo Formation of Western Queensland.

In 1964, geologists of the Australian Aquitaine Petroleum Pty Ltd collected fossils in the Fergusson River area; the Chief Geologist of that Company, Mr R. Guillaume, sent them to the Bureau of Mineral Resources for identification and also supplied field data and a measured section. The material consists of friable sandstone.

The material was collected about 7 miles south-west from Claravale homestead, latitude 14°25′, longitude 131°32′, Fergusson River 1 : 250,000 Sheet area (Randal, 1962). The sequence, in brief, consists of two parts: a lower part represented in the collection by samples SN 103 and SN 104 and consisting of a friable glauconitic red sandstone, and an upper essentially calcareous part which begins below with a buff-coloured sandstone coquinoid represented by the sample SN 106. The contact between the two parts is, however, not exposed. According to Randal (1962) the rocks belong to the Oolloo Limestone and are Middle Cambrian in age.

Sample SN 106

This sample contains the youngest fossils collected from the sequence; these are: Brachiopods: (1) *Lingulella* and (2) the orthoid *Apheoorthis* Ulrich & Cooper; Trilobites: (3) *Asaphellus* Callaway, (4) *Dactylocephalus* Hsu, (5) a richardsonellid, and (6) a small indeterminate form of Ptychopariina.

Apheoorthis is a late Upper Cambrian and Tremadocian genus. *Asaphellus* and *Dactylocephalus* are essentially Tremadocian trilobites unknown in Upper Cambrian. Many species of *Asaphellus* occur in the early Tremadocian, and *Dactylocephalus* (known only from China) starts with two species at the beginning of that epoch.

In south China (Lu, 1959) the earliest Tremadocian (as well as Ordovician) Zone is the Zone of *Asaphellus inflatus* and *Dactylocephalus dactyloides*. Of course, a correlation with this zone would be premature because the specific identity of the Fergusson River forms is unknown; furthermore, the *Dactylocephalus* from SN 106 is rather fragmentary and unsuitable for specific identification.

The richardsonellids of SN 106 can be described as Richardsonellinae without a frontal brim. Such forms are Tremadocian or even early Tremadocian in age, and have been referred to in the literature as *Richardsonella (Hukasawaia)* Kobayashi, 1953, or *'Apatokephalus' (A. hoytan* Kobayashi), or *Pseudokainella?,* or *Praepatokephalus* Lochman, 1964. The late Upper Cambrian Siberian *Artokephalus* (in Rosova, 1960) belongs, apparently, to the same group of forms.

The small indeterminate species of Ptychopariina is apparently related to the *Clelandia* of the early Tremadocian of North America.

Samples SN 103 and SN 104

These two samples from the lower part of the sequence can be treated together because the fossils are similar. The matrix, a glauconitic red sandstone, is identical with the late Upper Cambrian Clark Sandstone of the Joseph Bonaparte Gulf area. The fossils are large fragments of trilobites with concave border and ventrally fused free cheeks. These may represent Asaphacea or Dikelocephalacea (Dikelocephalidae or Dikelokephalinidae); *Dactylocephalus* also has fused cheeks and belongs to the Dikelokephalinidae; furthermore, one form of the 'Richardsonellidae without a frontal brim' is also present. I assume that this part of the sequence represents either the top of the Upper Cambrian, or the base of the Tremadocian, although the available fossils cannot be interpreted conclusively.

Correlation

The discussion of the age of the fossils leaves little doubt that the sequence is Tremadocian. A part of the Pacoota Sandstone of the Amadeus Basin is also contemporaneous with the Tremadocian sequence at Claravale.

Conodonts (Communicated by P. J. Jones)

The samples SN 103, SN 104, and SN 106 were examined for conodonts. SN 104 contains species of conodonts belonging to the genera *Acodus, Chosonodina, Drepanodus, Oneotodus,* and *Scandodus.* These species occur in the Pander Greensand (Tremadocian to early Arenigian) of the Joseph Bonaparte Gulf area, and the upper portion of the Ninmaroo Formation (late Tremadocian) at Black Mountain, Queensland. Furthermore, this assemblage indicates a relationship with the early Ordovician of South Korea (Mueller, 1964), especially by the presence of the genus *Chosonodina.* SN 106 contains species belonging to the genus *Drepanodus.*

Thus, the conodonts, independently, establish an early Ordovician (Tremadocian) age of the Claravale sequence and a relationship with Korean faunas; the position within the Tremadocian cannot be determined, as no descriptions of early Tremadocian conodonts have yet been published. A full report of the conodont fauna of the Tremadocian sequence of the Pander Greensand, the Ninmaroo Formation, and at Claravale will be published at a later date.

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LOWER CRETACEOUS TRIGONIIDAE FROM STANWELL, EASTERN QUEENSLAND

by S. K. Skwarko

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SUMMARY

A new collection of fossils from Stanwell — the classical locality for fossils of Neocomian age in Australia — provides material for the redescription of Whitehouse's *Pisotrigonia* sp. and *Indotrigonia(?)* sp. as *Pterotrigonia (Rinetrigonia) verrucosa* sp. nov. and *Austrotrigonia secunda* sp. nov. respectively.

A new species of *Nototrigonia, N. zetesiana* sp. nov., is described from the new collection. This is the first representative of Nototrigoniinae to be reported from Stanwell.

A new subfamily of the Trigoniidae, Austrotrigoniinae, is erected for the inclusion of the typically Australian genus *Austrotrigonia* Skwarko, 1963. One other genus, *Prorotrigonia* Cox, 1952, from the Upper Triassic beds of Ceram, is also included in Austrotrigoniinae.

The previous dating of Stanwell fauna as Neocomian is substantiated in this paper, but it is thought that the fauna belongs in the late rather than in early (Valanginian) Neocomian as was previously believed. This is because of suggested correlation with the late Neocomian fauna from Unit 2 of the Coastal Belt Suite of the Northern Territory, and with collection MH4 of the Nanutarra Formation of the Carnarvon Basin, which is also regarded as late Neocomian.

INTRODUCTION

In 1962 Lower Cretaceous fossils were collected from a classical locality at Stanwell near Rockhampton, eastern Queensland. Fossils from this area were the first molluscs of definite Neocomian age to be reported from Australia, and in addition they constitute the first Trigoniidae of an Indo-Pacific character to be found in this country. The recent investigation of the Neocomian-Albian Mullaman sediments and faunas of the Northern Territory (Skwarko, 1963, 1967) intensified the interest in the Stanwell fauna, and the purpose of re-collecting this assemblage was to provide additional material for comparison with the Neocomian fossils of the Northern Territory.

Whitehouse, who in 1946 described and dated the Stanwell fossils, described the locality as '. . . . on Portions 128 and 129, Parish of Stanwell, a locality about 20 miles west-south-west of Rockhampton'. No fossils were found on Portion 128 in 1962, but this may not be surprising as outcrops are limited in number as well as in area, and much of the region is covered by thick scrub. In addition, since the original collection at least one other collection has been made. On Portion 129, however, a single patch of loose boulders yielded a small number of Lower Cretaceous molluscs, which are preserved in hard brownish slightly calcareous sandstone. It was found necessary to dissolve them out with hydrochloric acid and then make latex impressions of the internal and external casts before they could be studied.

I wish to thank Professor Dorothy Hill of the Queensland University for making available for my use the University's material from the Stanwell area.

CORRELATION AND AGE

Whitehouse (1946) identified the following fossils from the original collection from the Stanwell bed:

Iotrigonia limatula Whitehouse, 1946.

Pisotrigonia sp.

Indotrigonia(?) sp.

Pseudomonotis sp.

Astarte(?) sp.

Panopea(?) sp.

Hibolites sp.

These he dated as Neocomian, probably lower Neocomian (Valanginian), mainly because of the presence of *Iotrigonia* and *Pisotrigonia.* Subsequent work resulted in the following changes and additions to this list:

Brunnschweiler (1960) referred *Pseudomonotis* sp. to *Meleagrinella* Whitfield, 1885, and was of the opinion that it may be conspecific with *Meleagrinella* sp. cf. *M. superstes* (Spitz, 1914) from the Jowlaenga Formation (which he dated as early Neocomian) of the Dampier Peninsula, Western Australia.

In 1963 I figured and described another species of the Megatrigoniinae, *Iotrigonia stanwellensis,* and figured a new specimen of *Indotrigonia(?)* sp. as *(?)Austrotrigonia prima* Skwarko, 1963 — both these species were derived from a collection made by members of the Queensland University from apparently the same spot that Whitehouse's material was collected from.

In the present paper *Pisotrigonia* sp. is redescribed as *Pterotrigonia* (*Rinetrigonia*) *verrucosa* sp. nov., while *Indotrigonia(?)* sp., that is *(?)Austrotrigonia prima* Skwarko, 1963, is redescribed as *Austrotrigonia secunda* sp. nov. There is no new material which would help to establish closer identity of *Astarte(?)* sp., *Panope(?)* sp., and *Hibolites* sp., but it is found possible to describe a new species, *Nototrigonia zetesiana.*

Thus, the revised and supplemented list of determinations from the Stanwell bed is:

Iotrigonia limatula Whitehouse, 1946.

Iotrigonia stanwellensis Skwarko, 1963.

Pterotrigonia (Rinetrigonia) verrucosa sp. nov.

Nototrigonia zetesiana sp. nov.

Austrotrigonia secunda sp. nov.

(?)Meleagrinella sp. cf. *M. superstes* (Spitz, 1914).

Astarte(?) sp.

Panopeat(?) sp.

Hibolites sp.

I have suggested (Skwarko, 1967, pp. 67-70) the correlation of the Stanwell fauna with the late Neocomian Unit 2 of the Coastal Belt Suite of sediments (Northern Region, Northern Territory) as well as with the fauna from locality MH4 of the Nanutarra Formation in the north-eastern Carnarvon Basin, both of which are late rather than early Neocomian. This suggestion was made despite the virtual absence of ammonites, which are the most reliable correlation criteria, from the three assemblages. Although the Unit 2 and Nanutarra faunas are much more prolific in genera and species than the Stanwell fauna, conspicuous affinities exist between the three.

One of the most striking and characteristic features of the Unit 2 assemblage is the relative abundance of Trigoniidae. The four subfamilies which are regarded as the most typical of this unit are the Pterotrigoniinae, which is represented by *P. (R.) capricornia* Skwarko, 1963; Austrotrigoniinae nov. (see below), which is represented by a single species of *Austrotrigonia, A. prima* Skwarko, 1963; Nototrigoniinae, represented by some six species of *Nototrigonia;* and finally Megatrigoniinae with *Iotrigonia (Zaletrigonia) hoepeni* Skwarko, 1963, as its representative.

In all three assemblages Pterotrigoniinae are abundant, and the fact that their morphology is closely similar is a significant factor, particularly since in Lower Cretaceous times endemic forms evolved rapidly in semi-isolated pericontinental embayments in Australia. They seem, therefore, to be very closely related indeed.

Austrotrigonia prima of the Unit 2 assemblage and *A. secunda* of the Stanwell fauna are also very similar and closely related. *Austrotrigonia* is unknown from the Nanutarra Formation.

Nototrigoniinae, which abound in both the Neocomian and younger assemblages of the Coastal Belt Suite, Northern Territory, and the Aptian and Albian sediments of the Great Artesian Basin, occur but are rare in the Nanutarra and Stanwell sediments. The original collection from Nanutarra Formation described by Cox (1961) yielded no Nototrigoniinae, but two specimens were later collected from this area (Skwarko, 1967). No specimens of Nototrigoniinae were known from Stanwell until an immature specimen was collected in 1962. This is figured and described in the present paper under the name of *Nototrigonia zetesiana* sp. nov.

Iotrigonia occurs abundantly in both the Unit 2 and the Stanwell assemblages, but in Unit 2 it is the subgenus of this genus, *Zaletrigonia,* which was identified. *Zaletrigonia* has not been so far identified from the very limited Stanwell outcrop, but this is not regarded as necessarily a significant factor, since even its occurrence in Unit 2 is limited to the lower horizons, where, however, it occurs in profusion. A single specimen of *Zaletrigonia, I.* (*Z.*) *nanutarraensis* (Cox, 1961), was identified from the Nanutarra assemblage.

The reasons for correlation of the three areas of Neocomian sedimentation appear convincing, and the Stanwell assemblage therefore is late Neocomian rather than early Neocomian, as was suggested originally by Whitehouse.

Family TRIGONIIDAE

Subfamily PTEROTRIGONIINAE van Hoepen, 1929, em. Kobayashi & Nakano, 1957

Genus PTEROTRIGONIA van Hoepen, 1929

In the present paper Kobayashi & Nakano's (1957) subdivision of Pterotrigoniinae is followed.

Type species: *Pterotrigonia cristata* van Hoepen, 1929.

Subgenus RINETRIGONIA van Hoepen, 1929

Type species: *Trigonia ventricosa* Krauss, 1847.

RINETRIGONIA VERRUCOSA sp. nov.

(Pl. 12, figs 1-6; Pl. 14, figs 8, 11)

1946 *Pisotrigonia* sp., Whitehouse, *Proc. Roy. Soc. Qld,* 57(2), 2-15, pl. 1, figs 2, ?3; text-fig.

1963 *Pterotrigonia (Rinetrigonia)* sp. (Whitehouse); Skwarko, *Bur. Miner. Resour. Aust. Bull.* 67, 21, pl. 2, fig. 9.

Material: One large but incomplete and fractured external impression of a mature right valve; an almost complete external impression of a juvenile left valve; external impression of a central portion of an immature left valve; impression of an anteroventral portion of a left valve.

Holotype: Plate 12, figure 6 (CPC6140), an incomplete external impression of a mature but fractured right valve.

Paratypes: Plate 12, figures 1, 2 (CPC6141), and 3-5 (CPC6142), an external impression of the juvenile left valve, and the impression of an anteroventral portion of a left valve.

Diagnosis: The anterior inflated portion of the flank is wide, and ornamented with up to six robust but widely spaced ribs with prominent and closely set clavate tubercles; the posterior rapidly deflating portion of the flank has up to ten simple ribs which are straight and tend to become parallel to each other in mature specimens.

Comparison with other species: Whitehouse's illustrated specimens from Stanwell are not available for examination, and comparison of his figure 2 on plate 1 with specimens of *P.*(*R.*) *capricornia* Skwarko, 1963, creates an illusion that the umbo of the Stanwell species is the more pointed one. Comparison of the recently acquired specimens, however, shows that the opposite is true. The only well preserved specimen in my possession which shows a complete and undamaged anterodorsal portion of the shell is a juvenile form (paratype CPC6141), whose anterior portion is much broader than that of *P.*(*R.*) *capricornia,* while its umbo tends to be blunt and rounded. The spacing of ribs on the inflated portion of the new species is wider and the number of ribs fewer than in *P.*(*R.*) *capricornia.*

In the bluntness of its umbo and in the greater width of its inflated area the new species is much more reminiscent of *P.*(*R.*) *australiensis* Cox, 1961, from the Neocomian Nanutarra Formation of the Carnarvon Basin, Western Australia. This similarity is best brought out by comparison of the enlarged figure of the paratype CPC6141 (Pl. 12, fig. 2) of the new species with plate 2, figure 1 of Skwarko (1963). Comparison of the latter figure with those of Cox (1961, pl. 3, figs 3-5) illustrates the intraspecific variation in *P.*(*R.*) *australiensis.*

P.(*R.*) *australiensis* can be readily distinguished from *P.*(*R.*) *verrucosa* sp. nov. by the closer spacing of ribs on its anterior portion, by the more densely spaced and less prominent tubercles of its anterior ribs, and finally by its smaller size.

Of the overseas species, *P.*(*R.*) *ventricosa* (Krauss, 1842), from the Neocomian Uintenhage beds of South Africa and Tithonian-Neocomian Oomia beds of India, has much fewer, sparser, and more sinuous ribs on its posterior portion, the ribs on its inflated portion are more closely spaced, and the tubercles which they carry do not reach the size of those in the new species. In *P.*(*R.*) *salebrosa* (van Hoepen, 1929) from the Uintenhage beds, the ribs on the inflated portion of the shell are also more closely spaced, and those on the depressed portion sinuous and thick. Finally, *P.* (*R.*) *kraussi* (Kitchin, 1908), also from the Uintenhage beds, can be distinguished from the new species by much less prominent and more irregular type of tuberculation on the anterior ribs, by their more sudden increase in width, and by other features such as the narrower inflated portion of the shell.

Description: The shell is large and thick, with a strongly inflated anterior portion and a weakly inflated posterior portion. In the juvenile specimens the reduction of inflation from the midanterior to the posteroventral part of the shell is very rapid.

The overall shape of the shell is one typical of *Pterotrigonia,* but without the tendency for the posterior attenuated extremity (particularly its dorsal margin) to curve upwards.

The umbo is opisthogyrous and depressed. The inflated portion of the flank is wide and ornamented with up to six robust and tuberculate ribs. These originate on the posterodorsal portion of the flank margin and proceed, increasing in breadth distally, concentrically on the umbo, and diagonally on the rest of the inflated portion of the shell, the ventral direction component increasing in each successive rib. The ribs are widely spaced and the interspaces are almost flat and conspicuously striated with prominent growth-lines and rugae. The tubercles are clavate and increase in height and density with the increase in the width of ribs.

Ribs on the remaining depressed portion of the flank number about ten. In the juvenile specimens all ribs originate at the posterodorsal flank margin, but with increasing age only the front ones remain in contact, the distance between the margin and the proximal end of ribs increasing posteriorly with each successive rib and being occupied by the area. Ribs are rather thin, subparallel to each other in juvenile forms, parallel in mature specimens. They are weakly tuberculate or lack tubercles altogether and are separated from each other by interspaces which are about twice their width, and which are lined with concentric growth-lines.

A marginal carina is seen clearly only in juvenile and immature forms, in which it is prominent. Similarly, the transversely ribbed area with its dividing longitudinal groove is clearly seen only on the juvenile specimen, the mature form having the detail effaced. The escutcheon is not available for examination.

In the shell's interior the ventral margin is occupied by deeply incised conspicuous crenulations.

Remarks: The holotype is an incomplete, fractured, and — it is thought — a somewhat aberrant form. It was chosen as holotype because it was the only mature specimen available for description. Its anterior portion is only a little more inflated than the posterior portion. A diagonal fracture divides the holotype into two almost even parts, the posterior part being offset on a higher plane than the anterior part. The fact that the two parts of the shell are in close contact with each other would imply that the fracture occurred after deposition. The break, however, is not a simple one, and there are features on the distal portion of the shell which could be interpreted as caused by healing-up of the fracture.

The specimens chosen as paratypes are a juvenile left valve and a fragment of a mature left valve which shows the nature of the anteroventral portion. The mature fragment supplements information gained from the study of the holotype in that it shows the large thickness of the shell, the prominent inflation of the anterior portion, the extreme development of the tubercles, and the presence of crenulations on the inside of the ventral shell margin.

New name: The name of the new species, *verrucosa,* is derived from the Latin *verrucosus,* full of warts.

Subfamily NOTOTRIGONIINAE Skwarko, 1963

Genus NOTOTRIGONIA Cox, 1952 em.

Type species: *Nototrigonia cinctuta* (Etheridge Jnr, 1902).

NOTOTRIGONIA ZETESIANA sp. nov.

(Text-fig. 1)

Material: A single external impression of a complete left valve of an immature specimen.

Holotype: Text-figure 1 (CPC6143) as above.

Diagnosis: The chief diagnostic feature of the new species is the nature of the ornament on the escutcheon, which consists of relatively robust riblets which originate beneath the umbo and proceed posteriorly subparallel to the dorsal shell margin. The width of the area, which is rather large for the genus, is also regarded as a diagnostic feature.

Comparison with other species: Of the previously described forms *N. crescenta* Skwarko, 1963, may most closely resemble the new species. It has, however, a considerably narrower area and a somewhat wider disc, while its escutcheon is lined with much finer and somewhat differently oriented riblets.

Description: The shell is strongly inflated, very inequilateral, strongly produced posteriorly. The umbo is well defined and opisthogyrous. The disc is relatively

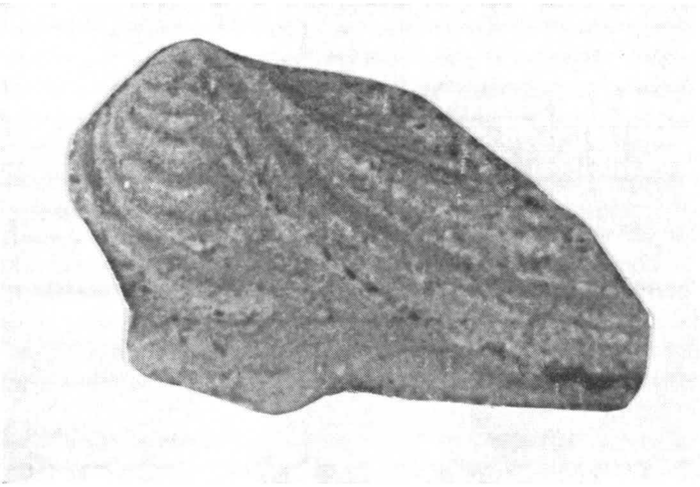

Fig. 1 *Nototrigonia zetesiana*, **holotype, x 4**

small, with prominent concentric ribs which depart from the anterior shell margin and diverge from each other, and rapidly increase in relief rearwards. These ribs may or may not be tuberculate.

The sulcus is narrow close to the umbo and increases gradually in width and breadth away from the umbo. Its posterior margin is sharply terminated by a prominent, narrow, sharp edged, and tuberculate marginal carina.

The area is moderately wide for the genus, longitudinally striated, with possibly four radial riblets which are separated into two pairs by a deep and wide radial groove.

The escutcheon carina is less elevated than the marginal carina, but has more pronounced tubercles, especially towards its distal extremity. The escutcheon is invaginated, striated with unusually prominent and straight escutcheon riblets which originate beneath the umbo and proceed to the rear of the shell subparallel to the dorsal shell margin.

The name of the new species is from the Greek *zetesis*, seeking, searching.

Subfamily AUSTROTRIGONIINAE nov.

The new subfamily Austrotrigoniinae includes trigoniid shells possessing the following characteristics:

i. Shape strongly inequilateral, posteriorly produced, attenuated and subrostrate;

ii. Orthogyrous or somewhat opisthogyrous umbo;

iii. Large, concentrically ribbed disc with ribs and grooves extending with reduced relief on to the sulcus;

iv. Sulcus broad, triangular, shallowly concave or flat;

v. Very poorly defined or obsolete marginal carina;

vi. Area very narrow proximally, undefined distally, with a single radial groove present along its entire length;

vii. Narrow escutcheon, smooth or striated with growth-lines;

viii. Short internal ridge present at the posterior extremity of each valve.

It is proposed to include one additional genus in the new subfamily in addition to the Australian genus *Austrotrigonia* Skwarko, 1963 (type species *A.prima* Skwarko, 1963, from the late Neocomian strata of the Northern Territory). This is *Prorotrigonia* Cox, 1952 (type species *Trigonia seranensis* Krumbeck, 1923, from the Upper Triassic beds of Ceram), which was previously included in Prosogyrotrigoniinae Kobayashi, 1954, but which is thought to have closer affinity with *Austrotrigonia.*

Genus AUSTROTRIGONIA Skwarko, 1963

Type Species: *Austrotrigonia prima* Skwarko, 1963.

AUSTROTRIGONIA SECUNDA sp. nov.

(Pl. 13, figs 1-7)

1946 *Indotrigonia(?)* sp. Whitehouse, *Proc. Roy. Soc. Qld,* 57(2), 12, 13, pl. 1, figs 4a, b, 6, text-fig.

1963 *(?)Austrotrigonia prima* Skwarko; Skwarko, *Bur. Miner. Resour. Aust. Bull.* 67, 33, 34, pl. 6, fig. 4.

Material: Two somewhat incomplete external and two incomplete internal impressions of the right valve; one mature and one immature internal impressions of the left valve.

Holotype: Plate 13, figures 4, 5, 7 (CPC6144): a specimen showing well preserved external and internal aspects of the right valve.

Diagnosis: The disc is ornamented with broad and flat concentric regular costae which extend with reduced relief on to the sulcus. Secondary costae, convex in transverse cross-section, have a tendency to form on the primary costae in the anterior and ventral portions of the disc.

Comparison with other species: *Austrotrigonia secunda* sp. nov. can be distinguished from *A.prima* Skwarko, 1963, from the Neocomian strata of the Northern Territory, by its greater flank-to-rest-of-shell ratio and smaller height-to-length ratio. In *A.prima* the concentric flank costae are slightly convex in cross-section, not flat as in *A.secunda,* and show a tendency to split up only in the ventral portion of the flank.

Description: A mature shell is about 10 cm long and a little over half that in height. The maximum height is in the anterior quarter of the shell, decreasing evenly and fairly rapidly to the rear. The umbo is orthogyrous, somewhat incurved.

The maximum tumidity is in the middle of the disc; inflation is not great, and decreases gradually to the back of the shell and more rapidly along the anterior part of the sulcus.

The anterior shell margin is very regularly and rather strongly convex; the ventral margin of the disc is equally evenly but not as strongly arched; the remaining portion of the ventral margin may be straight or somewhat pushed up in the front portion of the sulcus; the dorsal margin of the sulcus is slightly and evenly concave; the dorsal margin of the escutcheon is gently concave at its rear but probably convexly flexed closer to the umbo.

The area occupied by the disc is greater than that occupied by the sulcus and is almost as big as the rest of the shell.

The disc is subtriangular: its anterior, dorsal, and ventral margins are defined by the shape of the anterior portion of the shell, its posterior margin is a straight line running diagonally across the shell from the umbo to the ventral shell margin. Costae and interspaces anterior to this line have a much greater relief than to the rear. The disc is ornamented with regularly concentric costae. In its proximal portion they are flat and broad and separated by shallow interspaces about one-third to one-fourth their width. In its distal portion and also, in some specimens, in the front part of the proximal costae the ribs become split up parallel to their length into two or rarely three riblets which are convex in cross-section and separated by v-shaped interspaces.

The sulcus is triangular and very broad as it occupies the portion of the shell between the disc and the medium groove. It is shallow. Its surface is concave at the umbo, but seems to flex up until it is almost on the same plane as the disc in the dorsal third of the shell; then it becomes progressively more concave ventrally, especially along its anterior margin.

The interspaces as well as the rectangular costae continue with reduced relief off the disc and along the whole sulcus; they arch around immediately in front of the mid-areal groove and are replaced by growth-lines and rugae on the escutcheon.

The marginal carina, if present at all, is limited to the proximalmost portion of the shell. It, as well as the area, becomes quite indistinct in the middle and distal portion of the shell. The mid-areal groove, however, continues as far as the posterior shell margin.

An escutcheon carina was not observed. The escutcheon is narrow, concave both transversely and longitudinally, striated with growth-lines and rugae only.

Dentition and internal structure of the right valve are as follows: 3a is a robust large tooth which is best developed away from the umbo, giving an impression of being separated from it. 3b, which is less robust and more attenuated than 3a, seems even farther separated from the umbo. Both these teeth are transversely striated on both sides and inclined to each other at an obtuse angle. 5a is almost as long as 3a, but it is narrow, inconspicuous, and closely adpressed to the inside of the anterior wall of the shell. Anterior and posterior adductor muscle scars are large and their proximal extremities deeply incised. The posterior pedal retractor muscle scar is about four times larger, and deeper, than the anterior pedal retractor muscle scar. A conical pedal elevator muscle scar is present. A short internal radial ridge at the mid-posterior extremity of shell is also present.

Discussion: There is no doubt that specimens described in this paper as *Austrotrigonia secunda* sp. nov. belong to the same genus and species as specimens from the same locality which were described by Whitehouse in 1946 as *Indotrigonia(?)* sp. Whitehouse's reconstruction of the fossil (an unnumbered text-figure) appears in the light of the present knowledge to be quite accurate, even though his material was obviously inferior to that collected more recently.

Neither the fossils here described nor Whitehouse's specimens belong to *Indotrigonia* Dietrich, 1933: in addition to other structural differences the new species lacks radial ribbing on its area and escutcheon, which is present in *Indotrigonia.* Of established genera, the only one which will admit the new species is the recently described *Austrotrigonia,* hitherto known only from the late Neocomian strata of the Northern Territory of Australia. The Northern Territory material, though prolific, is quite imperfect, and although in the diagnosis of the genus the area is described as being '. . . . very narrow, with no obvious radial lineations . . . .' (Skwarko, 1963, p. 33), the genus was placed — with a qualification — in the Nototrigoniinae on the assumption that better-preserved material might come to hand and show the presence of radial ribbing on the area. Specimens which furnish material for the description of the new species are not perfect, but examination of their posterodorsal portions leaves little doubt that radial ribbing is absent from both the area and the escutcheon. This is the reason for withdrawing *Austrotrigonia* from its provisional placing in the Nototrigoniinae and the erection of Austrotrigoniinae subfam. nov.

In his description of *Indotrigonia* (?) sp., Whitehouse (op. cit. p. 12) writes: 'There is a wide, shallow postero-ventral sulcus, a broad carina and a shallow trough-like posterior cardinal area'. In the proximal portion of the shell of our specimen the area is very narrow and bisected by a conspicuous radial groove. The area is short, as both inconspicuous ridges which occupy the position of the marginal carina and escutcheon carina quickly disappear. Thus in the central and distal portion of the shell there is no marginal carina, and it is not possible to place a boundary between the sulcus and the area. Indeed, the sulcus has an appearance of extending as far as the radial groove, while from the opposite end the escutcheon also extends as far as the radial groove.

Name: The name of the new species, *secunda,* is derived from a Latin word *secundus,* following.

It was thought desirable to illustrate the remaining members of the Stanwell fauna. This was done mainly for the sake of completeness of record, but also because in at least one case the recently acquired material is more revealing than Whitehouse's original material, which in addition was not very clearly illustrated.

I have contented myself with merely reproducing (Pl. 14, figs 1 and 2) Whitehouse's specimens of '*Pseudomonotis* sp.' (Whitehouse, 1946, pl. 1, figs 7 and 8) as there is no new material available for examination. Similarly the specimen of *Panopea* sp. on Plate 14, figure 10 throws no new light on the affinities of this species. On the other hand, two juvenile specimens of *Iotrigonia limatula* Whitehouse, 1946, which are shown on Plate 14, figures 3-6, show well the early stages of growth of this species.

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CAPTIONS TO PLATES

All specimens are photographed in lateral view and all are of natural size unless stated to the contrary.

CPC — Commonwealth Palaeontological Collection, Canberra.
UQGD — University of Queensland Geology Department.
GSQ — Geological Survey of Queensland.

PLATE 12

FIGS		PAGE
1-6.	*Pterotrigonia* (*Rinetrigonia*) *verrucosa* sp. nov.	172

1, 2. Paratype CPC6141. Latex cast of external impression of juvenile left valve. x1 and x3 respectively.

3, 4, 5. Paratype CPC6142. Anterior, ventral, and lateral views of latex cast of external impression of anteroventral portion of left valve,

6. **Holotype** CPC6140. Latex cast of external impression of incomplete mature left valve.

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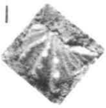

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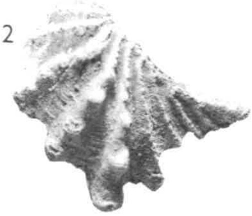

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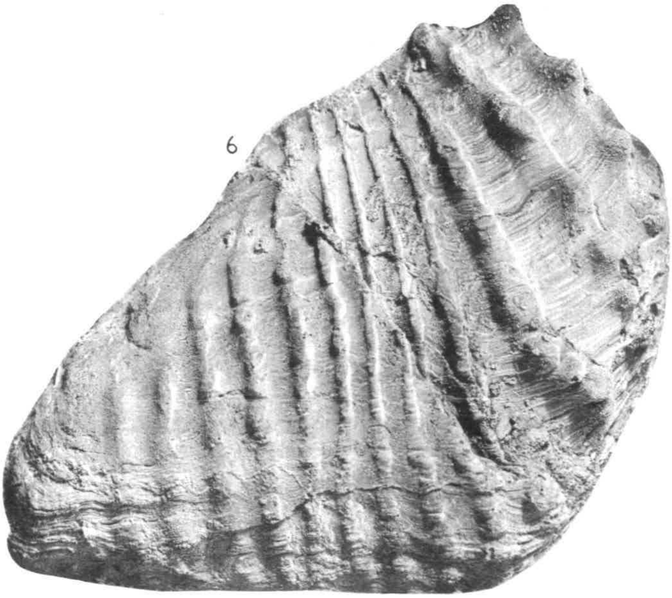

Pterotrigonia (Rinetrigonia) verrucosa sp. nov.

PLATE 13

FIGS		PAGE
1-7.	*Austrotrigonia secunda* sp. nov.	177

1, 3. Latex cast of external impression of anterodorsally incomplete right valve in dorsal and lateral views respectively. CPC6145.

2. Latex cast of internal impression of immature left valve. CPC6146.

4, 5, 7. **Holotype** CPC6144. 4. Latex cast of internal impression of right valve, ventrally incomplete. 5. Latex cast of external impression of right valve, ventrally incomplete. 7. Dorsal view of latex cast of proximal portion of right valve.

6. External impression of left valve. F39371 UQGD.

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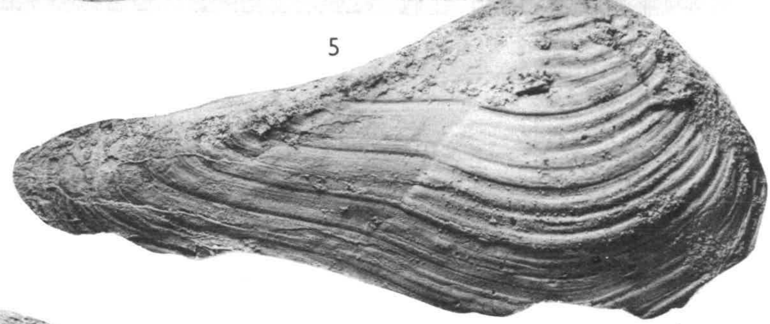

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Australotrigonia secunda sp. nov.

PLATE 14

FIGS		PAGE
1, 2.	*(?)Meleagrinella* sp. cf. *M. superstes* (Spitz, 1914). 1, 2. Latex moulds of Whitehouse's specimens (his pl. 1, figs 7 and 8 respectively), twice magnified. Both are left valves. GSQ F2443 and F2442.	180
3-6.	*Iotrigonic limatula* **Whitehouse, 1946** **3, 4. Latex mould of juvenile portion of valve in end-on view. x2 and x4 respectively. F47301 UQGD.** **5, 6. Latex cast of juvenile portion of valve. x2 and x4 respectively. CPC6743.**	**180**
7.	*Iotrigonia Stanwellensis* Skwarko, 1963 **Latex cast of distally incomplete external impression of immature left valve. CPC6744.**	
8, 11.	*Pterotrigonia* (*Rinetrigonia*) *verrucosa* sp. nov. 8, 11. Latex mould of external impression of juvenile bivalve with valves almost in position. x2 and x4 respectively. F39374 UQGD.	180
10.	*Panopea* sp. Posteriorly incomplete impression of right valve. F39367 UQGD.	180
9, 12.	*Pterotrigonia* (*Rinetrigonia*) *capricornia* Skwarko, 1963. Latex mould of external impression of young right valve. x1, x3 respectively. CPC6745. Locality TT35. Late Neocomian.	173

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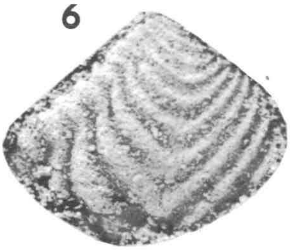

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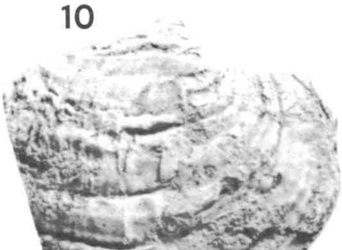

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Cretaceous Trigoniidae

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A NEW RECORD OF BOTHRIOLEPIS IN THE NORTHERN TERRITORY OF AUSTRALIA

by Joyce Gilbert-Tomlinson

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SUMMARY

New discoveries of placoderm fishes constitute the first record of late Devonian animal fossils in the south-western part of the Northern Territory, west-south-west of Alice Springs. Fragmentary plates of the dermal armour of the cosmopolitan antiarch *Bothriolepis* Eichwald occur in the lower part of the Pertnjara Formation, a widely distributed clastic sequence reaching a maximum thickness of 12,000 feet. Apart from spores recovered from about the same stratigraphic level, the vertebrates are the only diagnostic fossils known from the whole formation. The newly-discovered *Bothriolepis* is dated as Upper Devonian, probably no older than late Frasnian. The sediments in which the fossils occur represent the establishment of terrestrial conditions that in this area have persisted until the present time, replacing the marine environment of the Cambrian and Ordovician Periods. They form part of a consistent picture of late Devonian lacustrine and fluviatile sedimentation over wide areas in central and eastern Australia. The *Bothriolepis* plates illustrated in this paper, although too fragmentary for a detailed systematic study, are of considerable anatomical interest. One of them displays a structure not previously noted in described species of the genus; in other respects the specimens show a resemblance to the Victorian *B. gippslandiensis* Hills. The existence of an indigenous group of *Bothriolepis* species is suggested.

INTRODUCTION

The early discovery of late Devonian vertebrate fossils in Australia is concerned with the States of New South Wales (first record in 1907) and Western Australia (first record in 1910). Later work has extended the known distribution of the fossils, and at present South Australia and Tasmania alone are lacking in known representatives (Text-fig. 1). The discoveries in central Australia, in the southern part of the Northern Territory and adjacent parts of western Queensland, are an achievement of the last decade, the first record, from the Dulcie Range, north-east of Alice Springs, having been published in 1959. Geologists of the Bureau of Mineral Resources and of oil companies operating in the area have subsequently found similar fossils at other localities, and this paper summarizes the present state of knowledge of the central Australian Devonian vertebrates and describes the material from the most westerly known locality, Dare Plain, in the southern part of the Northern Territory, west-south-west of Alice Springs.

If considered in isolation, the central Australian fishes, represented almost entirely by placoderms, are difficult to date except within wide limits. They are so poorly preserved that many of the specimens cannot even be generically determined, and at best no specific identification is possible. Even without these limitations, lack of detailed knowledge on the fish faunas in other parts of Australia has so far prevented the erection of a chronological scale into which the central Australian examples may be fitted. Moreover, the latter are nowhere associated with marine invertebrates that can be independently dated, and the scale-positions of the rare plant fossils are themselves uncertain. Attempts to arrive at a satisfactorily limited time span for the central Australian fishes by extrapolation from the established ranges of oversea genera recognized in the local faunas — in this case the antiarch *Bothriolepis* and the arthrodire *Phyllolepis* — are impeded first by the long span of *Bothriolepis* in the Northern Hemisphere (late Middle Devonian to late Upper Devonian), secondly by the fact that the association in central Australia of *Bothriolepis* with the shorter-ranging *Phyllolepis* has not been conclusively proved, and, thirdly, by the necessity of avoiding the uncritical assumption that either genus necessarily has the same range in Australia as elsewhere.

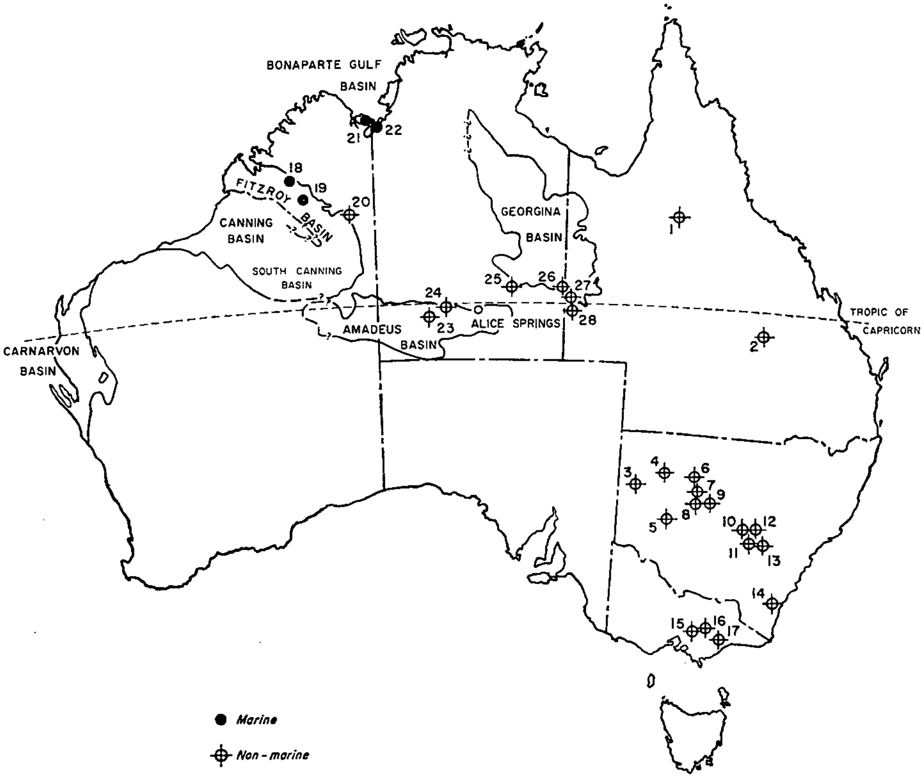

Fig. 1. Australian localities for late Devonian fishes

Queensland: 1. Gilberton; 2. Springsure. New South Wales: 3. Mootwingee; 4. Mount Jack; 5. Jacks Lookout; 6. Mount Deerina; 7. Wittagoona Station; 8. Mount Grenfell Station; 9. Bulgoo Station; 10. Coradgery; 11. Jemalong Gap; 12. Herveys Range; 13. Mount Canoblas; 14. Majors Creek. Victoria: 15. Blue Hills; 16. Mansfield; 17. Freestone Creek. Western Australia: 18. Barker Gorge; 19. Emanuel Range/Bugle Gap; 20. Billiluna; 21. Hargreaves Hills. Northern Territory: 22. Spirit Hill No. 1 Well; 23. Dare Plain; * 24. Gosses Bluff; 25. Dulcie Range; 26. South of Mithaka Waterhole; * 27. Toomba Bore; 28. Toomba Range.
*** May be older than Upper Devonian.**

On the face of it, the central Australian fish-bearing beds may have been deposited at any time within an interval extending from late in Middle Devonian time to near the end of the Period, and there is no direct evidence to refute such a possibility. But when the problem is viewed in perspective, and the broader aspects of regional geology and palaeogeography are taken into consideration, a comparatively late date for the central Australian deposits, no older than late Frasnian (early Upper Devonian) and probably extending into Famennian time (late Upper Devonian), seems to emerge, and is here advanced as a working hypothesis.

Notwithstanding the comparative neglect of the Australian late Devonian fishes themselves, the rock sequences in which they occur and the marine invertebrates, where present, have been studied in some detail. The fish-bearing beds fall into two categories, separable on a regional, ecological, provincial, and temporal basis. In north-western Australia, the beds are, with one possible exception, marine, the associated invertebrates are generally considered to have European affinities, and the indicated age is Frasnian; generally most of the known vertebrate fossils occur in rocks of early Frasnian age. In eastern Australia, negative evidence in the form of a consistent absence of marine invertebrates is taken to indicate a freshwater environment. At the few localities (in eastern New South Wales) where marine fossils occur in sequence with the fishes (invariably at a lower horizon), they display North American relationships. Their age (Chemung) and approximate correlation with the European scale (late Frasnian or early Famennian) provide a lower limit to the time of deposition of the overlying fish-bearing beds that is near the upper limit of the western Australian sequence.

Among the placoderm genera whose ranges are controlled by datable invertebrates in eastern New South Wales are *Bothriolepis* and probably *Phyllolepis* and the Greenland genus *Remigolepis,* indicating that whereas the last two have much the same scale position here as elsewhere, *Bothriolepis* makes a comparatively late appearance on the local scene. The vertebrate faunas of south-eastern Australia display an overall generic similarity, even in the wide areas — in western and central-western New South Wales and in Victoria — not subjected to the marine invasion that affected eastern New South Wales. The similarity is shared by the central Australian faunas and invites the assumption that the beds in which their remains are found were all laid down during the same sedimentary cycle and in a comparatively short interval near the close of the Devonian Period, when continental conditions prevailed. Morphological resemblances between the most westerly known example of the fauna, the newly-discovered *Bothriolepis* from the south-part of the Northern Territory, and *B. gippslandiensis* from Victoria suggest that the animals inhabited chains of lakes connected by a common river system, with the drainage from the central Australian area toward the south-east.

The marine faunas of north-western Australia, which apparently include none of the genera conspicuous in the south-east, represent a slightly earlier chapter in the Australian vertebrate record. The little-known terrestrial faunas of northern and central Queensland may, on the other hand, prove to be contemporaneous with those of south-eastern and central Australia, though possibly of distinct faunal relationship. Continental conditions probably prevailed in late Devonian time in many parts of Australia that have so far yielded few or no fossils: in Tasmania (Middle or late Devonian spores), and in South Australia, the greater part of Western Australia, and the northern part of the Northern Territory (no fossils). The proto-Australian continent seems to have had a similar extent to the present one, except for a few disconnected embayments on the east coast in Queensland and New South Wales and in the west and north-west in Western Australia, where marine sediments were deposited. And even here there is evidence of interrupted sedimentation in Famennian time.

In the following summary of the late Devonian fish faunas of Australia, the determinations are the responsibility of the author unless otherwise stated. The numbers placed in brackets after the names of localities correspond to those shown on the locality map (Text-fig. 1).

ACKNOWLEDGMENTS

My thanks are due to the following organizations and individuals for material used in this paper:

Mr H. O. Fletcher, Australian Museum, Sydney (reference to unpublished reports on fossils from Mootwingee, N.S.W., and Toomba Range, N.T.); Professor D. A. Brown, Australian National University, Canberra, and Mr N. E. A. Johnson (reference to an unpublished thesis); Alliance Petroleum Australia N.L. (reference to occurrence of fossils in Toomba Range, N.T.); American Overseas Petroleum Ltd and Mr A. W. Lindner (fossils from Springsure, Queensland, and Jacks Lookout, N.S.W., and reference to occurrence of fossils at Mootwingee, N.S.W.); Electrolytic Zinc Co. of Australia and Mr J. H. Hill (fossils from Mount Deerina, N.S.W.); French Petroleum Co. (Aust.) Pty Ltd (fossils from Toomba Range, Queensland); Magellan Petroleum Corporation and Mr R. M. Hopkins (fossils from Dare Plain, N.T.); Shell Development (Aust.) Pty Ltd and Dr C. J. Mulders (fossil from Toomba Range, Queensland); and Dr G. Seddon, University of Western Australia (information on fossils from Carnarvon Basin, W.A.).

LATE DEVONIAN FISH-BEARING BEDS OF CENTRAL AUSTRALIA

General

For the purposes of the present discussion, 'central Australia' means the southern part of the Northern Territory together with the extreme west of Queensland, whose faunas are conveniently considered in conjunction with those of adjacent parts of the Territory. Geographically the late Devonian sediments have been distributed by sedimentary geologists among two main areas: (1) the Amadeus Basin, south and west of Alice Springs and south of the Tropic of Capricorn, and (2) the southern Georgina Basin, north-east of Alice Springs and extending in the east into western Queensland, and lying north of the Tropic. The late Devonian vertebrates of the Amadeus Basin are restricted to the lowermost division of the threefold Pertnjara Formation, the 'Pertnjara siltstone'. They occur at Dare Plain west-south-west of Alice Springs, which has yielded fragmentary plates of the armour of the antiarch *Bothriolepis,* which are described in this paper, as well as spores described by E. A. Hodgson (this Bulletin). The late Devonian vertebrates of the southern Georgina Basin are found in the upper Dulcie Sandstone of the Dulcie Range, north-east of Alice Springs, and are associated with the upper part of the Cravens Peak Beds in the Toko Syncline, east of the Dulcie Range and crossing the border between the Northern Territory and Queensland. The fossils from the Dulcie Range include *Bothriolepis* and the arthrodire *Phyllolepis.* They were the first Devonian vertebrates recorded from the central Australian area (Hills, 1959). In the Toko Syncline, very fragmentary plates of the armour of *Phyllolepis* have been found, together with other, unidentified, arthrodires. The material has been collected by geologists attached to oil companies and, except for one of the arthrodiran fragments, is not available for description. I have, however, examined some of the other material.

In the absence of evidence for a marine environment, it is assumed that the beds containing the fossils are river or lake deposits. At the generic level, the central Australian faunas are markedly different from most of those of north-western Australia and, as far as can be determined, northern and eastern Queensland as well. Faunal relationships are, however, evident between central and south-eastern Australia, which in some sections can be dated by other fossils as no older than late Frasnian. A local peculiarity of the central Australian fossil record is the apparent absence of the otherwise ubiquitous *Leptophloeum.*

Pertnjara Formation

Concept and terminology

The Pertnjara Formation constitutes the record of geological events during the closing phases of Palaeozoic sedimentation in the Amadeus Basin, in the south-western part of the Northern Territory, west and south of Alice Springs. The Formation was deposited under terrestrial conditions, and its upper levels reflect a powerful folding movement. Its base is Upper Devonian in age; the top cannot be dated on its own merits. Lower Carboniferous seems a reasonable approximation, but a younger date is not impossible.

The terminology employed in this paper follows the current official usage of the Bureau of Mineral Resources instituted by Prichard & Quinlan (1962). The name 'Pertnjara' was introduced by Chewings (1931) as a descriptive non-geographical term to designate 'the Post-Ordovician Conglomeratic-Sandstone formation' — 'Pertnjara' means 'many stones' in the language of the local Arunta or Aranda tribe. Madigan (1932) refers to a 'Pertnjara Series'; he seems to

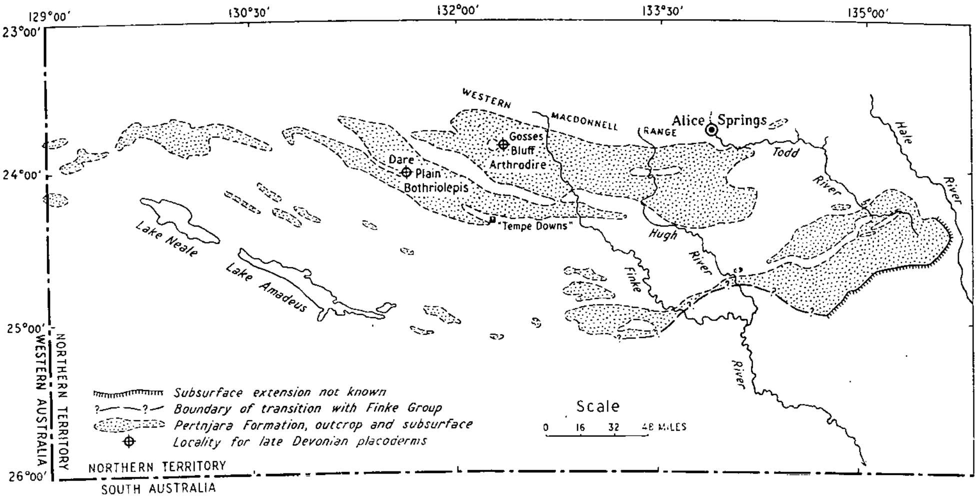

Fig. 2. Pertnjara Formation — outcrop and subsurface (geology by A. T. Wells). The arthrodire at Gosses Bluff may be older than Upper Devonian.

have regarded its lithology as exclusively conglomeratic. Since the Bureau of Mineral Resources began mapping the region in 1956, its geologists have identified outcrops of Pertnjara Formation over a very large area (Text-fig. 2) and in grainsizes ranging from siltstone to boulder conglomerate. In its present connotation, the Pertnjara Formation has become so unwieldy that geologists have adopted an informal subdivision, based on lithological characters, into three superimposed rock bodies: 'Pertnjara siltstone' at the base, 'Pertnjara sandstone', and 'Pertnjara conglomerate'. As this refinement adds greatly to stratigraphic precision, I have followed their example. The present intentions of the geologists responsible for mapping the region are to give the Pertnjara the status of a group consisting of three formations corresponding to the lithological units listed above (A. T. Wells, pers. comm.); the names will be published in the near future. The following brief summary of Pertnjara geology includes information from a bulletin, now in preparation, on the regional geology of the area.

Details of the rather complex lithology of the Pertnjara Formation and its structural relationships in different parts of the Basin are given by the following authors: Ranford et al. (1966); Wells et al. (1964, 1965, 1966, and 1967).

Distribution and fossils

The 'Pertnjara siltstone' has been recognized mostly in the area west and south of the Finke River. A comparatively small outcrop has been mapped about 45 miles south of Alice Springs on the Hugh River, and D. R. Woolley, former Resident Geologist at Alice Springs, has noted an occurrence about 10 miles south-south-west of Alice Springs (pers. comm.). At the south-eastern end of the Mereenie Anticline, at Dare Plain [23]*, a prominent bed of sandstone is present in the lower part of the siltstone. The only fossils so far recovered from the Pertnjara siltstone, and the only diagnostic fossils known from the whole formation, occur near the top of this sandstone — spores described by Hodgson (this Bulletin) and the *Bothriolepis* plates illustrated in this paper. Both have a theoretical Middle to Upper Devonian range; for reasons given in detail below (pp. 212), an Upper Devonian age (no older than late Frasnian) is preferred for the fish-remains.

The 'Pertnjara sandstone' is much more widespread. It may overlie the 'Pertnjara siltstone', but in sections where the latter is not recognized it forms the local base of the Formation. Its only known fossils consist of fragments of bark, found at a single locality near Tempe Downs homestead. They have been identified as *Sigillaria* (Leslie, 1960), but in my opinion are too poorly preserved for reliable identification.

The 'Pertnjara conglomerate' overlies the sandstone; in some sections a siltstone intervenes. Its main development is in the north, immediately south of the Western MacDonnell Range. From here it thins rapidly to the south and passes laterally into sandstone. The only fossils noted in the conglomerate are marine invertebrates derived from the local Ordovician sequence. The conglomerate is considered to be of orogenic origin (Quinlan, 1962), with a source area north of the present outcrops.

Geological context

The oldest sediments of the Amadeus Basin (area about 60,000 square miles) are Proterozoic, Cambrian, and Ordovician in age. In contrast to the terrestrial Pertnjara, they were deposited in shallow seas. Intervening between the Ordovician rocks and the Upper Devonian base of the Pertnjara Formation is a transitional sequence, the Mereenie Sandstone, not distinguished by Chewings. Fragmentary arthrodiran fish plates from a single locality — Gosses Bluff†, about 50 miles east-north-east of Dare Plain — indicate a Devonian age for at least part of the formation. Petrological investigation indicates an aeolian origin for some of the sand; I consider that the beds of pipe-rock within the sequence reflect shallow-water marine sedimentation, possibly alternating with periods of emergence. Large-scale current bedding suggests deltaic sedimentation. The Mereenie Sandstone is separated from the older rocks by a regional unconformity. No obvious structural break has been noted between it and the overlying 'Pertnjara siltstone', but the higher levels of the Pertnjara Formation display in places a marked unconformity against the older Palaeozoic and Proterozoic rocks.

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*The number references, [23] etc., are to Figure 1.

† The fossils were first thought to occur in the lower part of the Pertnjara Formation, about the same stratigraphic level as the Dare Plain *Bothriolepis* (Wells & Tomlinson *in* Johnstone et al., International Devonian Symposium, 1967). Detailed investigations of Gosses Bluff geology by Dr. D. J. Milton, United States Geological Survey, have since proved them to originate in the Mereenie Sandstone.

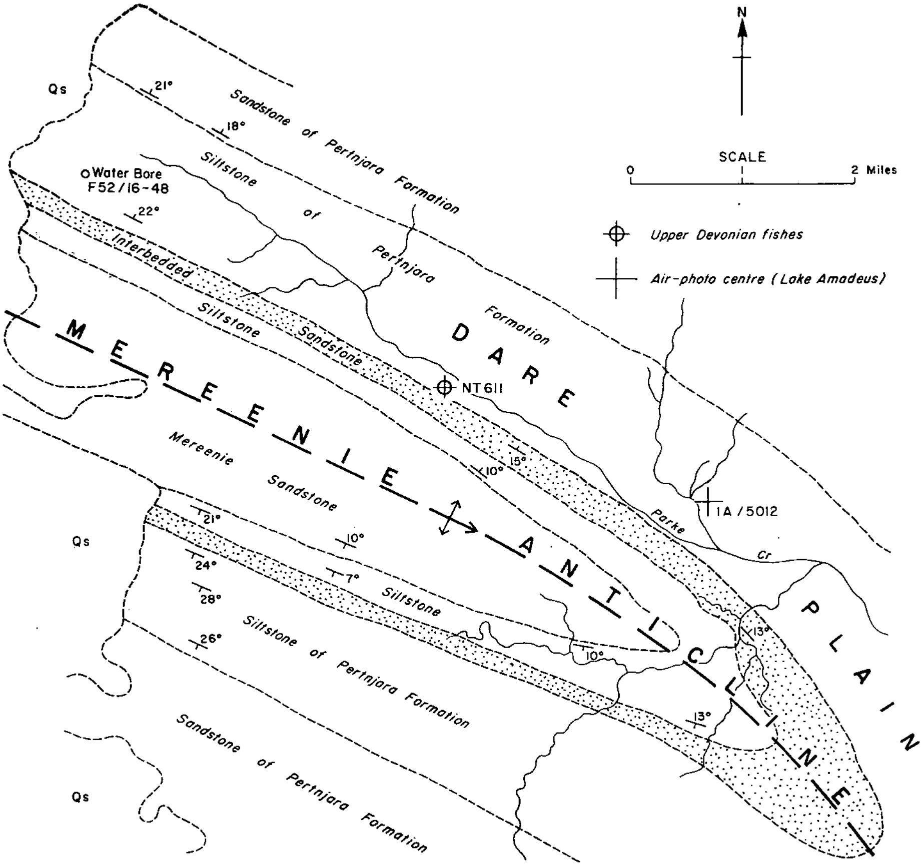

Fig. 3. Geology of Dare Plain, N.T. (geology by A. T. Wells)

The Pertnjara Formation is overlain by thin laterally discontinuous outcrops of freshwater Tertiary sediments. In areas immediately adjacent to the Amadeus Basin, north and south-east, Upper Carboniferous and Permian spores (Evans, 1965, and pers. comm.) have been recovered from sediments whose structural relationship to the Pertnjara Formation is obscure. Unlike many areas in inland Australia, the Amadeus Basin was apparently unaffected by the widespread late Lower Cretaceous marine transgression (Skwarko, 1967).

Local geology at Dare Plain

Dare Plain lies on the outcrop of 'Pertnjara siltstone' at the south-eastern closure of the Mereenie Anticline, about 140 miles west-south-west of Alice Springs (Text-fig. 3). The Pertnjara Formation is here represented by the two older units only; the top of the sequence is eroded, and 'Pertnjara conglomerate' is not recognized. The total thickness is about 5000 feet, the 'Pertnjara siltstone' being about 2800 feet thick. Mereenie Sandstone occupies the core of the Anticline, and its contact with the overlying 'Pertnjara siltstone' is apparently conformable. The lower part of the siltstone contains a bed of sandstone extending uninterrupted around the nose of the Anticline. It is 300-400 feet thick, and its upper limit is 600-700 feet above the base of the Formation. Halite pseudomorphs have been noted in this sandstone, and all the known fossils occur near its top.

The spores were recovered from waterbore F52/16-28 (Hodgson, this Bulletin); the *Bothriolepis* plates were collected at the surface about 4 miles east-south-east of the waterbore (loc. NT608, 611). Both localities are on the north-eastern limb of the anticline, and A. T. Wells (pers. comm.) considers that their stratigraphic levels are almost identical.

Significance of fossils

The best preserved of the Dare Plain placoderm specimens is morphologically important in having preserved a structure not previously noted in *Bothriolepis* and thus adding to our knowledge of the genus. Moreover, resemblances to the best-known Australian species, the Victorian *B. gippslandiensis* Hills, may foreshadow the recognition of an indigenous Australian group of species when the faunas are better known.

But the fossils are also particularly important as temporal documents. Their chronological value may best be judged from the fact that they mark the only datable level in the whole of the 12,000 foot Pertnjara Formation. Moreover, the stratigraphic level of the fossils, comparatively close to the base of the Formation, is useful for determining the time of establishment of enduring terrestrial conditions in the Basin, particularly as they have persisted without interruption until the present time. Lastly, as the final folding, represented by the 'Pertnjara conglomerate', was apparently unaccompanied by igneous activity whose products might serve for radiometric dating, the fossils in the earlier 'Pertnjara siltstone' provide a lower limit for the time of the movement. An attempted correlation of the central Australian fish-bearing beds is given in Text-figure 6.

The fossils do not in themselves constitute ecological documents: the ecology of the early fishes is still the subject of considerable disagreement, and spores may well be carried long distances by wind. But the consistent absence of associated marine invertebrates, not only locally, but in other parts of central Australia and in eastern Australia, must be accepted as indicating non-marine sedimentation. The existence of late Devonian continental conditions in wide areas of eastern Australia has long been known. More recently, discoveries in the Dulcie Sandstone (below) in the south-eastern part of the Northern Territory (Hills, 1959) have greatly enlarged the known extent of the proto-Australian continent. The latest discoveries, in the south-western part of the Territory, provide evidence for a further enlargement of about 300 miles to the south-west.

Dulcie Sandstone

The Dulcie Sandstone (Text-fig. 4) is exposed in the south-western part of the area known as the Georgina Basin, where it occupies the core of the Dulcie Syncline, a north-west-trending structure, whose south-eastern extremity lies near

Huckitta homestead, about 150 miles north-east of Alice Springs. The sandstone rests unconformably on Cambrian and Ordovician rocks; the top is eroded. In the Dulcie Range [25], near the south-eastern end of the Syncline, a thickness of 2100 feet of fine to medium-grained sandstone with interbedded siltstone and pebble conglomerate has been measured. At the opposite end of the Syncline, about 100 miles to the north-west, the maximum preserved thickness is 300 feet (Smith, 1964; Smith & Milligan, 1964, and pers. comm.).

Two distinct assemblages of Devonian placoderms have been recovered from the sandstone. The first and best known is restricted to the south-eastern exposures and to the upper 500 feet of the section. The fossils were first discovered in 1958 by M. A. Condon and K. G. Smith of the Bureau of Mineral Resources (H80) and by geologists of the Frome-Broken Hill Co. Pty Ltd (JW30). They have been identified as *Bothriolepis* and *Phyllolepis* and dated as Upper Devonian (Hills, 1959). In the measured section *Bothriolepis* occurs 1600 feet above the base and *Phyllolepis* 400 feet higher. Supplementary collections from the *Bothriolepis* level (H80) and the *Phyllolepis* level (H183), made by K. G. Smith, R. R. Vine, and E. N. Milligan, are awaiting description. My estimate of an advanced Upper Devonian age results from comparison with the known occur-

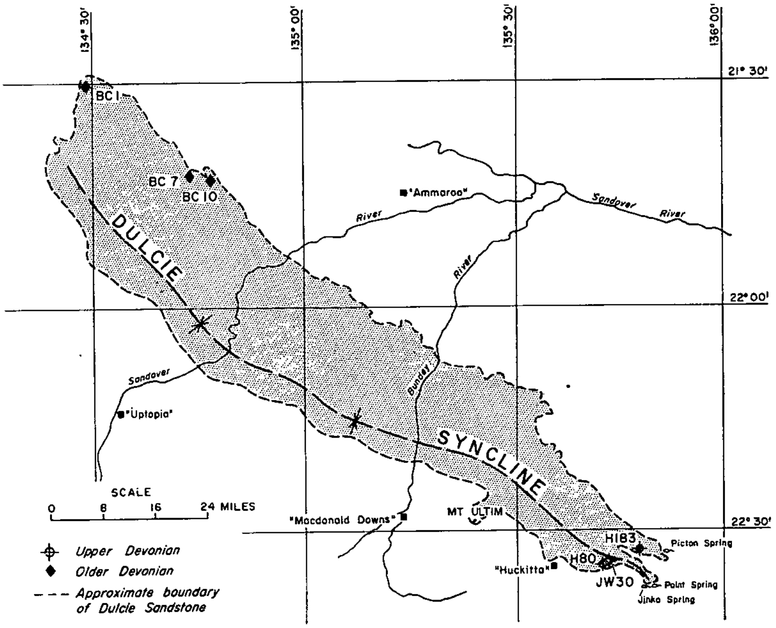

Fig. 4. Localities for Devonian fishes, Dulcie Syncline, N.T. (geology by K. G. Smith)

rences of *Bothriolepis* and *Phyllolepis* in south-eastern Australia. The *Phyllolepis* is probably Famennian. Details of the collecting points are as follows:

H80 — 8 miles east-north-east of Huckitta homestead;

H183 — about 4 miles north of Jinka Spring;

JW30 — about ½ mile east-north-east of H80.

The fossils of the second placoderm assemblage were collected in 1961 by E. N. Milligan at three localities near the north-western end of the Dulcie Syncline and in the lowermost 15 feet of the section:

BC1 — 50 miles north-west of Ammaroo homestead;

BC7 — 30 miles west-north-west of Ammaroo homestead;

BC10 — 28 miles west-north-west of Ammaroo homestead.

They are now being studied by Professor E. S. Hills of the University of Melbourne, who (pers. comm.), after a preliminary examination, has suggested that they may be older than the *Bothriolepis* of the earlier collection.

Cravens Peak Beds

Like the Dulcie Sandstone, the sequence mapped as Cravens Peak Beds (Text-fig. 5) occupies the core of a syncline, in this case the Toko Syncline, which crosses the border between Queensland and the Northern Territory about 140 miles east-south-east of Huckitta. The beds occur as scattered outcrops of current-bedded gritty sandstone with clay-pellets, resting unconformably on Ordovician sediments. They are overlain by Cretaceous and, possibly, Permian sediments. The maximum exposed thickness is 450 feet (Reynolds *in* Smith, 1965; Smith, Vine, & Milligan, 1961; Reynolds, 1964; Reynolds & Pritchard, 1964).

Again, like the Dulcie Sandstone, the Cravens Peak Beds have two distinct suites of vertebrate fossils associated with them. The older assemblage, and the only one found in situ, has been identified by P. J. Jones (*in* Reynolds & Pritchard, 1964), who has recognized, for the first time in Australia, scales of primitive jawless vertebrates of the family Coelolepididae. They date the rock in which they occur as Upper Silurian to Lower Devonian (early Siegenian). Associated with the coelolepidids are undetermined ostracodes and valves of the etidostracan *Cryptophyllus* (P. J. Jones, pers. comm.). The fossils were recovered from shot-hole samples in an area east of the axis of the Toko Syncline and west of the Toko Range.

The younger assemblage is also a recent discovery and is Upper Devonian in age. It is included in the discussion with some reservation, because (1) none of the fossils occurs in situ, (2) one of the collections has certainly been transported to its place of discovery by human agency, and (3) search of the outcrops has consistently failed to reveal comparable fossils. On the other hand, the

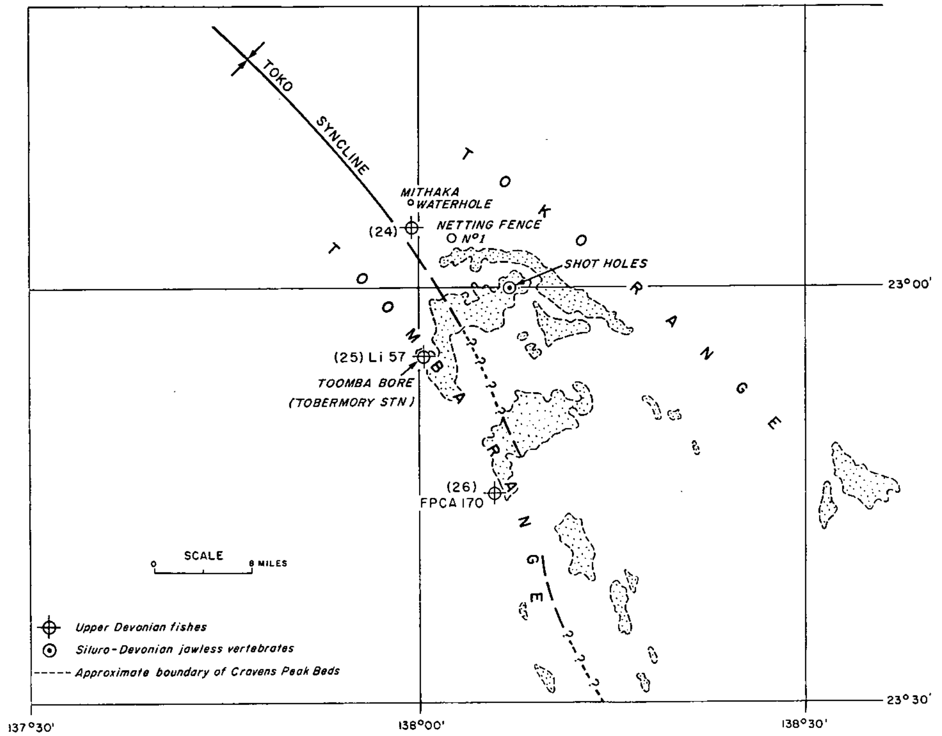

Fig. 5. Localities for vertebrates, Toko Syncline (geology by K. G. Smith). The figures (24), (25), and (26) should read [26], [27], and [28]; Longitude 138° E. marks the boundary between the Northern Territory and Queensland.

fossils have now been found at no less than three widely-separated spots, and, moreover, if they are not of local provenance their place of origin is difficult to determine. The nearest locality for late Devonian vertebrates is in the Dulcie Range, 140 miles away, but the absence of *Bothriolepis* and the presence of a lycopod plant and pustulose arthrodires distinguishes the Cravens Peak assemblage from that of the upper Dulcie Sandstone. The Cravens Peak assemblage shows some resemblance to that of the Mulga Downs Formation of western New South Wales (below, p. 208). The aborigines are known to be in the habit of transporting stones over long distances, but the idea that the fossils in question should have been carried for 600 miles seems extravagant.

Available information on the collecting points of the fossils is given below. It will be noted that they are all farther west than the localities yielding the Siluro-Devonian coelolepidid fauna: two of the collections are from the Toomba Range, on the western limb of the Toko Syncline; the third and most northerly lies near the axis of the Syncline, between the Toomba and Toko Ranges.

(1) In 1963, Mr R. B. Wilson of Geosurveys of Australia Ltd, reporting for Alliance Petroleum Australia N.L., recorded the occurrence of 'a large fragment of sandstone,

with well preserved fossil fish fragments . . . . at the base of a prominent group of hills composed of . . . . . sandstone of uncertain age.' Fossils were searched for but not found in these and the neighbouring outcrops. The presence of aboriginal artefacts suggested that the fossiliferous sandstone might have been carried to the spot where it was found by aborigines, although 'being rather heavy . . . . it would not have been carried for long distances' (loc. cit.). After examining the fossils Mr H. O. Fletcher, of the Australian Museum, Sydney, concluded that they were almost certainly identical with those of the Mulga Downs Formation of western New South Wales (*in* Wilson, loc. cit.). K. G. Smith (pers. comm.), after examining the unnamed locality [26], which is about 2½ miles south of Mithaka Waterhole, states that the sandstone is now mapped as Cravens Peak Beds, here more than 50 feet thick.

(2) In 1964, Dr C. J. Mulders of Shell Development (Aust.) Pty Ltd collected a sandstone floater preserving an impression of arthrodiran armour from the lower part of a sequence then unnamed but now mapped as Cravens Peak Beds (Li57). The locality is in the Toomba Range in Queensland, very close to the border with the Northern Territory, and about ¾ mile north-east of Toomba Bore (Tobermory station) [27]. The fragment is not generically identifiable; the surface sculpture recalls *Coccosteus*, and resembles that of the Gosses Bluff arthrodire (p. 197). It may be older than Upper Devonian.

(3) In 1964, geologists of the French Petroleum Co. (Aust.) Pty Ltd collected two specimens of fossiliferous sandstone (FPCA170) resting on an outcrop of Ordovician sandstone. The locality [28] is about 12½ miles east-south-east of Toomba Bore. The fossils are unquestionably of late Devonian age. One specimen represents a poorly-preserved impression of lycopod bark, *?Protolepidodendron*. The other contains very fragmentary arthrodiran plates, *Phyllolepis* and an unidentified genus with pustulose ornament; a possible dipnoan fragment is also present. K. G. Smith (pers. comm.), after examining the locality, states that it is possibly an aboriginal corroboree ground to which the fossils have been carried. The nearest outcrop of Cravens Peak Beds is about half a mile to the east. This, like other outcrops, has yielded no fossils.

Correlation of Younger Palaeozoic Sediments

Sequence of Post-Ordovician Events

From Proterozoic time until near the end of the Ordovician Period, central Australia was covered by shallow seas in communication with those in other parts of Australia. Sedimentation was interrupted from time to time, and the depositional history differed in detail in various parts of the area, but the broad outline of geological events was essentially the same in both the Amadeus and southern Georgina Basins.

By late Devonian time a complete change in environment had taken place, and the seas of Proterozoic, Cambrian, and Ordovician times had given way to dry land occupied by lakes linked by rivers to a sea that had by this time retreated far to the east.

Apart from its own intrinsic significance, one of the most important results of the recognition of the late Devonian terrestrial sedimentation is to highlight the preserved record of the poorly documented transitional phase, represented by the sediments intervening between the late Ordovician and late Devonian rocks (Text-fig. 6).

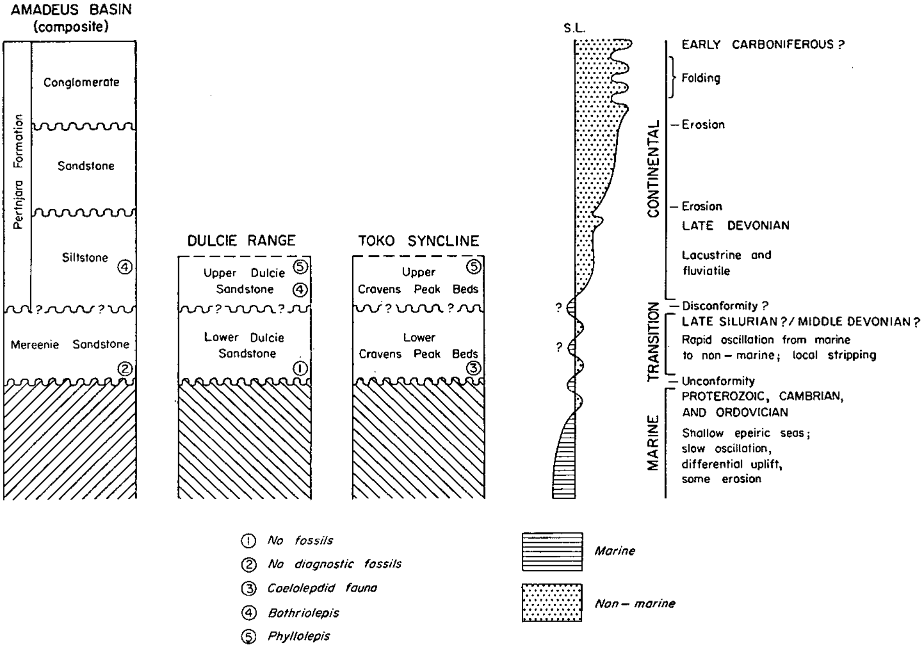

Fig. 6. Correlation of post-Ordovician Palaeozoic sediments, central Australia (not to scale)

Transition beds

The transition beds consist almost entirely of clastic sediments. They are represented in the Amadeus Basin by the Mereenie Sandstone (max. 3000 feet) and in the southern Georgina Basin by the lower Dulcie Sandstone (1600 feet in the Dulcie Range) and, farther east, the lower Cravens Peak Beds (max. 450 feet in the Toko Syncline). In each case the beds rest unconformably on the underlying marine lower Palaeozoic rocks but display no obvious structural discordance against the overlying late Devonian terrestrial sediments. The beds are clearly linked by their structural relationships with the underlying and overlying rocks, and, except for the lower Dulcie Sandstone, by the presence of rare marine fossils (distinguishing them from the overlying continental sediments); also, in lithology and the scale of its current bedding, the lower Dulcie Sandstone is reminiscent of the Mereenie Sandstone. No biological correlation of the various sequences is, however, possible. If the beds can be proved to belong to the one sedimentary cycle, the obvious thickening from east to west may suggest sea communications by way of north-western Australia. This interpretation may, however, oversimplify matters. A good deal more evidence in the form of datable fossils must be accumulated before the depositional history of these rocks is mastered.

Late Devonian lacustrine beds

The 'Pertnjara siltstone' (2800 feet), the upper Dulcie Sandstone of the Dulcie Range (500 feet), and the upper Cravens Peak Beds (thickness unknown), containing fragments of vertebrates and rare plant remains and showing no evidence of marine life, are assumed to have been deposited in freshwater lakes. The environment distinguishes them from the marine Upper Devonian fish-bearing beds of Western Australia and suggests connexions with eastern Australia — a suggestion upheld by the apparent restriction in Australia of the cosmopolitan

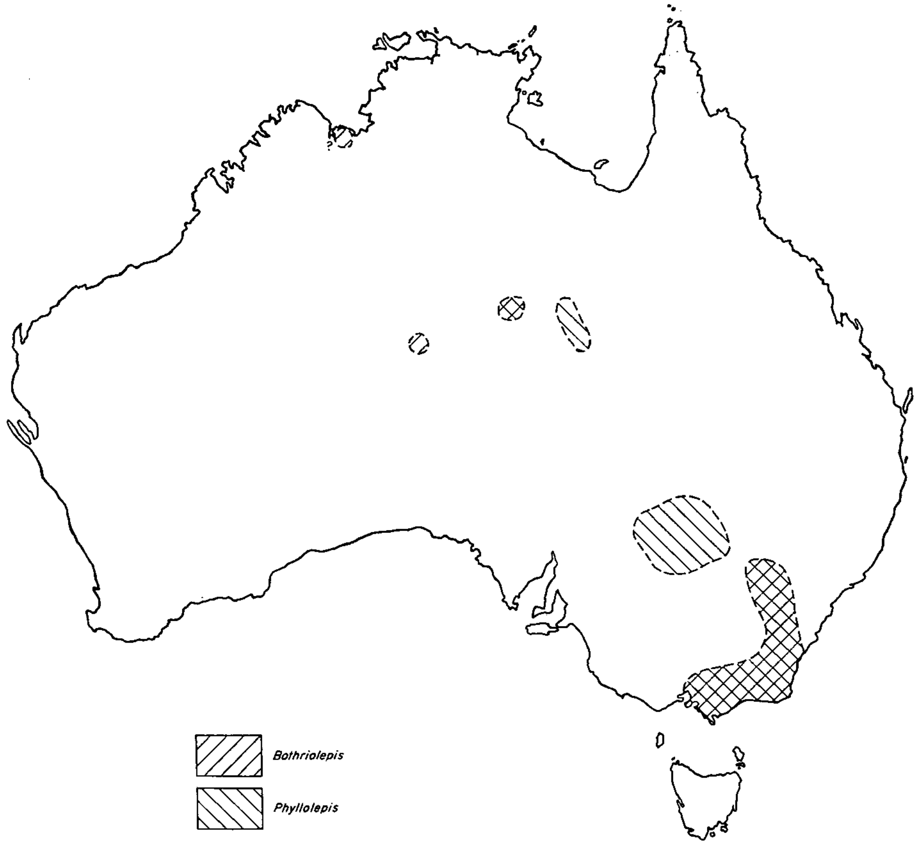

Fig. 7. Distribution of *Bothriolepis* and *Phyllolepis* in Australia

placoderms *Bothriolepis* and *Phyllolepis* to central and south-eastern Australia (Text-fig. 7) and by resemblances of the Dare Plain *Bothriolepis* to the Victorian *B. gippslandiensis.* The earliest possible date for the first appearance of *Bothriolepis* and *Phyllolepis* in the south-east is late Frasnian, and deposition almost certainly continued into Famennian time. It seems likely that members of the assemblage reached the Central Australian area from the present south-eastern part of the continent. Hence the deposits in which their remains are found would be no older than those in the south-east.

Whether the central Australian fish faunas represent a single fauna or a succession of faunas is at present difficult to determine. Evidence from the Dulcie Range, where *Phyllolepis* appears 400 feet higher in the section than *Bothriolepis,* suggests the presence of two superimposed faunas. Further, the absence of *Bothriolepis* from the Toko Syncline collections may indicate that only the younger fauna is present in this deposit, whereas the absence of *Phyllolepis* from the Amadeus Basin collections would suggest that this area has preserved the older fauna only. But the association of *Bothriolepis* and *Phyllolepis* in Victoria and other parts of the world is well documented, and detailed collecting in the Dulcie Range may establish the presence of a similar association. Nevertheless, the existence of a Famennian fauna with arthrodires (including *Phyllolepis*) and without *Bothriolepis* is established in western New South Wales, showing that the provisional correlation scheme outlined in Text-figure 6 is not entirely fanciful.

LATE DEVONIAN FISHES IN OTHER PARTS OF AUSTRALIA

General

A summary of the Australian vertebrate record, as known in 1954, has been published by Hills (1958). The succeeding period has seen considerable advances in knowledge in this field, including the late Devonian fish-bearing beds. The number of new discoveries of the latter indicates that they are not uncommon in Australia. Equally important is the elucidation of Devonian stratigraphy, enabling many of the fish-bearing sediments to be more accurately dated than hitherto. Mainly because of fragmentary preservation, taxonomic studies are generally delayed.

It is now possible to divide the Australian late Devonian vertebrate faunas into two groups, an older marine (Frasnian) and a younger freshwater (Famennian) group, in south-eastern and central Australia. Apart from differences in age and ecology, the faunal composition in the two regions is also distinct. Investigations have so far failed to establish the presence of genera common to the eastern and western deposits. In the present context, the younger eastern Australian faunas are the more important and will be considered first.

Three of the four eastern States have yielded vertebrate fossils, Tasmania alone being without representatives of the subphylum. In Queensland (north and central) the record is scanty, but suggests a faunal composition distinct from that of the south-eastern part of the continent. In New South Wales, three main regions have yielded large collections. To the classical terrains in the central part of the State, themselves now known in greater detail, may now be added an important new discovery in the south-east. Knowledge of the faunas in the west has been greatly increased. In sequences in the eastern part of the State, marine inverterbrates below the fish-bearing beds provide invaluable stratigraphic control. The Victorian faunas are still the best known and include the only local taxa. No new discoveries have been recorded since 1958. All the deposits listed above are non-marine. No vertebrates are recorded from the marine late Devonian sediments of north-eastern New South Wales and eastern Queensland.

In Western Australia, nearly all the fishes are found in association with marine invertebrates. They occur in sedimentary sequences skirting the Kimberley Block, in the Bonaparte and Fitzroy Basins, as well as in the extreme west of the State, in the Carnarvon Basin. A new discovery in the Billiluna area in the eastern Canning Basin may represent a non-marine sequence. A single subsurface find in the northern part of the Northern Territory is conveniently included in the Western Australian discussion. No systematic description of Western Australian Devonian vertebrates has yet been published.

Eastern Australia

Queensland

Late Devonian vertebrate remains are rare. Apart from the occurrences in and near the Toomba Range discussed above, they are restricted to the Gilberton and Springsure areas. The Gilberton area [1] has yielded a single specimen of antiarchan trunk armour illustrated by Hills (1936) and later identified by him as *Asterolepis* (1958). It is associated with *Leptophloeum australe* (M'Coy) (White & Wyatt, 1960). The most recent estimate of the age of the deposit is Upper Devonian. In 1965, geologists of American Overseas Petroleum Ltd collected impressions of unidentifiable rhomboid scales in the Telemon Formation of the Springsure area [2]. Veevers et al. (1964, p. 11) state 'that at least part of the formation is Upper Devonian'.

New South Wales

Most of the Australian records of late Devonian fishes come from New South Wales; much of the material, however, is undescribed. The localities are conveniently grouped into three areas — south-east, central, and western.

In the south-east, the fishes are a new discovery by Johnson (1964 and pers. comm.). They occur in the Majors Creek area [14], south-south-west of Braidwood, in a non-marine sequence overlying marine sandstone containing brachiopods closely allied to those of the Lambian fauna of east-central New South Wales (below, p. 212). In a large collection, the discoverer (loc. cit.) has identified *Bothriolepis* and possibly *Remigolepis* and *Phyllolepis.*

The fish-bearing deposits in the central part of the State are best divided into an eastern and a western group. The east-central group is represented only at Mount Canoblas [13], on its western slope, south-west of Orange. Hills (1932) has illustrated a plate of *Bothriolepis* from this area. Stratigraphically the Mount Canoblas deposit is important because it is underlain by the Lambian brachiopod-bearing sediments; it is also of historical interest in containing the first late Devonian fish recorded in Australia (Süssmilch, 1907). The late Devonian sediments of west-central New South Wales are entirely non-marine, the fossils consisting exclusively of plants and fishes. Most of the latter are recorded from Herveys Range [12], north-north-east of Parkes, which has yielded the following forms: *?Striacanthus sicaeformis* Hills, *Bothriolepis, Phyllolepis, Dipterus,* and *?Holoptychius* (Hills, 1932, 1936, 1958). The formation in which most of the fish remains occur, the Caloma Sandstone, may reach a thickness of 1700 feet; 'fish-plate horizons occur at intervals throughout the succession' (Conolly, 1965b, p. 51). South of Herveys Range, in the Gooloogong area (not marked on map), well-preserved specimens of *Bothriolepis* have been recovered (Hills *in* Conolly, 1965b, p. 56). Hills (1932, 1958) has recorded fishes from two localities farther west, *Bothriolepis* at Jemalong Gap [11], west of Forbes, and *Phyllolepis* at Coradgery [10], north-west of Parkes. Conolly (loc. cit.) mentions the occurrence of fish plates at other localities in the west-central area, but does not identify the forms.

The late Devonian fishes of western New South Wales are assigned to a single body of rock, the Mulga Downs Formation (Mulholland, 1940), that occurs in scattered outcrops in a very large area east and west of the Darling River. The Formation rests unconformably on older Devonian marine sediments of the Amphitheatre Formation. The only fossils described from the Mulga Downs Formation have been collected in the Mount Jack area [4], north-north-east of Wilcannia, by Rade (1964), who has identified among them the acanthodian *Striacanthus* and the arthrodires *Groenlandaspis, Holonema,* and *Phyllolepis.* Fragmentary fish remains have been recovered from a number of localities east of the Darling River, including Bulgoo station [9], south-west of Cobar, and Wittagoona [7] and Mount Grenfell [8] stations, in the area of Dunlops Range. From these and other sites, the following forms have been identified by Dr Thor Ørvig *(in* Fletcher, 1964): undetermined antiarchs; *Phyllolepis* and other arthrodires. Some of the forms are believed to be new. Both Rade and Ørvig independently date the fossils examined by them as Famennian; Rade concludes that the sediments are river and lake deposits.

Vertebrate fossils have also been noted at three hitherto-unpublished localities. The first is on the slopes of Mount Deerina [6], south of Louth and on the same line of strike as Dunlops Range. Here, in 1963, Mr J. H. Hill of Electrolytic Zinc Co. of Australia collected a sample in which the author has identified fragmentary *Phyllolepis* plates and possible acanthodian spines. The other two localities were each collected by geologists of American Overseas Petroleum Ltd. At Jacks Lookout [5], about 80 miles east-south-east of Menindee, an acanthodian spine resembling *Striacanthus* is preserved; fossils in the Mootwingee area [3] have been examined by Mr. H. O. Fletcher of the Australian Museum, who considers them to be comparable with those of the Mulga Downs Formation.

Victoria

The late Devonian fish faunas of Victoria have been studied in more detail than those from other parts of Australia (Hills, 1929, 1931, 1936, 1958) and are the only ones for which new taxa have been erected. As in western and west-central New South Wales, no marine sediments are known. The following forms are recorded:

Blue Hills, Taggerty, [15] — *Bothriolepis gippslandiensis* Hills, *?Remigolepis, Phyllolepis, Dipterus microsoma* (Hills);

Mansfield [16] — *Bothriolepis, Phyllolepis;*

Freestone Creek, north of Briagolong [17] — *B. gippslandiensis, Striacanthus sicaeformis* Hills.

Western Australia

The late Devonian vertebrate-bearing beds of Western Australia are confined to the northern and western parts of the State. Those in the north are mainly found in the sedimentary basins on the periphery of the Kimberley Block — the Bonaparte Basin to the north-east and the Fitzroy Basin in the south and south-west. The only northern occurrence outside these areas lies far to the east, at the eastern end of the Canning Basin, near the boundary with the Northern Territory. In the western part of the State, vertebrates have been noted in the Carnarvon Basin.

Although the first record of Devonian vertebrates postdates its eastern counterpart by only three years, no systematic studies of the faunas have yet been published. A brief summary has been presented by Hills (1958), who notes that the faunas appear to differ from those of eastern Australia. More recently, a preliminary announcement of important discoveries in the Fitzroy Basin has been made (Toombs *in* Rolfe, 1966). On the other hand, the sedimentary sequences and their contained invertebrates have been studied in such detail that, although the lists of vertebrates are sketchy, the fossils themselves can generally be securely dated.

Most of the finds and all the published references are from the Fitzroy Basin, including the first record from the State, a coccostean from Barker

Gorge [18] in the Napier Range (H. Woodward *in* Glauert, 1910). The most fruitful area for vertebrates is south-east of the Napier Ranges in the vicinity of the Emanuel Range and Bugle Gap [19]. Here, Teichert (1949) recovered fragments subsequently identified by Hills (1958) as a dipnoan from the *Manticoceras* zone (Frasnian) and a dinichthid from the *Cheiloceras* zone (Famennian). The sediments in which they occur are now assigned to the Virgin Hills Formation (Guppy et al., 1958; Veevers & Wells, 1961). Fossils recovered from the area of Virgin Bore, Gogo station, about 8 miles north-west of Bugle Gap, include antiarchs and arthrodires, palaeoniscids and rhipidistians (Toombs *in* Rolfe, loc. cit.). They were collected in the Gogo Formation, and the associated invertebrates date them as early Frasnian.

References to vertebrates from the Carnarvon, Canning, and Bonaparte Basins have not hitherto been published. In the Carnarvon Basin, Dr G. Seddon, University of Western Australia (pers. comm.), has found dipnoan palatal plates and ganoid scales in the marine Gneudna Formation, essentially Frasnian, but probably Givetian (late Middle Devonian) in its lower levels. In the Billiluna area [20] in the eastern part of the Canning Basin, Drs J. J. Veevers and J. Roberts of the Bureau of Mineral Resources in 1966 collected arthrodiran plates associated with *Leptophloeum australe* in the Knobby Hills Sandstone. Unlike other Western Australian vertebrates, these are not associated with marine fossils. The fishes in the Bonaparte Basin occur in the Cockatoo Formation (Matheson & Teichert, 1948), in the Hargreaves Hills [21], 10 miles west of Ninbing. The fossils were collected in 1965 by geologists of the Bureau of Mineral Resources. Unidentifiable fish remains had previously been noted in outcrops of extremely friable sandstone in the same area by Dr A. A. Öpik (*in* Traves, 1955) but could not be collected. The present collections include fragmentary plates of antiarch armour, *?Bothriolepis* (sample 431/10), from a sequence that has yielded Frasnian conodonts at a lower level (Jones & Druce, 1966). The Cockatoo Formation is also identified in Western Oil and Oil Development N.L.'s Spirit Hill No. 1 Well [22], in the Northern Territory, about 62 miles east of Wyndham. It has yielded a scale of cosmoid structure at a depth of 2564 feet (Thomas, 1963).

SUMMARY OF AUSTRALIAN LATE DEVONIAN FISH FAUNAS

Composition of faunas

Of the four classes of Palaeozoic fishes, one, the Chondrichthyes, has not been noted in Australian Devonian rocks. Ichthyodorulites are, however, recorded in Lower Carboniferous sediments of western Victoria (Chapman, 1917), and teeth and spines of sharks are present in Western Australia (Thomas, 1959; author, unpubl.) and New South Wales (Benson, 1921), also in Lower Carboniferous rocks.

As observed by Hills (1958), the armoured fishes (class Placodermi) dominate the faunas, both antiarchs and arthrodires being present. *Bothriolepis* is the most widespread of the antiarchs; it occurs in central and south-eastern New South Wales, Victoria, and the southern part of the Northern Territory, and may also be present in north-western Australia. It has not been noted, however, in western New South Wales nor in any of the Queensland deposits, including those of the Toko Syncline on the Northern Territory border. North Queensland has preserved a record of *Asterolepis* unique in Australia. *Remigolepis* is restricted to the south-east — Victoria and central and south-eastern New South Wales. Fragmentary preservation hinders identification of many of the arthrodires; *Phyllolepis* with its characteristic ornament is an exception. It is restricted to the south-east (Victoria and New South Wales) and the south-eastern part of the Northern Territory and adjoining parts of Queensland (Text-fig. 7). The only other genera recorded are *Groenlandaspis* and *Holonema* in western New South Wales and a *Dinichthys*-like form in Western Australia. Well-preserved arthrodires are known in the marine older Devonian limestones of New South Wales and Victoria (White, 1952). The placoderms do not survive into Carboniferous time.

The acanthodians (class Acanthodii) are restricted to New South Wales and Victoria. In New South Wales they are represented by finely-ribbed spines resembling those of the indigenous Victorian genus and species *Striacanthus sicaeformis* Hills. The earliest known representatives of the class in Australia have been found in Lower Devonian marine sediments about 14 miles south of Canberra (author, unpubl.). Acanthodians are also present in freshwater Lower Carboniferous deposits in Queensland and Victoria (Hills, 1958).

Until recently, it was believed that the bony fishes (class Osteichthyes) were represented in late Devonian Australian sediments solely by the dipnoans, known chiefly from palatal plates preserved in south-eastern and western Australia in both non-marine and marine sediments. Australia has preserved the longest known record of the group, starting in the older marine Devonian (late Lower or early Middle) of south-eastern Australia and persisting until the present time in some Queensland rivers. The other two groups of bony fishes are now known to be present but are rare. Crossopterygians are recorded in New South Wales (Hills, 1958) and Western Australia (Toombs, *in* Rolfe, 1966). Actinopterygians are apparently confined to the marine limestones of Western Australia (Toombs, loc. cit.). Representatives of both groups are found in the non-marine Lower Carboniferous sediments of Victoria (Woodward, 1906), and palaeoniscids are recorded in the Lower Carboniferous of Queensland (Hills, 1958).

Age of faunas

The reason for the investigation of the late Devonian fish-faunas outside the central Australian area is the need to date the Dare Plain *Bothriolepis,* unique in the south-western part of the Northern Territory, as narrowly as possible.

The genus has a very long span in the Northern Hemisphere, from late Middle Devonian time to near the end of the Period. The Dare Plain form cannot be dated on internal evidence, because most of the other Australian species have not been studied in detail, and no chronological scale exists. Nor is its age controlled by associated fossils. The alternative is to try to determine, from evidence in better-documented sections, the time of first appearance of the genus in Australia.

The bulk of the evidence comes from New South Wales, and is provided by superposition of the *Bothriolepis*-bearing sediments above a datable assemblage of marine invertebrates. The relationship was first noted in east-central New South Wales by Süssmilch (1907), and has been confirmed by Johnson's (1964) stratigraphic studies in the Braidwood area of south-eastern New South Wales. The invertebrates, listed by Benson (1922), are conveniently referred to as the 'Lambian fauna'. A recent revision of one of the commonest brachiopods (Mackay, 1964) confirms its earlier identification with the North American Chemung species *Cyrtospirifer disjunctus* (J. de C. Sowerby). Correlation with the standard European scale would fix it in late Frasnian or early Famennian time. At a conservative estimate, placing the brachiopod as low in the scale as possible, and assuming an almost negligible hiatus between the cessation of marine and the initiation of non-marine sedimentation, a very late Frasnian age is indicated as the earliest possible date for the base of the *Bothriolepis* sequence in those areas where it is underlain by sediments containing the Lambian fauna. That the top of the sequence may extend well into Famennian is indisputable. In parts of the south-eastern Australian area to which the Lambian inundation did not penetrate, the lack of detailed systematic study prevents a strict correlation, at the specific level, with the post-Lambian faunas, although the generic composition suggests contemporaneity of deposition. In any case, all the late Devonian sequences display the same unconformable relationship to the underlying rocks, suggesting that the *Bothriolepis* assemblage is no older than the Lambian fauna. Obviously, it may well be younger, but speculations are unprofitable at this stage.

The evidence from north-western Australia, although not conclusive because of uncertainties in identifying the placoderm and in dating the horizon, tends to support that from the south-east. The plates certainly belong to a *Bothriolepis*-like antiarch, and the control provided by conodonts in an earlier part of the sequence proves them to have, at the oldest, an advanced Frasnian age. There is thus no evidence of any *Bothriolepis* in Australia in rocks older than late Frasnian, and, as it seems probable that representatives of the genus reached Australia by marine routes, the specimens in the central Australian area would be no older than those on the coastal fringes.

Investigations on the range of *Bothriolepis* in Australia carry a bonus in clarifying the local time-span of *Phyllolepis,* which, unlike *Bothriolepis,* shows no appreciable sign of a comparatively late appearance in Australia. This result may be exploited with confidence in local stratigraphy. The stratigraphic level of *Remigolepis* in south-eastern Australia needs careful checking. If it occurs at the base of the succession, and if that base is as old as late Frasnian, an interesting conclusion results — the genus appears earlier in south-eastern Australia than in the type area of east Greenland. Finally, the faunal difference noted by Hills (1958) between the fishes of eastern and north-western Australia seems to be accounted for, at least in part, by stratigraphical control; most of the Western Australian forms are older than those in the east.

A possible Carboniferous age for the latest Australian placoderms can be eliminated by negative evidence only. It seems that, as in other parts of the world, the placoderms disappeared about the end of the Devonian Period and were replaced by representatives of other groups of fishes. In the marine sequences of Western Australia, for example, the early Carboniferous rocks contain the remains of sharks but no placoderms. In the non-marine areas of the east, evidence for superimposed Carboniferous sediments above the late Devonian fish-bearing beds is scanty. The best-known occurrence is in the Mansfield area of Victoria, which has yielded distinct late Devonian and early Carboniferous fish-faunas that display no evidence of mingling.

Ecology

Habitat of early fishes

The problem of the ecology of the early fishes, particularly the salinity of the water in which they lived, has aroused the interest of many workers, and no general agreement has yet been reached. Exponents of the two rival theories, fresh water and salt water, have sought support for their views in such diverse fields of enquiry as, for example, the physiology of modern fishes and the origin of the continents. The problem began with investigations in both the biological and geological fields. Studies on the kidney of modern fishes suggested a descent from freshwater ancestors, and the discovery of large numbers of vertebrate fossils in the non-marine Old Red Sandstone gave the impression that the animals in life favoured a freshwater environment. Later discoveries of similar fossils in an undoubted marine association could always be explained away by advocates of the freshwater hypothesis as examples of river or lake-dwellers washed into the sea after death.

The widening of geological investigations to cover increasingly large areas of the earth's surface has, however, brought to light evidence that casts considerable doubt on an exclusively freshwater habitat, at least for some of the fishes. *Bothriolepis*, for example, has an enormous geographical distribution from Greenland and Novaya Zemlya in the north to Antarctica in the south, and covering every continent except South America. In order to explain this dispersal, assuming a common origin for all the species, believers in the non-marine theory must invoke the theory of continental drift as well as persistent river-capture. Below are listed some alternative ideas:

1. The fishes may have been able to adapt themselves to a wide range of salinity, as do some modern fishes of the two surviving classes.

2. The presence of their remains in non-marine sediments may indicate not that the animals lived in the waters in which the sediments were deposited, but that they *died* there, having swum or been washed from the sea into an inimical environment, to which they succumbed.

3. Explanation 2 is not applicable to occurrences far from the sea, as, for example, the central Australian area, which in late Devonian time, as at present, must have been some hundreds of miles inland. It is not impossible, however, that, like some modern fishes and one of the cyclostomes, the late Devonian placoderms were anadromous, spending most of their lives at sea and at maturing entering fresh waters, where they spawned and died.

Australian late Devonian palaeogeography

The Devonian palaeogeography of Australia is discussed by contributors to the International Devonian Symposium (1967). This section sets on record some points relevant to, or arising from, the present investigation. From the remarks in the preceding section it will be evident that the fishes are not to be regarded as ecological documents; conclusions on the distribution of land and sea are reached from the evidence of other fossils, or the lack of them. Also, it should be noted that the locality map (Text-fig. 1) is intended solely to illustrate the known occurrences of the late Devonian fishes and is in no sense a palaeogeographic map; areas of late Devonian marine sedimentation in eastern Queensland and north-eastern New South Wales, for example, have been ignored as they have yielded no vertebrate fossils. The map does, however, give some idea of the extent of the land surface built up in eastern and central Australia by late Devonian time, in contrast to the wide distribution of marine sediments in the early part of the Period (proved in eastern Australia; suspected in central Australia). The newly-formed continent was occupied by chains of lakes communicating by rivers with the coast. Detailed studies on the late Devonian palaeogeography and the fluviatile and lacustrine sediments of west-central New South Wales have been published by Conolly (1963; 1965a, 1965b) and by Wolf & Conolly (1965).

The similarity of the fish-faunas of the south-eastern part of the Northern Territory to those of south-eastern Australia and the restriction of *Phyllolepis* to these two areas (Text-fig. 7) prompt the suggestion that the rivers were part of a system draining toward the sea in the south-east. Whether the lakes in the south-western part of the Territory were also connected with the south-east flowing rivers cannot be conclusively proved, owing to scarcity of fossils, but the morphology of the Dare Plain *Bothriolepis* suggests the possibility.

The provincial relationships of the late Devonian invertebrates underlines some fundamental differences between eastern and western Australia. Most workers on the west Australian marine fossils agree on the European aspect of the faunas, whereas the brief Lambian transgression of the east, which now appears to have affected part of north-eastern Queensland as well as eastern and south-eastern New South Wales, brought with it animals of North American relationship. The relationship seems to be reflected also in some of the vertebrates of south-eastern and central Australia. In this case, of course, the resemblance is to the extremely well known faunas of east Greenland. It was noted by Hills as long ago as 1932, and later studies reinforce his observations. The Greenland placoderm genera *Groenlandaspis* and *Remigolepis* are both recorded in south-eastern Australia, and the Dare Plain *Bothriolepis,* though specifically distinct, shows points of resemblance with *B. groenlandica* Heintz.

Finally, the apparent absence of the lycopod *Leptophloeum australe* from central Australia must be noted. Remains of the plant are widespread in eastern and western Australia, in both marine and non-marine sediments. As the branches were probably not very buoyant, their occurrence in marine rocks is taken to indicate proximity to the shore. The non-marine late Devonian sediments of central Australia, however, have yielded one impression of bark doubtfully assigned to *Protolepidodendron,* but not a single fragment of *Leptophloeum.* It is generally a conspicuous fossil and would not be overlooked, particularly as the rocks now proved to be late Devonian by their fish content have been combed by many geologists for fossil evidence that would indicate the age of these troublesome sandstones. The distribution of the plant now suggests that it was probably an inhabitant of low-lying areas, generally near the coast, and if, as seems likely, the central Australian fish-bearing beds were deposited in upland lakes, the spread of *Leptophloeum* to these areas may have been inhibited by climatic factors such as low humidity and wide fluctuations in temperature.

DESCRIPTION OF FOSSILS

All the fossils are deposited in the Commonwealth Palaeontological Collection, held at the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T.

Class PLACODERMI

Subclass ANTIARCHI

Genus BOTHRIOLEPIS Eichwald, 1840

BOTHRIOLEPIS sp.

(Pl. 15, figs 1, 3-6; Text-fig. 8)

Material: Two fragmentary plates of the trunk armour, a left and a right anterior dorsolateral plate. The fossils are preserved as external moulds in sandstone; no bone is preserved.

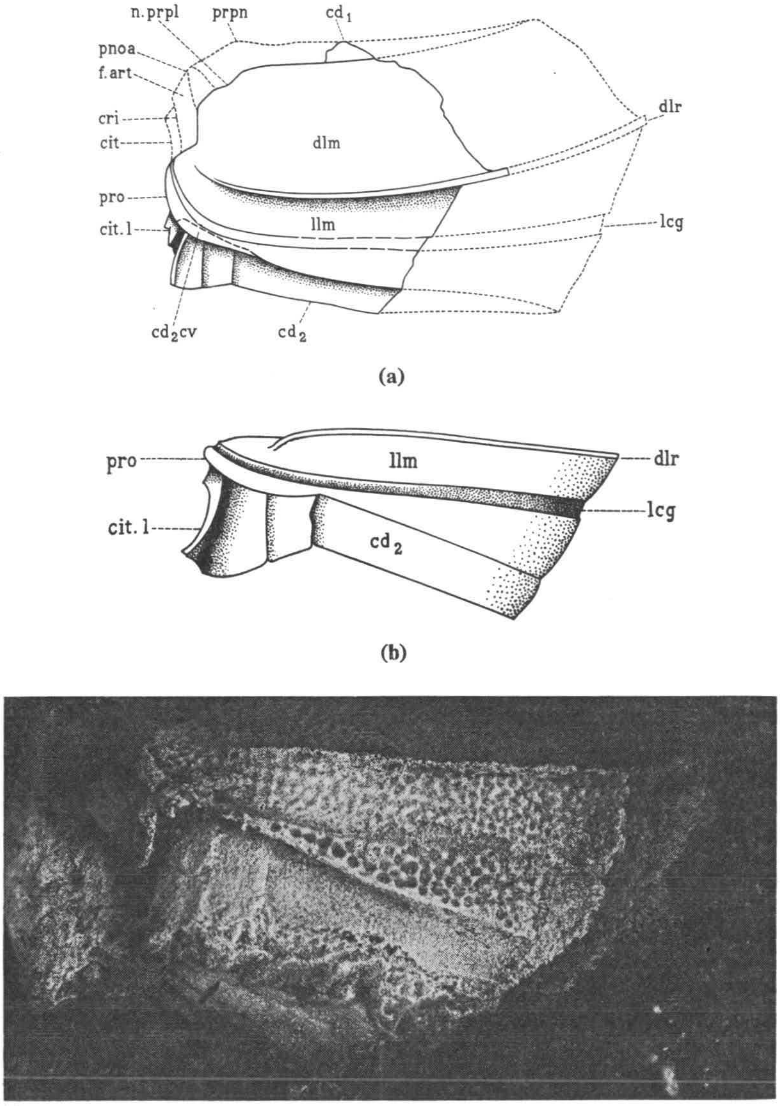

Fig. 8. *Bothriolepis* **sp., left anterior dorsolateral plate: (a) dorsolateral view; (b) and (c) ventrolateral view, x 1.5**

cd_1, area overlapped by anterior median dorsal plate; *cd_2*, area overlapped by anterior ventrolateral plate; *cd_2cv*, part of lateral lamina both overlapped by and overlapping anterior ventrolateral plate; *cit*, vertical part of crista transversalis interna anterior, forming an anterior transverse lamina; *cit.l*, lateral (free) extension (anterior lamella) of crista transversalis interna anterior; *cri*, infra-articular crest; *dlm*, dorsal lamina; *dlr*, dorsolateral ridge; *f.art*, articular fossa; *lcg*, main lateral line groove; *llm*, lateral lamina; *n.prpl*, notch in dorsal margin of ornamented area for external postlevator process of anterior median dorsal plate; *pnoa*, postnuchal ornamented corner; *pro*, processus obstans; *pr.pn*, internal postlevator process.

Collections: The left anterior dorsolateral plate (CPC6922) was collected in 1963 by R. M. Hopkins of Magellan Petroleum Corporation. The right anterior dorsolateral (CPC6923) was collected in 1964 by W. H. Morton and I. P. Youles, then Resident Geologists at Alice Springs in the Northern Territory.

Locality: The specimens were collected at the same locality (NT 608, 611) on Dare Plain, about 140 miles west-south-west of Alice Springs, on the north-eastern limb of the Mereenie Anticline, near its south-eastern closure.

Formation: A sandstone lens in the basal unit (siltstone) of the Pertnjara Formation; 600-700 feet above the local base of the formation.

Age: Upper Devonian.

Observations: The two plates represent the remains of different individuals. Preservation is inadequate to determine whether they are conspecific, but they show some common features. Resemblance is also evident between the specimens from Dare Plain and the *Bothriolepis* illustrated by Hills (1959, pl. 8, fig. B) from the Dulcie Range, Northern Territory, and a relationship, not necessarily specific, to the Victorian *B. gippslandiensis* Hills seems to be present.

Terminology: The terminology of Stensiö (1948) is used in the following description; the classification is that of Obruchev (1964).

Description of individual plates

Left anterior dorsolateral plate (CPC6922; Pl. 15, fig. 1, 3-5; Text-fig. 8)

Preservation: This is the most complete *Bothriolepis* plate so far recorded from the Northern Territory, and may have been perfect when embedded. It is preserved as an external mould in a flute cast in fine-grained silty sandstone, stained reddish brown and black on the weathered surface, but yellowish when fresh. In general, the parts that have been developed from the matrix are fairly well preserved; those that have been exposed to weathering are damaged. Also, some unavoidable damage has been caused in preparation of the fossils to reveal critical structures at the front of the plate.

The greatest deficiency is at the rear of the plate, where a portion of both dorsal and lateral laminae is missing. The preserved anterior part of the lateral lamina is complete except for a negligible patch near the front of the ornamented part, just above the main lateral line. In the same part of the lamina, the junction of the exposed and overlapped parts has not been completely developed, as this would destroy the evidence of the slight underlap of the adjacent anterior ventrolateral plate. Most of the anterior articulatory part of the plate is lost. The articular fossa for the paranuchal trochlea of the head-shield is not preserved, and part of the crista transversalis interna anterior has been deliberately removed in order to expose the processus obstans and the anterior course of the main lateral line. On the dorsomedial margin of the plate (dorsal lamina), the postnuchal ornamented corner and most of the part overlapped by the anterior median dorsal plate, including the internal postlevator process, are lost. The dorsolateral ridge and the surface sculpture are well preserved and show no obvious sign of abrasion.

Description. The *dorsolateral ridge* separating the dorsal and lateral laminae is a sharply defined keel, more strongly accentuated at the rear of the fragment than at its front.

The preserved part of the *dorsal lamina* lacks a number of important structures, and neither its proportions nor the position of the widest measurement can be estimated. A residue of the area overlapped by the anterior median dorsal plate is preserved at the rear of the fragment. The anterior boundary of the notch for the reception of the external postlevator process is missing, but, as far as can be judged from the part that remains, the notch is rather shallow. Behind it, the dorsal edge of the ornamented part of the lamina runs back to the rear of the fragment as an almost straight line. Some idea of the outline of the rear margin of the lamina can be gained from the pattern of the ornamental meshwork, which suggests that the margin should have a slightly sigmoid curvature — convex medially, concave laterally. The outer edge of the lamina, against the dorsolateral ridge, has a gentle outward curvature along its entire length. The sculpture of the lamina is rather delicate and consists of a nodose reticulation near the dorsomedial and preserved rear margins of the fragment. Nearer the dorsolateral ridge, the pustules are more closely crowded and the reticulation is less evident.

The ornamented (exposed) part of the *lateral lamina* bears a reticulate sculpture similar to that of the dorsal lamina. The meshes are noticeably coarser in the area below the lateral line than above it (Text-fig. 8c). The processus obstans appears to be nearly smooth. Its outer edge is very gently convex. The part overlapped by the anterior ventrolateral plate (Text-fig. 8b,c) is preserved along the length of the fragment. At the rear, its ventral edge is nearly concentric with the ventral edge of the ornamented part of the lamina, both having a slightly convex downward curvature. Near the front of the lamina, the overlapped part reaches its greatest height, the result of a rather abrupt downward slope in the ventral margin. In this area it is marked by two parallel rounded vertical crests separated by narrow furrows. In front of these crests the overlapped part of the lamina bends around toward the midline of the trunk. Here the crista transversalis interna anterior is split laterally into two vertical lamellae, anterior and posterior, meeting at an acute angle. The anterior lamella is free-standing, supports the processus obstans, and is gently curved with the concavity directed forwards; the posterior lamella is the anterior medial extension of the overlapped part of the lateral lamina itself. Thus the anterior ventrolateral plate is securely wedged to its dorsal neighbour at two places and in two planes — at the front of the trunk (transverse plane) between the anterior and posterior lamellae of the crista transversalis interna anterior, and at the side (exsagittal plane) between the lateral and medial lamellae of the lateral lamina.

At the rear of the lateral lamina, the *main lateral line* is broad, shallow, and rather ill defined. It becomes narrower and more clearly accentuated at the front of the fragment. Over the greater part of its preserved length it runs nearly parallel to the dorsolateral ridge. It is set rather low on the ornamented part of the lamina and, behind the processus obstans, closely approaches the junction of the ornamented and overlapped parts of the lamina before bending upwards and crossing the processus obstans to reach the anterior edge of the plate in front of the anterior end of the dorsolateral ridge (Pl. 15, fig. 1).

Measurements. Maximum preserved length — 40 mm. Maximum preserved width of dorsal lamina (ornamented part) — 20 mm. Maximum preserved height of lateral lamina (including overlapped part) — 17 mm. Angle between dorsal and lateral laminae (rear of fragment) — c. 125°.

Right anterior dorsolateral plate (CPC6923; Pl. 15, fig. 6).

Preservation. The fossil is preserved as a very fragmentary external mould in a flute cast in sandstone similar to that which contains the left anterior dorsolateral plate described above. It is much more fragmentary, however, than the left-hand plate. Except for part of the overlap area on the lower edge of the lateral lamina, none of the margin is preserved. Details of the surfaces of both laminae are obscure, because of weathering. The course of the main lateral line cannot be satisfactorily plotted.

Description. The dorsal lamina, as preserved, is long and narrow. Its outer edge, against the dorsolateral ridge, is gently convex. The ornament is a delicate nodose network with a marked longitudinal arrangement of the meshes. The dorsolateral ridge is distinctly marked off from the lateral and dorsal laminae. The pattern of the netting on the lateral lamina is similar to that on the left anterior dorsolateral plate described above.

Measurements. Maximum preserved length — 47 mm. Maximum preserved width of dorsal lamina — 14 mm. Maximum preserved height of lateral lamina (including preserved overlapped part) — 15 mm. Angle between dorsal and lateral laminae — c. 125°.

Comparisons

The two anterior dorsolateral plates seem to belong to different individuals, but imperfections in preservation at critical points of both plates hinder specific comparison. In particular, the right-hand plate is deficient in just those areas that contain the chief peculiarities displayed by the better-preserved left-hand plate — the curious sutural connexion with the (missing) anterior ventrolateral plate and the unusually low-set and indistinct main lateral line. As far as the two specimens are comparable they show some points of resemblance: the ornament (especially on the lateral lamina), the definition of the dorsolateral ridge, and the angle between the dorsal and lateral laminae.

On the other hand, the sculpture on the dorsal lamina of the right-hand plate shows more reticulation and less tuberculation, and the outward bulge of the lateral edge of the dorsal lamina of the right-hand plate is less marked than that of the left. These differences are probably not specific but are to be attributed to individual variability. Because of the imperfections of both plates, the apparent differences in proportion are not significant. There is thus at present no evidence to show that the two plates are not conspecific. The right-hand plate, showing a greater proportion of reticulation to tuberculation on the dorsal lamina, may belong to a smaller, and younger, individual, although its preserved length is greater. This conclusion has been taken into consideration in reconstructing the left-hand plate (Text-fig. 8a).

Comparison with other species is inconclusive. The anterior dorsolateral plate illustrated by Hills (1959, pl. 8, fig. B) from the Dulcie Range has a similar sculpture and a well-defined dorsolateral ridge. Its lateral line is much more sharply incised, but this may be explained by the fact that the small plate probably belongs to a youthful individual. No comparison is possible with the fragmentary material so far published from New South Wales, and resemblances must be sought among extra-Australian species and the best-known Australian form, *B. gippslandiensis* Hills from Victoria. The vaulted trunk armour of the Dare Plain material, with the dorsal and lateral laminae meeting at an obtuse angle, recalls *B. gippslandiensis* as well as the British *B. obesa* Traquair and the Asian *B. turanica* Obruchev. A further similarity to *B. turanica* (of Frasnian age and known only from a mixilateral plate) is the delicate mesh-like ornament with tubercular thickenings at the points of anastomosis of the ridges. The ornament of the dorsal lamina of the left anterior dorsolateral plate from Dare Plain shows an even stronger resemblance to that of the anterior ventrolateral plate of *gippslandiensis* (Hills, 1931, pl. 11, fig. 1), where tuberculate sculpture on the older part of the plate gives way to reticulation in the younger part.

The splitting of the lateral lamina into a lateral and a medial lamella for the reception of the anterior ventrolateral plate recalls *B. groenlandica* Heintz (Stensiö, 1948, text-fig. 288), although the length of the split is considerably less in the Dare Plain specimen. The bluntly rounded processus obstans of the Dare Plain form distinguishes it from *groenlandica,* in which the process is drawn out into a point. The unusual height of the overlapped part at the front of the lateral lamina of the Dare Plain specimen recalls that at the rear of the mixilateral plate of *groenlandica* (Stensiö, 1948, text-fig. 289), but the anterior course of the main lateral line leaves no doubt that we are dealing with an anterior and not a posterior plate.

The presence of a free outer edge (anterior lamella) to the crista transversalis interna anterior, behind which the anterior edge of the anterior ventrolateral plate is wedged, has not been illustrated in other *Bothriolepis* species. Hills (1931, p. 221), discussing the anterior dorsolateral plate of *B. gippslandiensis,* observes that 'At the anterior end a lamina of bone projects forwards and downwards parallel to the front edge', but whether this structure is comparable to that noted in the Dare Plain material or merely refers to the crista transversalis interna anterior in its normal development is not evident. It seems significant, however, that in *B. gippslandiensis* the anterior median dorsal plate (Hills, 1931, text-fig. 7) displays an unpaired transverse internal lamella (the horizontal lamina of Hills) sloping forward and slightly downward from its origin just in front of the anterior ventral pit. As observed by Stensiö (1948, pp. 112, 520), who terms it the floor to the levator fossa, the horizontal lamina is to be interpreted as the dorsal development of the crista transversalis interna anterior. The condition observed in *B. gippslandiensis,* of a single undivided lamella anterior to the anterior ventral pit, is almost unique, being known otherwise only in *B. canadensis* (Whiteaves), and then occurring fortuitously. Generally the dorsal part of the crista transversalis interna anterior (the postlevator crista), where present, takes the form of a pair of lamellae, right and left, separated by, and running forward from, the anterior ventral process, which encloses the anterior ventral pit itself. Thus in the two Australian forms in which it can be studied in detail the crista transversalis interna anterior shows peculiarities that may point to the existence of a local group of related species.

The evidence is not in itself sufficient to indicate that the central Australian and Victorian forms are conspecific. The proportions of the central Australian plates suggest that the trunk may be relatively longer than that of *gippslandiensis,* which is also distinguished by a median dorsal crest on the trunk and the unusual shape and relations of the postpineal and centronuchal plates of the head. As none of these plates is represented in the central Australian collections no comparisons on these critical points can be drawn.

The question of the generic assignment of the central Australian specimens cannot at present be satisfactorily resolved. Of the better-known related genera, *Grossilepis* with its essentially tubercular ornament can be eliminated, as can *Remigolepis* in which (a) the anterior median dorsal plate narrows to a sharp point in front and (b) the overlap of the anterior ventrolateral plate on to the anterior dorsolateral is limited to a small area at the front of the plate. *Bothriolepis* with its predominantly reticulate ornament and essentially similar structure is the nearest described genus. The practice of assigning imperfectly-preserved material to established genera entails a danger of enlarging their concept beyond desirable limits. In the present case this seems a lesser evil than erecting new taxa on material that does not permit an adequate diagnosis.

Placodermi incertae sedis

Genus indet.

(Pl. 15, fig. 2)

Material. A fragmentary plate of placoderm armour (CPC6924), preserved in yellowish laminated silty sandstone, was collected in 1964 by W. H. Morton and I. P. Youles at the same locality (Dare Plain) and stratigraphic level as the specimens of *Bothriolepis* described above.

Description. The specimen preserves part of the ornamented and overlapped parts of an unidentified plate, probably of trunk armour. The ornament consists of short vermicular ridges, partly anastomosing, partly discrete. The junction of the ornamented and overlapped parts of the plate is gently sigmoid. The illustration suggests that an area of overlap is also preserved on the lower left-hand side of the plate (as figured). This is not the case: the fossil here grades imperceptibly into a bedding-plane.

Comparison. The plate may represent an unknown species of *Bothriolepis.* Somewhat similar ornament is preserved in a specimen from Jemalong Gap, N.S.W. (Hills, 1932, pl. 56, fig. 7), identified as *Bothriolepis?* On the other hand, assignment to the arthrodires is not impossible.

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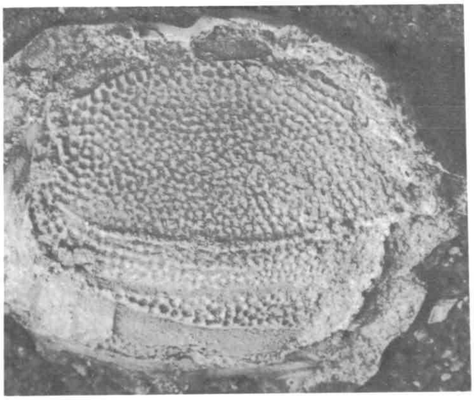
PLATE 15

The fossils were collected at the same locality and stratigraphic level on Dare Plain, 140 miles west-south-west of Alice Springs, Northern Territory, and 600-700 feet above the local base of the Pertnjara Formation. The photographs were taken by R. Miniotas from latex casts of the original sandstone moulds.

Figures 1, 3-5. — *Bothriolepis* sp. Left anterior dorsolateral plate (CPC6922). Fig. 1 x 1.35; fig. 3 x2; figs 4, 5 x1. The photographs have been taken in different orientations to display the characters of the fossil; figure 5 is a dorsolateral view and figure 4 a lateral view; figures 1 and 3 represent an intermediate position. For the anterior course of the main lateral line see Text-figure 8c.

Figure 2. — Placoderm of uncertain affinity (*?Bothriolepis*). Undetermined plate (CPC6924), x 1.7.

Figure 6. — *Bothriolepis* sp. Right anterior dorsolateral plate (CPC6923), x 1.75.



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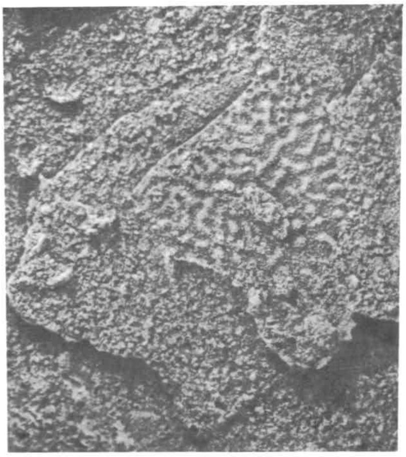

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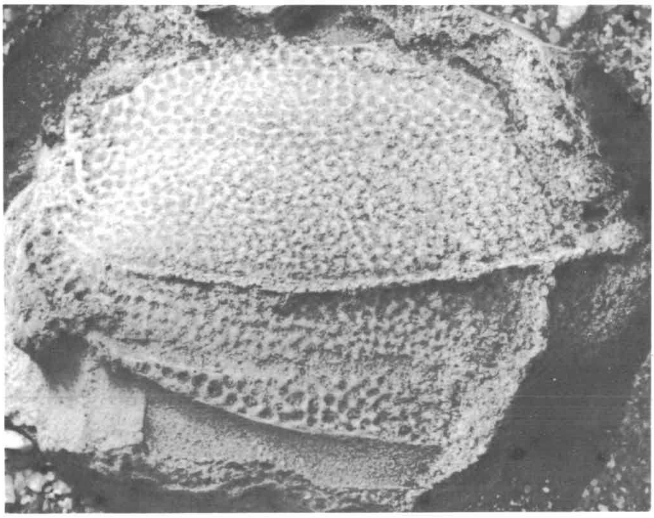

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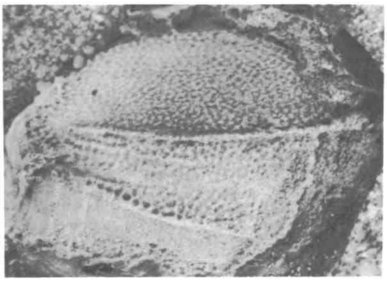

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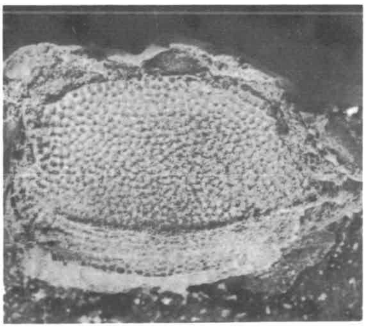

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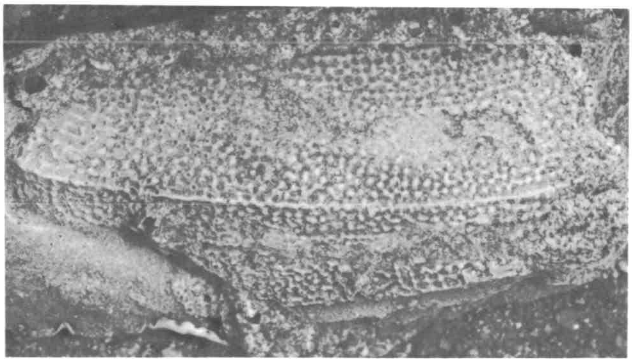

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Bothriolepis