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FORAMINIFERA FROM THE ILAGA VALLEY, NASSAU RANGE, IRIAN JAYA

by

D. J. Belford

SUMMARY

The foraminifera described in this paper were obtained from samples collected by D. B. Dow in 1961, during an attempt to climb Carstensz Pyramid in Irian Jaya. Samples from a limestone sequence named by Dow the Carstensz Limestone are late Eocene, late Oligocene, and early to middle Miocene in age. A planktonic foraminiferal fauna regarded as late Oligocene (lower zone N.3) in age was obtained from samples from a sequence of marls and calcareous siltstones named by Dow the Meleri Beds.

The planktonic foraminifera include *Globigerinoides quadrilobatus primordius* Blow & Banner, *Globigerina tripartita* Koch, *G. sellii* Borsetti, *G. gortanii gortanii* Borsetti, *Globorotalia (Turborotalia) kugleri* Bolli, and *G. (T.) opima nana* Bolli, an association which suggests a lower zone N.3 age. The fauna is of interest in connexion with the position of the Oligocene/Miocene boundary and with the first appearance of the subspecies *Globigerinoides quadrilobatus primordius;* both at present are placed at the base of zone N.4—the '*Globigerinoides*-datum'. Many published papers indicate that *Globigerinoides quadrilobatus primordius* first appeared before the base of zone N.4; it seems that the concept of the '*Globigerinoides*-datum' should be re-examined, and that the Oligocene/Miocene boundary should be lowered, perhaps to a level near the zone N.2/zone N.3 boundary, or to some other acceptable level.

INTRODUCTION

The foraminifera described in this paper have been obtained from samples collected by D. B. Dow in 1961, during an attempt by the New Zealand New Guinea Expedition to climb Carstensz Pyramid in Irian Jaya (then Netherlands New Guinea). Dow (1968) gave the results of a geological reconnaissance carried out in conjunction with the climbing attempt, and included the results of palaeontological examination of the samples by Crespin (1961). The samples are mainly from a limestone sequence (Fig. 1), named by Dow the Carstensz Limestone, containing abundant larger foraminifera and algae; three samples from a sequence of marls and calcareous siltstones named by Dow the Meleri Beds yielded abundant planktonic foraminifera. The planktonic fauna is of some interest not only in indicating an age for the Meleri Beds, but also in connexion with the problem of the Oligocene/Miocene boundary; these points are discussed later.

The figured specimens are deposited in the Commonwealth Palaeontological Collection, Canberra, Australia, under numbers CPC 13528 to CPC 13592.

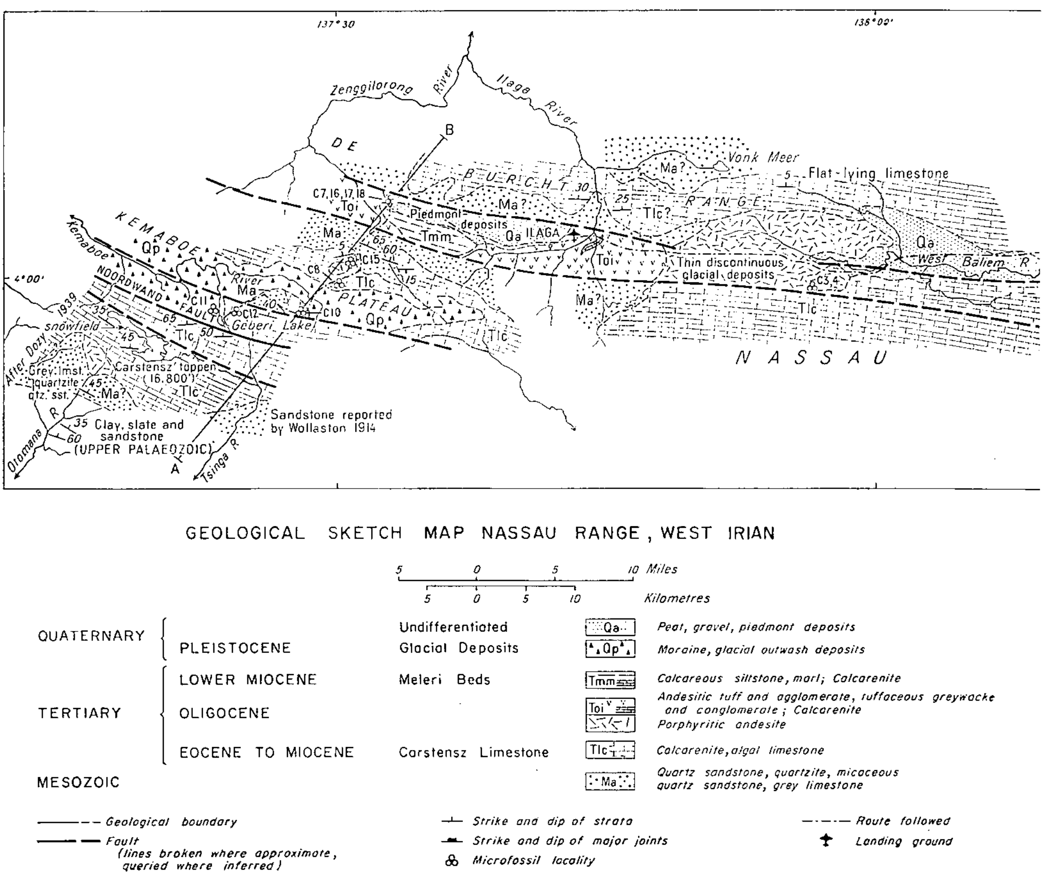

Fig. 1. Geological sketch map showing samples localities (after Dow, 1968).

ACKNOWLEDGMENTS

I wish to thank Mr D. B. Dow, Bureau of Mineral Resources, Dr D. Graham Jenkins, Department of Geology, University of Canterbury, and Mr J. M. Lindsay, Geological Survey of South Australia, for critically reading the manuscript and making valuable comments.

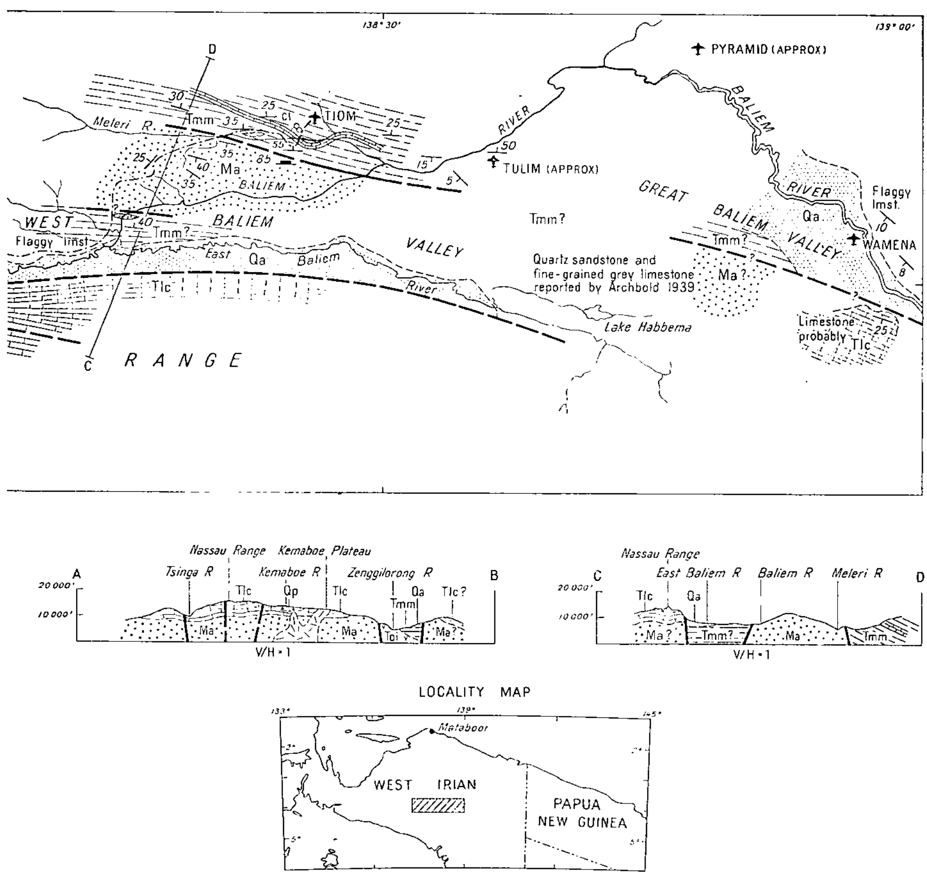

Fig. 1.—Continued.

NOTES ON THE LIMESTONES

Carstensz Limestone: This is the name given by Dow to the limestone along the Nassau Range between the Carstensz Mountains and the East Baliem River. Samples from the limestone are of late Eocene (*b* stage), late Oligocene (lower *e*), and early to middle Miocene (upper *e* to lower *f*) ages.

Eocene samples are C3, C4b, C4c, C8, and C15. Samples C3, C4b, and C4c are from boulders shedding from the Carstensz Limestone into the head of the West Baliem River. Sample C3 includes two lithological and faunal types. The first consists of worn specimens and fragments of larger foraminifera in a fine-grained matrix of organic debris; small specimens of *Asterocyclina* sp. are common, together with *Nummulites javanus* Verbeek, rare planktonic foraminifera and rare indeterminable benthonic smaller foraminifera. The second rock type is a skeletal calcarenite consisting of foraminifera and abundant algal fragments. Foraminifera are *Discocyclina* sp., *Operculina, Lacazinella wichmanni* (Schlumberger), *Halkyardia* cf. *minima* (Liebus), *Spiroclypeus vermicularis?* Tan, rare miliolids, and rare indeterminable benthonic smaller foraminifera. The age of each part of this sample is middle Eocene to basal late Eocene (a_3-b).

Sample C4b is also a skeletal calcarenite containing abundant foraminifera and algae. Foraminifera are *Discocyclina* cf. *omphala* (Fritsch), *Asterocyclina, Lacazinella wichmanni* (Schlumberger), *Spiroclypeus vermicularis* Tan, *Gypsina, Carpenteria, Operculina, Halkyardia* cf. *minima,* rare miliolids, and indeterminable smaller benthonic foraminifera. Also present in this sample is an uncentred oblique section of a coarsely perforate trochospiral foraminifer, with umbilical pillars but no umbilical plates observed; it resembles in some features the genus *Lockhartia* Davies, but because of the nature of the section cannot be definitely identified. An earlier record of *Lockhartia* from Borneo by Rutten (1948) was not accepted by Smout (1954), who considered the identification to be based on poorly preserved specimens of *Rotalia mexicana* Nuttall and of *Pellatispira.* Sample C4b is regarded as late Eocene (Tertiary *b*) in age.

Sample C4c is a micritic skeletal calcarenite with worn and broken tests of larger foraminifera in a fine-grained matrix consisting of quartz grains and organic fragments and is similar to one of the rock types of sample C3. Foraminifera are *Discocyclina, Asterocyclina, Nummulites* cf. *javanus, Spiroclypeus vermicularis* Tan, *Elphidium,* a coarsely perforate indeterminable rotaline genus, rare planktonic foraminifera, and indeterminable smaller benthonic foraminifera. Rare small and worn fragments of the distinctive alga *Distichoplax biserialis* (Dietrich) also occur. The age of sample C4c is late Eocene (Tertiary *b*), with the alga *Distichoplax biserialis* indicating some reworking of Paleocene or early Eocene sediments.

Samples C8 and C15 have a similar fauna of late Eocene (Tertiary *b*) age. Each sample contains *Discocyclina* (including a large pillared form), *Asterocyclina, Nummulites javanus* Verbeek, and poorly preserved *Lacazinella wichmanni* (Schlumberger). Sample C8 has also rare *Operculina* sp., numerous small trochospiral specimens and other indeterminable smaller foraminifera; C15 has abundant large *Operculina* and large specimens of *Discocyclina* similar to *D. omphala* (Fritsch).

Sample C4a is a skeletal calcarenite containing foraminifera, rare algal fragments, and rare echinoid spines. The foraminifera are *Lepidocyclina* (*Eulepidina*) sp. (mainly fragments), *Elphidium, Amphistegina, Asterigerina, Operculina, Num-*

mulites sp. similar to *N. javanus* Verbeek, and one possible fragment of *Discocyclina.* The sample is regarded as late Oligocene (upper *e*) in age, containing reworked Eocene specimens.

Samples from the Carstensz Limestone of early to middle Miocene age (upper *e* to lower *f*) are C10, C11, and C12a and b. C10 is a recrystallized skeletal calcarenite with fragments and poorly preserved specimens of larger foraminifera, and rare smaller benthonic and planktonic specimens. Foraminifera are *Lepidocyclina* (*Nephrolepidina*) sp., *Miogypsina* sp. (very rare), *Cycloclypeus* sp., *Operculina,* and *Amphistegina.* Sample C11 is a micritic skeletal calcarenite with foraminifera, algae, bryozoa, and coral fragments. Foraminifera are: *Lepidocyclina* (*?Nephrolepidina*) sp., *Cycloclypeus* sp. (rare fragments), *Carpenteria* or *Sporadotrema* (fragments), *Operculina, Amphistegina, Acervulina,* an indeterminable trochoid genus (Pl. 4, figs 1-2), and other indeterminable smaller foraminifera. One specimen of *Orbulina,* probably *O. suturalis* Bronnimann, also is present, and indicates a middle Miocene (lower *f*) age at least for this sample.

Samples C12a and b are recrystallized micritic calcarenites with foraminifera, algae, bryozoa, coral fragments, and echinoid spines. Foraminifera are: *Lepidocyclina* (*Nephrolepidina*) sp., *Gypsina globulus* Reuss, *Carpenteria, ?Acervulina, Amphistegina, Operculina, Planorbulinella, Elphidium, Cycloclypeus,* an indeterminable trochoid genus, rare planktonic foraminifera, and indeterminable smaller foraminifera.

Meleri Beds is a name given by Dow (1968) to a sequence of marl and calcareous siltstone on the northern side of the Meleri Valley, faulted against Mesozoic beds (Fig. 1). The Meleri Beds contain a prominent limestone member and lenses of calcarenite and minor glauconitic sandstone. Sample C1 is a float sample, probably from a calcarenite lens above the limestone member of the Meleri Beds; it is a skeletal calcarenite consisting mainly of foraminifera and algae; the foraminiferal specimens are worn. Foraminifera are: *Lepidocyclina* (*Eulepidina*) *ephippioides* (Jones & Chapman), *L.* (*Nephrolepidina*) sp., *Borelis* sp., *Spiroclypeus margaritatus* (Schlumberger), *Cycloclypeus* sp., *Heterostegina* sp., *Amphistegina, Carpenteria* or *Sporadotrema, Operculina, Gypsina globulus* Reuss, *Discocyclina* sp., *Biplanispira mirabilis* (Umbgrove), *Nummulites* cf. *javanus* Verbeek, *N. fichteli* Michelotti, and *Pellatispira?* sp. The age of this sample is late Oligocene (lower *e*) with reworked late Eocene and early or middle Oligocene specimens.

Sample C16 is a hard calcareous marl from the Meleri Beds at the head of the Ilaga Valley; it contains abundant planktonic foraminifera (Pl. 4, fig. 8). No specific determinations can be made; the sample is given a late Oligocene (N.3) age on its association with marls and siltstones containing an abundant planktonic fauna of this age.

The Carstensz Limestone is to be correlated with the New Guinea Limestone Group (Eocene to early Miocene). There is a stratigraphic gap in the present samples ranging from the Eocene to the late Oligocene; the same gap was reported by Visser & Hermes (1962) from the central foothills. In other areas of Irian Jaya (e.g. Carstensz Tops) a complete sequence from Eocene to early Miocene is known. Bär, Cortel, & Escher (1961) recorded Oligocene limestone of the New Guinea Limestone Group in the Kariem area, in the Central Range of the Star Mountains. The absence of early and middle Oligocene limestone in the present collection may indicate that this was a time of erosion or non-deposition, as noted by Dow (1968). Other possibilities are that there was no suitable shelf environment in the area for the formation of limestones, or that this is a sampling gap caused by the difficult conditions of the survey.

The limestone from the Meleri Beds is of the same age (lower *e*) as one sample from the Carstensz Limestone (C4a), but has a richer fauna with a larger element of reworked Eocene specimens, and also some Oligocene specimens. Bär, Cortel, & Escher recorded many lower *e* samples, but no reworked Eocene material is mentioned.

The marl and calcareous siltstone sequence cropping out at the head of the Ilaga Valley was referred by Dow to the Meleri Beds; this is supported by the late Oligocene (N.3) age of the planktonic foraminiferal fauna in these beds.

Beds equivalent to the marls and siltstone of the Meleri Beds probably were recorded by Visser & Hermes (1962) and referred to their *Globigerina venezuelana* subzone; the present fauna could be placed in the T2.4 to T2.5 interval of Visser & Hermes. Species occurring in the fauna of the *G. venezuelana* subzone include the *Globigerina dissimilis* Cushman & Bermudez group, and the *G. ciperoensis* Bolli group, but full details of the fauna were not given.

PLANKTONIC FORAMINIFERA

Genus GLOBIGERINA d'Orbigny, 1826

Type species: *G. bulloides* d'Orbigny, 1826; subsequent designation of Parker, Jones, & Brady, 1865.

GLOBIGERINA PRAEBULLOIDES OCCLUSA Blow & Banner, 1962
(Pl. 5, figs 1-5)

1962 *Globigerina praebulloides occlusa* Blow & Banner, p. 93, pl. 9, figs U-W, text-fig. 14 (I-II).

Material examined: 17 specimens.
Remarks: Apertural details are difficult to observe on all specimens here referred to *G. praebulloides occlusa*. The aperture of most specimens is a low, asymmetrical arch, and no indication of a lip or rim is present. Some specimens seem to have a highly arched aperture similar to that of *G. praebulloides praebulloides,* but lack the rapidly enlarging chambers and distinct spire of this subspecies. These specimens with a high, arched aperture can be distinguished from small specimens referred to *Globigerinoides quadrilobatus primordius* only in that they lack the supplementary aperture of the *primordius* group. Specimens of *G. quadrilobatus primordius* also seem to have a more coarsely reticulate test wall than those of *Globigerina praebulloides occlusa,* but no detailed examination of the test wall has been made.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13549	0.42	0.35	0.25
CPC 13550	0.30	0.26	0.23

Occurrence: Figured specimen CPC 13549 from sample C17a; figured specimen CPC 13540 from sample C17b. Also occurs in sample C7a.

GLOBIGERINA VENEZUELANA Hedberg, 1937
(Pl. 5, figs 6-8)

1937 *Globigerina venezuelana* Hedberg, p. 681, pl. 92, figs 7a-b.

1966 *Globigerina venezuelana* Hedberg, Reiss & Gvirtzman, fig. 84 (chart), pl. 89, figs 1a-b, 2, 3a-c, 5a-c.

1971b *Globigerina venezuelana* Hedberg; Jenkins, p. 156, pl. 16, figs 498-501.

1971 *Globigerina venezuelana* Hedberg; Raju, p. 27, pl. 5, fig. 4; pl. 6, figs 1a-c.

Material examined: 11 specimens.

Remarks: Bolli (1957a) discussed the variation observed in specimens of *G. venezuelana* from Trinidad; Blow (1969) selected the specimen illustrated by Bolli in figures 8a-b as typifying his concept of the species, and referred to a group of forms with four inflated chambers in the last whorl ranging from within zone N.3 to within N.19. Bolli noted that specimens of *G. venezuelana* ranging from the *Globorotalia opima opima* zone to the *G. kugleri* zone and from the *G. fohsi lobata* zone to the *G. menardii* zone generally have more spherical chambers, and those from the *Catapsydrax dissimilis* zone to the *Globorotalia fohsi fohsi* zone laterally compressed chambers. The Nassau Range specimens have generally spherical chambers, and would thus correspond to the oldest specimens recorded from Trinidad, occurring in beds ranging from zone N.2 to zone N.4.

In all specimens found in the Nassau Range samples, the last chamber is smaller than the preceding chamber, varies in size, and partly covers the umbilicus. Apertural details are obscured; the aperture appears to be umbilical, but no apertural teeth can be observed.

Specimens from Papua New Guinea previously identified as *Globoquadrina venezuelana* (Belford, 1962, pl. 6, figs 1-6) are now considered to be referable to *G. larmeui* Akers, s.l.

Dimensions of figured specimen (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13551	0.55	0.51	0.52

Occurrence: Figured specimen CPC 13551 from sample C17a; occurs also in samples C7a and C17b.

GLOBIGERINA TRIPARTITA Koch, 1926
(Pl. 5, figs 9-14)

1926 *Globigerina bulloides* d'Orbigny var. *tripartita* Koch, p. 746, text-fig. 21a-b.

1962 *Globigerina tripartita tripartita* Koch; Blow & Banner, p. 96, pl. 10, figs A-F, fig. 18.

1966 *Globigerina tripartita tripartita* Koch; Reiss & Gvirtzman, fig. 84 (chart), pl. 90, figs 1a-c, 2a-c, 3a-b, 4a-c.

1969 *Globigerina tripartita* Koch; Blow, p. 322, pl. 16, fig. 6 (with discussion of synonymy),

1971b *Globoquadrina tripartita* (Koch); Jenkins, p. 167, pl. 17, figs 525-530.

1971 *Globigerina tripartita tripartita* Koch; Nicora, p. 195, pl. 10, figs 1a-c, 2a-c, pl. 16, figs 1a-c.

1971 *Globigerina tripartita tripartita* Koch; Raju, p. 27, pl. 3, figs 3a-b.

1971 *Globigerina tripartita rohri* Bolli; Raju, p. 27, pl. 3, figs 2, 4a-b.

Material examined: 33 specimens.

Many specimens have the small and sometimes misshapen last chamber referred to by Blow & Banner (1962). Three chambers form the final whorl, and the aperture is intra-umbilical, with the apertural face sloping steeply from the umbilical margin.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13552	0.76	0.70	0.61
CPC 13553	0.48	0.41	0.40

Occurrence: Figured specimens CPC 13552 and 13553 from sample C17a; found also in samples C7a, C17b, C18a and C18b.

GLOBIGERINA SELLII (Borsetti, 1959)
(Pl. 6, figs 1-8)

1959 *Globoquadrina sellii* Borsetti, p. 209, pl. 1, figs 3a-d.
1962 *Globigerina oligocaenica* Blow & Banner, p. 88, pl. 10, figs G, L-N.
1968 *Globoquadrina sellii* Borsetti; Carloni, Cati, & Borsetti, pl. 10, figs 1a-c.
1971 *Globigerina sellii* (Borsetti); Raju, p. 26, pl. 3, figs 5a-b, 6.
1971 *Globigerina sellii* (Borsetti); Nicora, p. 193, pl. 10, figs 5a-c: pl. 16, figs 2a-c.

Material examined: 19 specimens.

Remarks: Blow & Banner (1962, p. 146) considered their taxon *G. oligocaenica* to be a synonym of *G. sellii* (Borsetti). Jenkins (1971b) considered these taxa to be different, basing his opinion on the absence of umbilical 'teeth' in *G. oligocaenica*; further, Jenkins placed *G. sellii* in the synonymy of *G. tripartita* (Koch).

Blow & Banner (op. cit.) indicated that a weak 'umbilical tooth' may be developed in *G. oligocaenica* by medial broadening of the apertural lip. The original description of *G. sillii* does not refer to an umbilical tooth, but states only that the aperture has a thin weakly rugose lip. There does not appear to be any reason or necessity to regard *sellii* and *oligocaenica* as distinct taxa, and the synonymy first given by Blow & Banner is followed here. *G. sellii* is also considered to be distinct from *G. tripartita* Koch, which has less strongly embracing chambers, a less strongly hispid test wall, and an aperture not set in a re-entrant as in *G. sellii.*

No apertural teeth have been observed in specimens of *G. sellii* from the Nassau Range. Many specimens have a large inflated last chamber covering the umbilicus; the wall of this chamber is finely perforate and reticulate and lacks the strongly hispid ornament of earlier chambers. One such specimen is figured (Pl. 6, figs 4-6).

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13554	0.62	0.56	0.55
CPC 13555	0.70	0.58	0.58
CPC 13556	0.54	0.53	0.51

Occurrence: Specimens CPC 13554 and 13555 from sample C17b; CPC 13556 from sample C17a; also occurs in samples C7a, C18a, C18b.

GLOBIGERINA SASTRII Raju, 1971
(Pl. 7, figs 1-8)

1971 *Globigerina sastrii* Raju, p. 26, pl. 4, figs 1a-c, 2a-c.

Material examined: 20 specimens.

All the Nassau Range specimens correspond very closely to the description given by Raju (1971). The chambers enlarge rapidly, particularly the last two or three, and strongly and progressively overlap earlier chambers.

Only two chambers are visible from the ventral side of large specimens. The aperture in the early chambers is a low elongate slit in a small re-entrant in the apertural face, and then becomes progressively more restricted and difficult to observe in large specimens.

The test wall is coarsely pustulose, particularly on the central side near the aperture, and on the umbilical shoulders of early chambers.

The coiling of the test, the apertural characteristics, and the ornament indicate a close relationship between *G. sellii* and *G. sastrii,* and *G. sastrii* could well have evolved directly from *G. sellii* by an increase in the rate of overlap of successive chambers, resulting in a bilobate appearance in adult forms.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13557	0.91	0.71	0.71
CPC 13558	0.81	0.63	0.63
CPC 13559	0.80	0.61	0.63
CPC 13560	0.50	0.49	0.46

Occurrence: Specimens CPC 13557 to 13560 from sample C17b; also found rarely in samples C18a and C18b.

GLOBIGERINA GORTANII GORTANII (Borsetti, 1959)
(Pl. 8, figs 1-6)

1959 *Catapsydrax gortanii* Borsetti, p. 205, pl. 1, figs 1a-d.
1962 *Globigerina turritilina turritilina* Blow & Banner, p. 98, pl. 13, figs D-G.
1969 *Globigerina gortanii gortanii* Borsetti; Blow, p. 320, pl. 17, fig. 1.
1971 *Globigerina gortanii gortanii* (Borsetti); Raju, p. 24, pl. 2, figs 1a-b, 2.

Material examined: 7 specimens.

Remarks: Blow & Banner (1962), after examining paratypes and topotypes of *Globigerina gortanii* Borsetti, concluded that their taxon *Globigerina turritilina turritilina* is a synonym. Jenkins (1971b) has raised the possibility that the two taxa are in fact different, on the basis that *G. gortanii gortanii* has a characteristic bulla lacking in *G. turritilina turritilina.*

Apart from this, the two taxa appear identical, and I regard them as such until detailed comparisons indicate that they do in fact differ, preferably, in my opinion, on some feature or features other than the nature of the bulla. Cati & Borsetti (1968) considered that *G. gortanii gortanii* developed from a non-bullate to a bullate form over the Eocene/Oligocene interval. Eocene specimens are those described by Blow & Banner (1962) as *Globigerina turritilina praeturritilina.* At the Eocene/Oligocene boundary a secondary chamber is developed; these specimens were described by Blow & Banner as *G. turritilina turritilina,* and all West Irian specimens observed are of this kind. A true bulla developed in the Oligocene.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13561	0.43	0.40	0.40
CPC 13562	0.50	0.46	0.50
CPC 13563	0.54	0.50	0.43

Occurrence: Figured specimens CPC 13561 to 13563 from sample C17a; found also in sample C17b.

GLOBIGERINA ANGUSTIUMBILICATA Bolli, 1957
(Pl. 8, Figs 7-12)

1957a *Globigerina ciperoensis angustiumbilicata* Bolli, p. 109, pl. 22, figs 12a-c, 12a-c.

1962 *Globigerina angustiumbilicata* Bolli, Blow & Banner, p. 85, pl. 9, figs X-Z.

1966 *Globigerina angustiumbilicata* Bolli; Reiss & Gvirtzman, fig. 84 (chart), pl. 88, figs 14a-c, 15a-c.

1971 *Globigerina angustiumbilicata* Bolli; Raju, p. 21, pl. 1, fig. 6.

1971b *Globigerina (Globigerina) ciperoensis angustiumbilicata* Bolli; Jenkins, p. 144, pl. 15, figs 451-453.

Material examined: 19 specimens.

Remarks: Small tightly coiled specimens similar to those referred to *G. ouachitaensis ciperoensis,* but with a smaller umbilicus and slightly asymmetrical aperture arched at the anterior end, are here referred to the long-ranging species *G. angustiumbilicata.*

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13564	0.30	0.25	0.20
CPC 13565	0.28	0.23	0.18

Occurrence: Figured specimens CPC 13564 and 13565 from sample C17a; also occurs in sample C18b.

GLOBIGERINA OUACHITAENSIS CIPEROENSIS Bolli, 1954
(Pl. 8, figs 13-18)

1954 *Globigerina ciperoensis* Bolli, p. 1, text-figs 3-6.

1957a *Globigerina ciperoensis ciperoensis* Bolli; Bolli, p. 109, pl. 22, figs 10a-b.

1962 *Globigerina ouachitaensis ciperoensis* Bolli; Blow & Banner, p. 90, pl. 9, figs E-G; fig. 9, I-III.

1966 *Globigerina ouachitaensis ciperoensis* Bolli; Reiss & Gvirtzman, fig. 84 (chart), pl. 90, figs 5a-c, 6a-b.

1971b *Globigerina (Globigerina) ciperoensis ciperoensis* Bolli; Jenkins, p. 145, pl. 14, figs 411-413.

Material examined: 26 specimens.

Remarks: Most of the Irian Jaya specimens examined conform to the description given by Blow (1969) for the forma *atypica,* distinguished by its smaller umbilicus, higher spire, and more closely appressed chambers. Only occasional specimens show more open coiling and a wider umbilicus, approaching the concept of Blow's forma *typica*.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13566	0.42	0.35	0.32
CPC 13567	0.47	0.42	0.33

Occurrence: Figured specimen CPC 13566 from sample C17a; figured specimen 13567 from sample C17b. Known only from these two samples.

Genus GLOBIGERINOIDES Cushman, 1927

Type species: *Globigerina ruber* d'Orbigny *in* de la Sagra, 1839; original designation.

GLOBIGERINOIDES QUADRILOBATUS PRIMORDIUS Blow & Banner, 1962
(Pl. 9, figs 1-16)

1962 *Globigerinoides quadrilobatus primordius* Blow & Banner, p. 115, pl. 9, figs Dd-Ff.
1968 *Globigerinoides quadrilobata primordia* Blow & Banner; Carloni, Cati & Borsetti, pl. 9, figs 8a-c.
1969 *Globigerinoides quadrilobatus primordius* Blow & Banner, 1962; Blow, p. 325, pl. 20, figs 1, 5, 6.
1971 *Globigerinoides primordius* Blow & Banner; Nicora, p. 199, pl. 15, figs 7a-c.
1971 *Globigerinoides primordius* Blow & Banner; Raju, p. 28, pl. 7, figs 1a-b, 2a-b.

Material examined: 38 specimens.

Remarks: Included here are all specimens which have as their common characteristic a single supplementary aperture; other morphological features show a wide range of variation. Some small specimens (Pl. 9, figs 1-6) have four regularly enlarging chambers visible from the the ventral side, with an arched primary aperture and usually very small supplementary aperture, difficult to observe. It is these specimens that most clearly show the development of the subspecies *primordius* from specimens referred to *Globigerina praebulloides occlusa*. Other and larger specimens have more rapidly enlarging chambers, with the last chamber forming relatively more of the test, the primary aperture being a low elongate slit and the supplementary aperture distinct (Pl. 9, figs 7-12). These in turn form a link to other specimens in which the last chamber forms almost half the test, and which have an elongate, low primary aperture (Pl. 9, figs 13-16). No purpose would be served by attempting to recognize and establish different morphological groups within the available specimens and all are here referred to the subspecies *primordius*.

Jenkins (1971b) identified specimens from the Otaian of New Zealand, with a small supplementary aperture, as *Globigerinoides altiaperturus* Bolli, and also regarded specimens from the *Globorotalia kugleri* Zone of Trinidad with low supplementary apertures as variants of *Globigerinoides altiaperturus*. On these observations, Jenkins doubted if *G. quadrilobatus primordius* is a valid taxon. The specimen figured by Jenkins (pl. 20, figs 604-606) as *G. altiaperturus* resembles small specimens from the Nassau Range samples which are here considered to show the development of *primordius* from *Globigerina praebulloides occlusa*. The primary aperture of the Nassau Range specimens differs from that of *Globigerinoides quadrilobatus altiapertura* in being oval, and not circular or almost circular; the supplementary aperture is also small. Bolli (1957a) did not mention size of the supplementary aperture in describing *altiaperturus,* but Banner & Blow (1965b, p. 111), referred to the 'high, broad primary and supplementary apertures' of *altiaperturus. G. quadrilobatus primordius* is in my opinion a valid taxon distinct in concept from *G. quadrilobatus altiaperturus.*

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13568	0.39	0.33	0.30
CPC 13569	0.42	0.33	0.28
CPC 13570	0.38	0.31	0.25
CPC 13571	0.49	0.38	0.35
CPC 13572	0.50	0.38	0.30
CPC 13573	0.50	0.40	0.33
CPC 13574	0.55	0.40	0.34

Occurrence: Figured specimens CPC 13568 and CPC 13570 to 13574 from sample C17b; figured specimen CPC 13569 from sample C17a. Also occurs in sample C18b.

GLOBIGERINOIDES sp.
(Pl. 10, figs 1-5)

Material examined: 16 specimens.

Remarks High-spired specimens of *Globigerinoides* with a wide umbilicus, a wide low arched central primary aperture, and two supplementary apertures on the dorsal side. These specimens seem to result from the addition of one chamber to larger specimens of *G. quadrilobatus primordius,* and no formal specific or subspecific recognition of them is made here.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13575	0.55	0.50	0.40
CPC 13576	0.51	0.42	0.35

Occurrence: Figured specimens CPC 13575 and 13576 from sample C17a; also occurs in samples C17a, C17b and C18b.

Genus GLOBOROTALIA Cushman, 1927

Subgenus TURBOROTALIA Cushman & Bermudez, 1949

Type species: *Globorotalia centralis* Cushman & Bermudez, 1937; original designation.

GLOBOROTALIA (TURBOROTALIA) KUGLERI Bolli, 1957
(Pl. 10, figs 6-9)

1957a *Globorotalia kugleri* Bolli, p. 118, pl. 28, figs 5a-c, 6.
1966 *Globorotalia kugleri* Bolli; Reiss & Gvirtzman, p. 314 (table), pl. 94, figs 13a-c, 14a-c, 15a-c.
1971b *Globorotalia (Turborotalia) kugleri* Bolli; Jenkins, p. 118, pl. 12, figs 315-317.
1971 *Globorotalia kugleri* Bolli; Raju, p. 32, pl. 10, figs 1a-b, 2a-b.

Material examined: 19 specimens

Remarks: G. kugleri has been found at only one locality in the Ilaga Valley area. The specimens agree well with published descriptions and figures, with a distinct umbilicus and curved dorsal intercameral sutures, not radial sutures as described by Blow (1969) for *G. (T.) pseudokugleri.*

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13577	0.31	0.27	0.18
CPC 13578	0.25	0.22	0.15

Occurrence: Figured specimens CPC 13577 and 13578 from sample C17b; found only in this sample.

GLOBOROTALIA (TURBOROTALIA) OBESA Bolli, 1957
(Pl. 10, figs 10-14)

1957a *Globorotalia obesa* Bolli, p. 119, pl. 29, figs 2a-c, 3.
1959 *Globorotalia obesa* Bolli; Blow, p. 218, pl. 19, figs 124a-c.
1966 *Globorotalia (Turborotalia) obesa* Bolli; Reiss & Gvirtzman, fig. 84 (table), pl. 94, figs 6a-c, 7a-c.
1968 *Globorotalia obesa* Bolli; Carloni, Cati, & Borsetti, tab. 1, pl. 8, figs 20a-c.
1971 *Globorotalia obesa* Bolli; Nicora, p. 185, pl. 8, figs 3a-c.
1971 *Globorotalia obesa* Bolli; Raju, p. 33, pl. 10, figs 6a-c
1971b *Globorotalia (Turborotalia) obesa* Bolli; Jenkins, p. 127, pl. 13, figs 348-350.

Material examined: 15 specimens.

Remarks: A long ranging and widely distributed species which occurs only rarely in the present material.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13579	0.43	0.35	0.28
CPC 13580	0.41	0.32	0.25

Occurrence: Figured specimens CPC 13579 and 13580 from sample C17b; found also in samples C17a and C18a.

Globorotalia (Turborotalia) siakensis (Le Roy, 1939)
(Pl. 11, figs 1-4)

1939 *Globerigerina siakensis* Le Roy, p. 262, pl. 4, figs 20-22.
1969 *Globorotalia (Turborotalia) siakensis* Le Roy; Blow, p. 356, pl. 34, figs 4, 5 (synonymy).
1971 *Globorotalia siakensis* Le Roy; Nicora, pl. 7, figs 4a, c; 5a-c.
1971 *Globorotalia siakensis* (Le Roy); Raju, p. 33, pl. 10, figs 4, 5a-c.

Material examined: 24 specimens
Remarks: Blow (1969) has noted that specimens of *G.* (*T.*) *siakensis* frequently have been misidentified as *G.* (*T.*) *mayeri* Cushman & Ellisor. The present specimens have the features of *G.*(*T.*) *siakensis* as outlined by Blow, namely, radial intercameral sutures dorsally and ventrally, an open deep umbilicus, a low elongate aperture, and 5 to 6 chambers in the final whorl.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13581	0.42	0.37	0.27
CPC 13582	0.43	0.36	0.28

Occurrence: Figured specimens CPC 13581 and 13582 from sample C17b; also occurs in sample C17a.

Globorotalia (Turborotalia) opima nana Bolli, 1957
(Pl. 11, figs 5-9)

1957a *Globorotalia opima nana* Bolli, p. 118, pl. 28, figs 3a-c.
1966 *Globorotalia (Turborotalia) opima nana* Bolli; Reiss & Gvirtzman, fig. 84 (table), pl. 94, figs 2a-c, 3a-c.
1968 *Globorotalia opima nana* Bolli; Carloni, Cati, & Borsetti, tab. 1, pl. 8, figs 18a-c.
1969 *Globorotalia (Turborotalia) opima nana* Bolli, 1957; Blow, p. 352, pl. 39, fig. 1.
1971b *Globorotalia (Turborotalia) nana nana* Bolli; Jenkins, p. 123, pl. 11, figs 303-308.
1971 *Globorotalia opima nana* Bolli; Nicora, p. 186, pl. 8, figs 5a-c.
1971 *Globorotalia opima nana* Bolli; Raju, p. 33, pl. 10, figs 3a-b.

Material examined: 5 specimens
Remarks: Blow (1969) has indicated that pseudomorphic forms of *G.* (*T.*) *opima nana* occur both concurrently with typical specimens and also in younger beds. However, the present specimens are considered to be referable to *G.* (*T.*) *opima nana* s.s. as they have a closed umbilicus, tight coiling, and a low slit-like aperture, with the final chamber strongly inflated and with a distinct narrow lip. Bolli (1957a) described *G.* (*T.*) *opima nana* as having 4 to 5 chambers in the final whorl; the holotype has 4 chambers. Blow (1969) in his discussion of *opima nana* also referred to small 4 to 5-chambered turborotaliid forms. The Nassau Range specimens referred to *opima nana* have 4½ to 5 chambers in the last whorl.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13583	0.29	0.25	0.20
CPC 13584	0.33	0.29	0.25

Occurrence: Figured specimen CPC 13583 from sample C17b; figured specimen CPC 13584 from sample C17a. Found also in sample C18b.

Genus GLOBOROTALOIDES Bolli, 1957

Type species: *Globorotaloides variabilis* Bolli, 1957; original designation.

GLOBOROTALOIDES SUTERI Bolli, 1957
(Pl. 11, figs 10-15)

1957a *Globorotaliodes suteri* Bolli, p. 117, pl. 27, figs 9a-c, 10a-b, 11a-b, 12a-b, 13a-b.
1957b *Globorotaloides suteri* Bolli; Bolli, p. 166, pl. 37, figs 10a-c, 11, 12.
1962 *Globorotaloides suteri* Bolli; Blow & Banner, p. 122, pl. 13, figs N-P.
1971b *Globorotaloides suteri* Bolli; Jenkins, p. 189, pl. 22, figs 646-648.
1971 *Globorotaloides suteri* Bolli; Nicora, p. 189, pl. 12, figs 1a-c, 2a-c.
1971 *Globorotaloides suteri* Bolli; Raju, p. 34, pl. 6, figs 5a-b.

Material examined: 11 specimens

Remarks: Specimens in the present material referred to *G. suteri* usually have a bulla-like last chamber, ranging from small and slightly inflated, only partly covering the umbilicus, to large and inflated, strongly covering the umbilicus. Only one infralaminal aperture is present on all specimens. Seven specimens are sinistrally and four dextrally coiled.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13585	0.40	0.37	0.31
CPC 13586	0.48	0.43	0.41
CPC 13587	0.31	0.26	0.22

Occurrence: Figured specimens CPC 13585 and 13586 from sample C17a; figured specimen CPC 13587 from C17b. Also occurs in sample C7a.

Genus GLOBIGERINITA Bronnimann, 1951

Type species: *Globigerinita naparimaensis* Bronnimann, 1951: original designation.

GLOBIGERINITA DISSIMILIS (Cushman & Bermudez, 1937)
(Pl. 12, figs 1-5)

1937 *Globigerina dissimilis* Cushman & Bermudez, p. 25, pl. 3, figs 4-6.
1957 *Catapsydrax dissimilis* (Cushman & Bermudez); Bolli, Loeblich, & Tappan, p. 36, pl. 7, figs 6a-c, 7a-b, 8a-c.
1962 *Globigerinita dissimilis dissimilis* (Cushman & Bermudez); Blow & Banner, p. 106, pl. 14, fig. D.
1962 *Globigerinita dissimilis ciperoensis* Blow & Banner, p. 107, pl. 14, figs A-C.
1968 *Globigerina dissimilis* Cushman & Bermudez; Carloni, Cati, & Borsetti, tab. 1, pl. 8, figs 1a-c.
1969 *Globigerinita dissimilis dissimilis* (Cushman & Bermudez); Blow, p. 327, pl. 25, figs 6-7.

1969 *Globigerinita dissimilis ciperoensis* Blow & Banner; Blow, p. 328, pl. 24, fig. 2.
1971b *Catapsydrax dissimilis* (Cushman & Bermudez); Jenkins, p. 182, pl. 21, figs 625-627.
1971 *Catapsydrax dissimilis* (Cushman & Bermudez); Nicora, p. 209, pl. 12, figs 3a, c, 6c.
1971 *Globigerinita dissimilis* (Cushman & Bermudez); Raju, p. 29, pl. 6, figs 2a-b, 3a-b.

Material examined: 12 specimens.
Remarks: In accordance with views which I have expressed previously (Belford, 1962, 1968), and following the opinion of several other workers (e.g., Hofker, 1961; Takayanagi & Saito, 1962; Parker, 1962; Bé, 1965; Cati & Borsetti, 1968), the taxonomic value of the bulla, in this case at the subspecific level, is questioned. Accordingly, the subspecific differentiation of the species *dissimilis* into the subspecies *dissimilis* and *ciperoensis,* as proposed by Blow & Banner (1962), is not followed. However, different stratigraphical ranges are reported for these two subspecies by Blow & Banner (1962) and Blow (1969), with *dissimilis* ranging from middle Eocene to early Miocene and *ciperoensis* from early Oligocene to early Miocene. Blow & Banner (op.cit.) stated (p.107) that the subspecies *ciperoensis* has features typical of advanced forms of *dissimilis,* from which it seems to be descended. Nevertheless, the bulla is a variable and inconsistent character on which to base taxa. One approach, which avoids formal recognition of taxa on the basis of the bulla, is the suggestion of Cati & Borsetti (1968) to consider bullate forms as 'morphotypes' of species. This would also enable stratigraphical use to be made of any variation in nature of the bulla with time, as appears to be the present case.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13588	0.55	0.50	0.42
CPC 13589	0.43	0.40	0.33
CPC 13590	0.50	0.46	0.43
CPC 13591	0.42	0.35	0.31

Occurrence: Figured specimen CPC 13588 from sample C18b; figured specimens CPC 13589 to 13591 from sample C17b. Also found in sample C17a.

GLOBIGERINITA UNICAVA UNICAVA (Bolli, Loeblich, & Tappan, 1957)
(Pl. 12, figs 10-12)

1957 *Catapsydrax unicavus* Bolli, Loeblich, & Tappan, p. 37, pl. 7, figs 9a-c.
1962 *Globigerinita unicava unicava* (Bolli, Loeblich & Tappan); Blow & Banner, p. 113, pl. 14, figs M, N.
1969 *Globigerinita unicava unicava* (Bolli, Loeblich & Tappan); Blow, p. 330, pl. 24, figs 8, 9.
1971 *Catapsydrax unicavus* Bolli, Loeblich & Tappan; Nicora, p. 210, pl. 12, figs 4a, d, 5a, c.

Material examined: 5 specimens.
Remarks: The specimens referred to this subspecies have an inflated bulla with a single accessory aperture extending for the breadth of the penultimate chamber. Four chambers are visible from the ventral side, and the test wall is coarsely pustulate.

Dimensions of figured specimens (mm)

	Max. diameter	*Min. diameter*	*Height*
CPC 13592	0.40	0.35	0.37

Occurrence: Figured specimen CPC 13592 from sample C17b; found also in samples C7a, C17a, and C18b.

SPECIES	SAMPLE NO.				
	C7a	C17a	C17b	C18a	C18b
Globigerina praebulloides occlusa	○	●	●		
G. venezuelana	×	●	○		
G. tripartita	○	●	●	●	○
G. sellii	×	×	●	○	×
G. sastrii			◪	○	○
G. gortanii gortanii		○	×		
G. angustiumbilicata		○			◪
G. ouachitaensis ciperoensis		◪	●		
Globigerinoides quadrilobatus primordius		●	◪		●
G. sp.	×	●	●		○
Globorotalia (Turborotalia) kugleri			◪		
G. (T.) obesa		●		○	×
G. (T.) siakensis		●	◪		
G. (T.) opima nana		×	○		×
Globorotaloides suteri	×	●	○		
Globigerinita dissimilis		○	●		×
G. unicava unicava	×	×	×		×

× 1–2 specimens
○ 3–5 specimens
● 6–10 specimens
◪ 11–25 specimens

Fig. 2 Distribution of species.

OLIGOCENE-MIOCENE BOUNDARY

In this section reference is made to the zonal scheme introduced by Banner & Blow (1965a) and fully documented by Blow (1969); for that part of the succession relevant to this paper the relationship between the formal taxon names for the zones and the letter/number system used by Banner & Blow is shown in Text-figure 3. In my opinion the use of formal taxon names is preferable, but for brevity of reference the letter/number system is used in the text.

ZONAL SERIES & NUMBER	FORMAL TAXON NAMES	EPOCHS
ZONE N 4	*Globigerinoides quadrilobatus primordius / Globorotalia (T.) kugleri* Partial-range Zone	Early Miocene
ZONE N3 (=P.22)	*Globigerina angulisuturalis* Partial-range Zone	
ZONE N.2 (=P.21)	*Globigerina angulisuturalis / Globorotalia (T.) opima opima* Concurrent range Zone	
ZONE * P.19/20(=N.1)	*Globigerina sellii* *Globigerina ampliapertura* Partial-range Zone	Oligocene
ZONE P.18	*Globigerina tapuriensis* Consecutive-range Zone	
ZONE P.17	*Globigerina gortanii gortanii / Globorotalia (T.) centralis* Partial-range Zone	
ZONE P.16	*Cribrobantkenina inflata* Total-range Zone	Late Eocene
ZONE P.15	*Globigeropsis mexicana* Partial-range Zone	
ZONE P.14	*Truncorotaloides rohri - Globigerinita howeii* Partial-range Zone	— —?— — Middle
ZONE P.13	*Orbulinoides beckmanni* Total-range Zone	Eocene (part)

* after Blow, 1970

Fig. 3 Relation between formal taxon zones and letter/number system (from Blow, 1959).

The fauna of the Irian Jaya samples is of some interest in connexion with the problem of the Oligocene/Miocene boundary. Blow (1969) recently discussed the position of this boundary; he accepted the recommendation of the 'Comité du Néogène' that it be placed at the base of zone N.4—the '*Globigerinoides*-datum'—as this level marks the base of the stratotype Aquitanian. This datum is based on the evolutionary development of *Globigerinoides quadrilobatus primordius* from *Globigerina praebulloides occlusa* (Blow, 1969, 1970). The necessity for specific definition of the datum was pointed out by Jenkins (1970, 1971a). *Globigerinoides quadrilobatus primordius* was described from the Cipero Formation, Trinidad, from the type locality of the *Globorotalia kugleri* Zone. Jenkins (1964, 1966) recorded *Globigerinoides* cf. *primordius* from the upper part of the lower Aquitanian; Banner & Blow (1965a) stated that this occurrence is at about the middle of the stratotype Aquitanian. Blow (1969) later stated that *primordius* first appeared at a level very close to the base of the lectostratotype Aquitanian.

The recommendation of the 'Comité du Néogène' is as yet unratified; as noted by Berggren (1971) in another detailed discussion of Tertiary boundaries, the base of the stratotype Aquitanian does not necessarily correspond to the base of the Miocene. Eames (1970) in discussing the Neogene/Paleogene boundary noted that in the type section the base of the Aquitanian (zone N.4) rests on middle Oligocene (within zone P.19), so that at least three planktonic zones are missing in the section.

Much discussion has centred on the Bormidian Stage, and on the beds at Escornebéou in the Aquitaine Basin. The type section of the Bormidian was examined by Vervloet (1966), and Lorenz (1965) studied sections at Millesimo and Lodola. Vervloet concluded that the *Globigerinoides* surface could not serve as the base of the Miocene, and that the genus appeared in the late Oligocene. Blow & Smout (1968) and Eames (1970) noted that the Bormidian ranged from zone N.1 to zone N.4, and Eames stated that the uppermost part of the Bormidian type section should be included in the Aquitanian, and is equivalent to the 'Aquitaniaro' at Millesimo. Blow & Smout (1968) and Blow (1969) placed the Bormidian in the late Oligocene, but Eames (1970), for historical and faunal reasons, disagreed with this and agreed with Lorenz (1965) that the Bormidian is to be included in the Miocene. The Bormidian Stage would appear to represent that part of the section missing below the stratotype Aquitanian.

Many recent publications suggest that the '*Globigerinoides*-datum', which at present marks the base of the stratotype Aquitanian and the base of planktonic zone N.4, should be placed at a lower stratigraphical level. Butt (1966) recorded *Globigerinoides quadrilobatus primordius* from beds at Escornebéou which he considered to be better placed in the Oligocene (Chattian) rather than added to an extended Miocene (Aquitanian). Berggren (1971) has examined Butt's specimens, revised most of his identifications (but stated that *primordius* was present), and concluded (p. 739) 'that faunas as young as *G. kugleri* Zone equivalent are present, and that faunas as old as *G. ciperoensis* Zone age may be present, or reworked'. He also (p. 750) concluded that a mixed fauna occurred at different levels within the Escornebéou section, raising the possibility that this is a marginal deposit containing a condensed composite fauna with elements of more than a single planktonic zone. Scott (1972) statistically compared populations of *Globigerinoides quadrilobatus primordius* from Escornebéou and from localities in the type region of the Aquitanian near Saucats, and concluded that the Escornebéou population represents an earlier stage in the lineage than do the populations from Saucats. He therefore supported Butt's conclusion that the Escornebéou strata are inferior to the Aquitanian stratotype, and considered that the first occurrence of *G. quadrilobatus primordius* appears to be unreliable as a criterion for correlation of the base of the Aquitanian Stage, as at the stratotype. The possibility that morphological trends may permit the discrimination of earlier populations from those of the stratotype was raised.

Vigneaux, Moyes, & Pujol (1970) and Pujol (1970) recorded faunas including *G. quadrilobatus primordius* from bores in the Aquitaine basin, including that at Soustons; *primordius* may occur here in zones older than N.4, but unfortunately the level of the first appearance in the sequence is masked by drilling contamination. A planktonic foraminiferal biozone was recognized corresponding to an Oligocene/Miocene transition zone previously established on the basis of benthonic foraminifera and bryozoa. Drilling contamination also may account for the anomalous stratigraphical ranges shown for other species of

Globigerinoides in the Soustons bore (Vigneaux et al., 1966); Berggren (1971) suggested that the anomalous stratigraphical ranges result from different taxonomic concepts.

Papp, Steininger, & Rogl (1971) reporting on a meeting of the working group on Paratethys, defined the base of the Egerien on the first appearance of *Miogypsina* (*Miogypsinoides*) *complanata* Schlumberger, and of the *Globigerinoides* group, without listing any specific names. The Egerien was stated to range from the late Oligocene to the early Miocene. *M.* (*M.*) *complanata* has also been recorded from the beds at Escornebéou (Drooger, 1960; Butt, 1966), suggesting a late Oligocene age, but as already noted, the possibility that these beds contain a mixed fauna, including *Globigerinoides quadrilobatus primordius,* has been raised (Berggren, 1971). Cicha, Hagn, & Martini (1971) recorded *G. quadrilobatus primordius* in the Pausramer Beds of the Alpine-Carpathian region, ranging through the Egerien and Eggenburgien. The subspecies first appears rarely at the P19/20 level in association with *Globigerina gortanii gortanii, G. tripartita, G. ouachitaensis ciperoensis, Globorotaloides suteri,* and several other species. In the upper part of the Egerien, in zones P.21 (= N.2) and P.22 (= N.3), *G. quadrilobatus primordius* occurs more frequently. They also recorded an occurrence of *primordius* in an assemblage containing, among other species, *Globorotalia opima opima, G. opima nana, Globigerinita dissimilis dissimilis,* and *G. dissimilis ciperoensis.* Nicora (1971), discussing the Oligocene/Miocene boundary, recorded (p. 200) *Globigerinoides quadrilobatus primordius* in his zones 2 and 3 (Miocene), but on one chart (Table 11, p.238) showed this subspecies occurring in his zone 1 (upper Oligocene). Carloni, Cati, & Borsetti (1968) showed specimens referred to as *Globigerinoides quadrilobata* occurring with *Globigerina* aff. *gortanii, Globorotalia opima nana,* and *Globoquadrina* aff. *sellii* in the Oligocene. The base of their *Globigerinoides triloba* zone is marked by representatives of the genus *Globigerinoides;* a specimen referred to the subspecies *G. quadrilobatus primordius* was illustrated.

Baldi (1970) studied the Oligocene/Miocene boundary in Hungary on the basis of the molluscan faunas, and concluded that the Eger beds (among others) are late Oligocene in age, and correspond to the Chattian of the North Sea Basin and the level of Escornebéou and Peyrere in the Aquitaine Basin. Baldi noted a boreal faunal predominance, and concluded that a connexion existed between Paratethys and the North Sea during the upper Oligocene. He also noted an increase in Mediterranean faunal influence in younger beds and from this concluded that a marine connexion existed between Paratethys and Tethys at least during the late Oligocene. Baldi also stated that a connexion existed with the Indo-Pacific Province from Chattian-Aquitanian to the end of the Helvetian; the planktonic foraminiferal fauna recorded from the Nassau Range area supports the view that a connexion was established not later than the Chattian.

Senes (1969) stated that Paratethys maintained communication with the Mediterranean to the end of the lower 'Tortonian', via the North Adriatic area. Communication with the Indo-Pacific region seems to have been active especially during the Burdigalian (Eggenburgian).

Adams (1970) gave the range of *Miogypsina* (*Miogypsinoides*) *complanata* in the Indo-Pacific region as ?Tertiary *d* and Tertiary lower *e,* that is ?middle and late Oligocene. He also stated (p. 121) that the *Globigerinoides quadrilobatus* group 'had certainly made its appearance in the Far East before *M. dehaarti* evolved' and gave the opinion that the planktonic zone N.4 must straddle the lower *e*/upper *e* boundary, that is the late Oligocene/early Miocene boundary. *Miogypsina* (*Miogypsinoides*) *dehaarti* occurs in the Tertiary upper *e* and possibly lower *f*, but is not known to occur before the early Miocene.

Poag (1972) recorded a fauna of late Oligocene age containing *primordius* from core 5, site 98, leg 11 of the Deep-Sea Drilling Project. The Oligocene/Miocene boundary was tentatively placed at 96.83 m; below this level the frequency of occurrence of *Globigerinoides quadrilobatus primordius* is abruptly reduced, and that of *Globigerina tripartita* increases. Other species occurring in the late Oligocene fauna are *Globigerina sellii* and *G. gortanii.*

The stratigraphical ranges of the species recorded from the Irian Jaya samples, as given by Blow (1969) are:

Globigerina angustiumbilicata: upper part P.16-N.22 (probably also N.23).

G. gortanii gortanii: base P.17-near N.2/N.3 boundary; probably extinct earliest N.3.

G. ouachitaensis ciperoensis (forma *atypica*): within N.3-within N.5.

G. praebulloides occlusa: P. 13-N.19.

G. sellii: P.16-within N.3 (Blow, 1969, p.222; in deep sea cores *G. sellii* seems to survive into earliest parts of zone N.4).

G. tripartita: P.14-N.3.

G. venezuelana: N.3-N.19.

Globigerinoides quadrilobatus primordius: base of N.4-early N.5.

Globorotalia (*Turborotalia*) *kugleri*: within N.3-top N.4.

G. (*T.*) *obesa*: within N.2-N.23.

G. (*T.*) *opima nana*: P.15 (?later P.14)-early N.3.

G. (*T.*) *siakensis*: latest N.2-top N.14.

Globigerinita dissimilis dissimilis: P.13-?top N.6.

G. dissimilis ciperoensis: lower to middle P.19-within N.6.

G. unicava unicava: within N.1-top N.6.

Globorotaloides suteri: near base P.13-within N.8.

On the basis of these ranges the Irian Jaya samples are regarded as lower zone N.3 in age.

The range of *Globigerinoides quadrilobatus primordius* as given by Blow does not overlap with that of such species as *Globigerina gortanii gortanii, G. tripartita, G. sellii,* and *Globorotalia* (*Turborotalia*) *opima nana*. However, many published papers indicate that in fact the stratigraphical ranges of these species do overlap. Difference of taxonomic interpretation is one difficulty to be considered in attempting to reconcile conflicting stratigraphical ranges given by different workers. Thus, the extension of the range of *Globigerina tripartita* Koch above zone N.3 was considered by Blow (1969) to result from misidentification of specimens of *Globoquadrina dehiscens praedehiscens*. Many papers show *Globorotalia* (*Turborotalia*) *opima nana* occurring at levels above zone N.3; Blow (1969) also referred to pseudomorphic forms superficially similar to *G.* (*T.*) *opima nana* in gross morphology, and occurring in zones N.4 and N.5.

In addition, in the Irian Jaya samples, the possibility that this is a mixed fauna resulting from the reworking of older specimens cannot be overlooked. Limestones in this area are known to contain reworked specimens. However, there is no indication of such faunal mixing from the nature of preservation of the planktonic specimens. The numerous records of faunas very similar to that recorded here suggest that the Irian Jaya occurrence is to be regarded as a natural association.

The faunal evidence from the Irian Jaya material, consisting as it does of few samples, not collected in stratigraphical sequence, cannot be expected on its own to have any major bearing on the problem of the Palaeogene/Neogene boundary; this can be solved only in the type areas. Nevertheless, it gives additional evidence concerning the occurrence of the genus *Globigerinoides,* and in particular the subspecies *G. quadrilobatus primordius.*

In my opinion the present usage of the '*Globigerinoides*-datum' for marking the base of the Miocene is open to question. If the first appearance of the subspecies *primordius* is to be kept as the criterion for the base of the Miocene, it would seem that the Oligocene/Miocene boundary should be lowered from the base of zone N.4. On present knowledge of the stratigraphical distribution of planktonic species, the Oligocene/Miocene boundary on this criterion would be at a level near the N.2/N.3 boundary. Another possibility is a level within the planktonic zone N.1, as originally proposed by Banner & Blow (1965a), as used by Berggren (1971) (although he added a postscript, p. 775, following the redefinition by Blow to the base of zone N.4), and as Eames (1970) maintained should still be the case. Considering the number of papers having a bearing on this problem which have been published, without general agreement being reached, it may be best to accept a level such as that proposed by the 'Comité du Néogène', or some other stratigraphical level which may be thought suitable.

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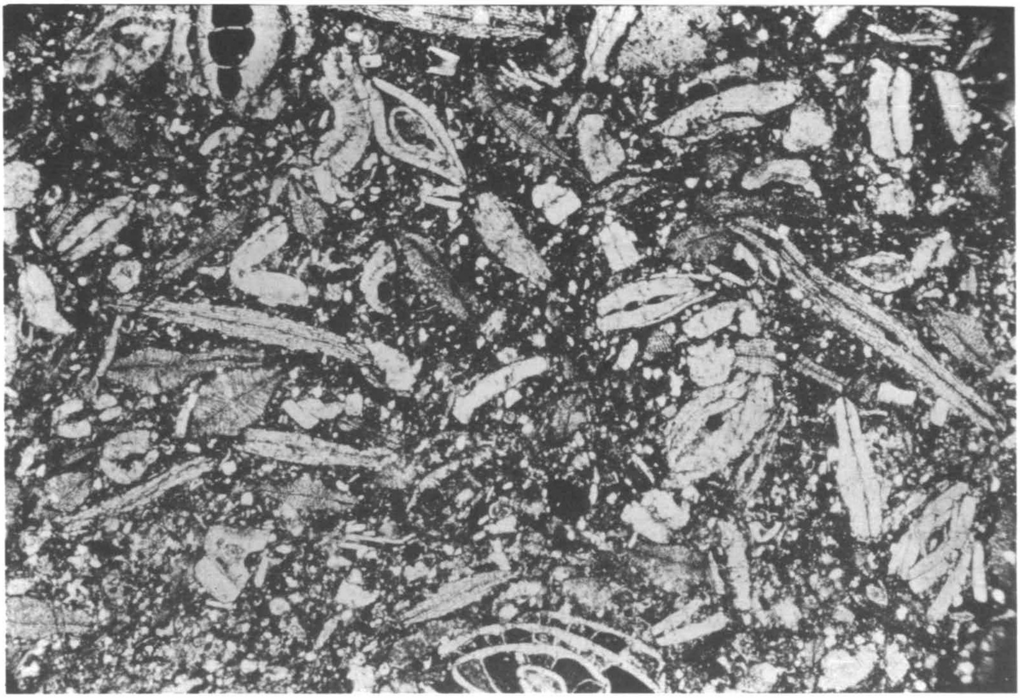
PLATE 1

Fig. 1 Sample C4c. *Discocyclina, Nummulites* etc. Eocene. x about 13.

Fig. 2 Sample C15. Large *Discocyclina* and *Operculina*. Eocene x about 13.



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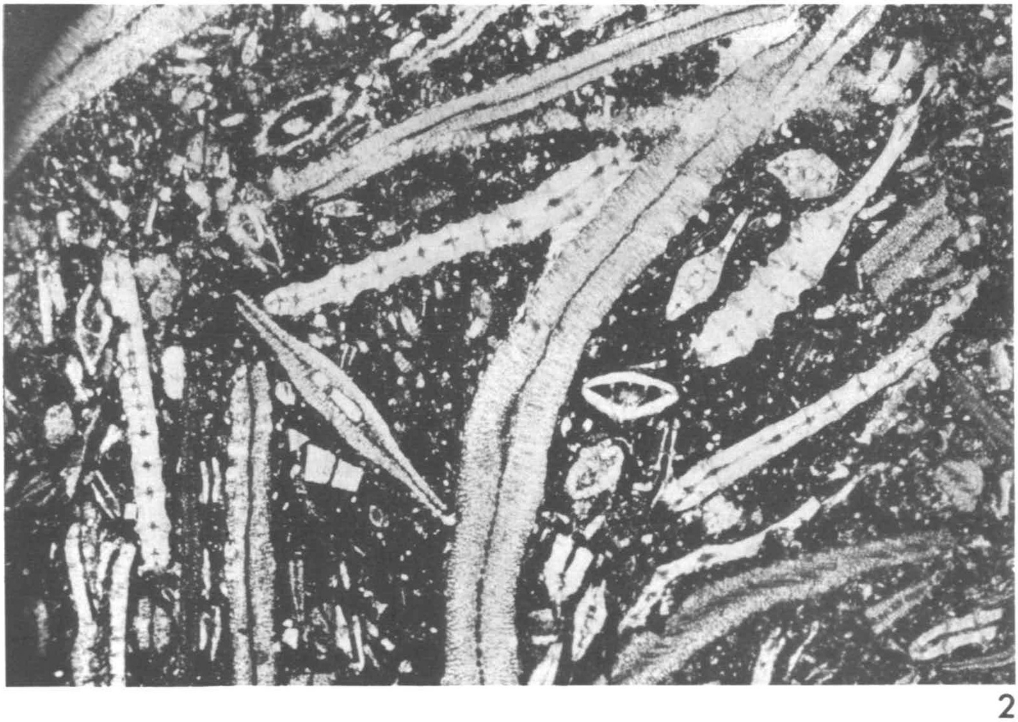

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PLATE 2

Fig. 1	*Discocyclina* (*?Asterocyclina*) sp., CPC 13528; sample C3. x 20.
Fig. 2	*Asterocyclina* sp., CPC 13529; sample C3. x 20.
Fig. 3	*Nummulites javanus* Verbeek, CPC 13530; sample C3. x 20.
Fig. 4, 5	*Halkyardia* cf. *minima* (Liebus), CPC 13531 and 13532; 4, cample C3, 5, sample C4b. Both x 50.
Fig. 6	Genus indet., CPC 13533; sample C3. x 50.
Fig. 7, 10	*Spiroclypeus vermicularis* Tan, CPC 13534 and 13535, sample C4b. x 20.
Fig. 8	*Operculina* sp., CPC 13536; sample C4b. x 20.
Fig. 9	Genus indet., cf. *Lockhartia,* CPC 13537; sample C4b. x 50.
Fig. 11, 12	*Discocyclina* sp., CPC 13538 and 13539; 11, sample C4b. 12, sample C15. Both x 20.
Fig. 13	*Lacazinella wichmanni* (Schlumberger), CPC 13540; sample C15. x 20.
Fig. 14	*Distichoplax biserialis* (Dietrich), CPC 13541; sample C4c. x 200.

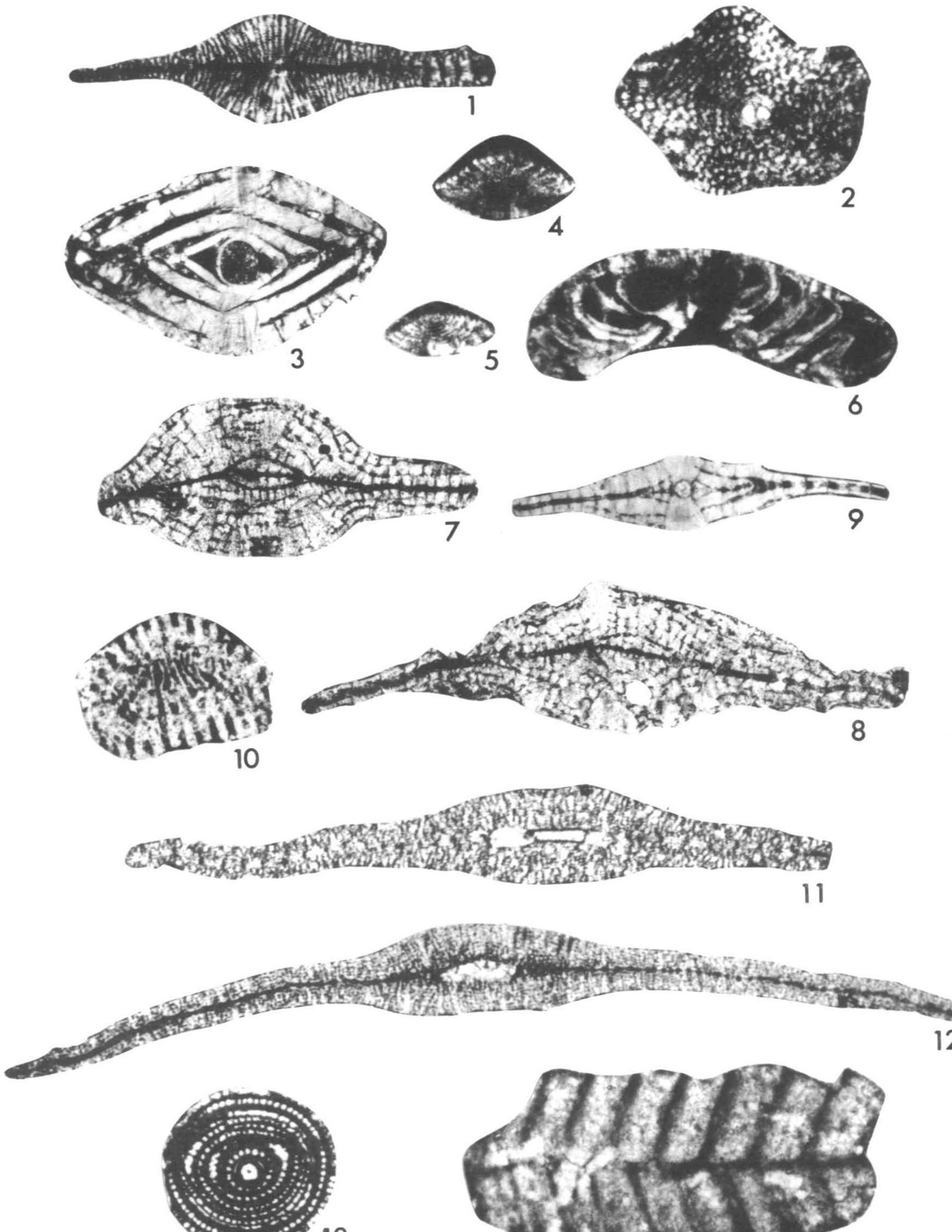
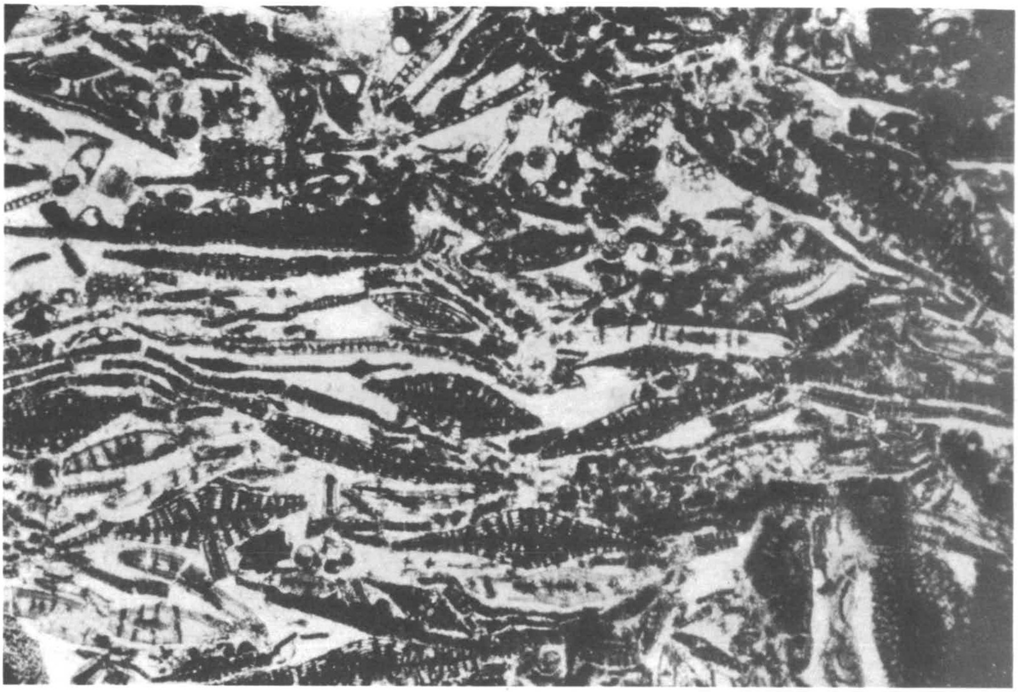


PLATE 3

Fig. 1 Sample C10. *Lepidocyclina, Operculina, Amphistegina* etc. Lower to Middle Miocene. x about 12.

Fig. 2 Sample C1. *Spiroclypeus margaritatus* (Schlumberger), *Lepidocyclina* (*Eulepidina*), reworked *Discocyclina,* etc. Upper Oligocene. x about 12.



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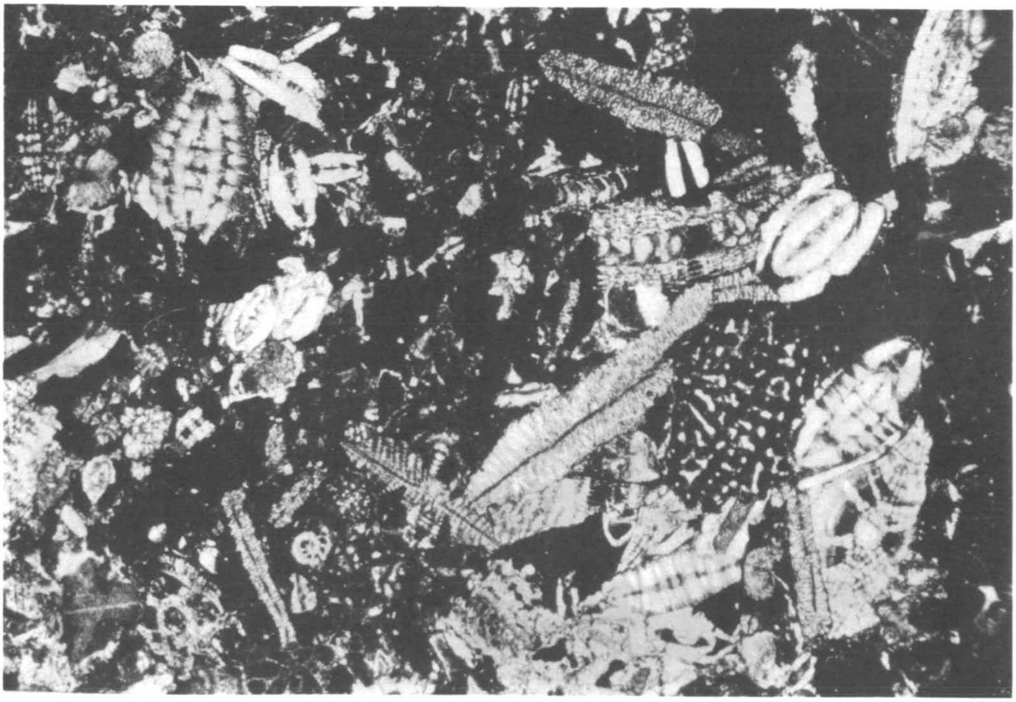

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PLATE 4

Fig. 1, 2	Genus indet., CPC 13542 and 13543; sample C11. x 20.
Fig. 3	*Operculina* sp., CPC 13544; sample C12a. x 20.
Fig. 4	*Lepidocyclina* (*Eulepidina*) cf. *ephippioides* (Jones & Chapman), CPC 13545; sample C1. x 10.
Fig. 5	*Biplanispira mirabilis* (Umbgrove), CPC 13546; sample C1 (reworked). x 20.
Fig. 6	*Discocyclina* sp., CPC 13547; sample C1 (reworked), x 20.
Fig. 7	*Nummulites fichteli* Michelotti, CPC 13548; sample C1 (reworked). x 20.
Fig. 8	Sample C16, planktonic foraminiferal limestone. Upper Oligocene. x about 13.

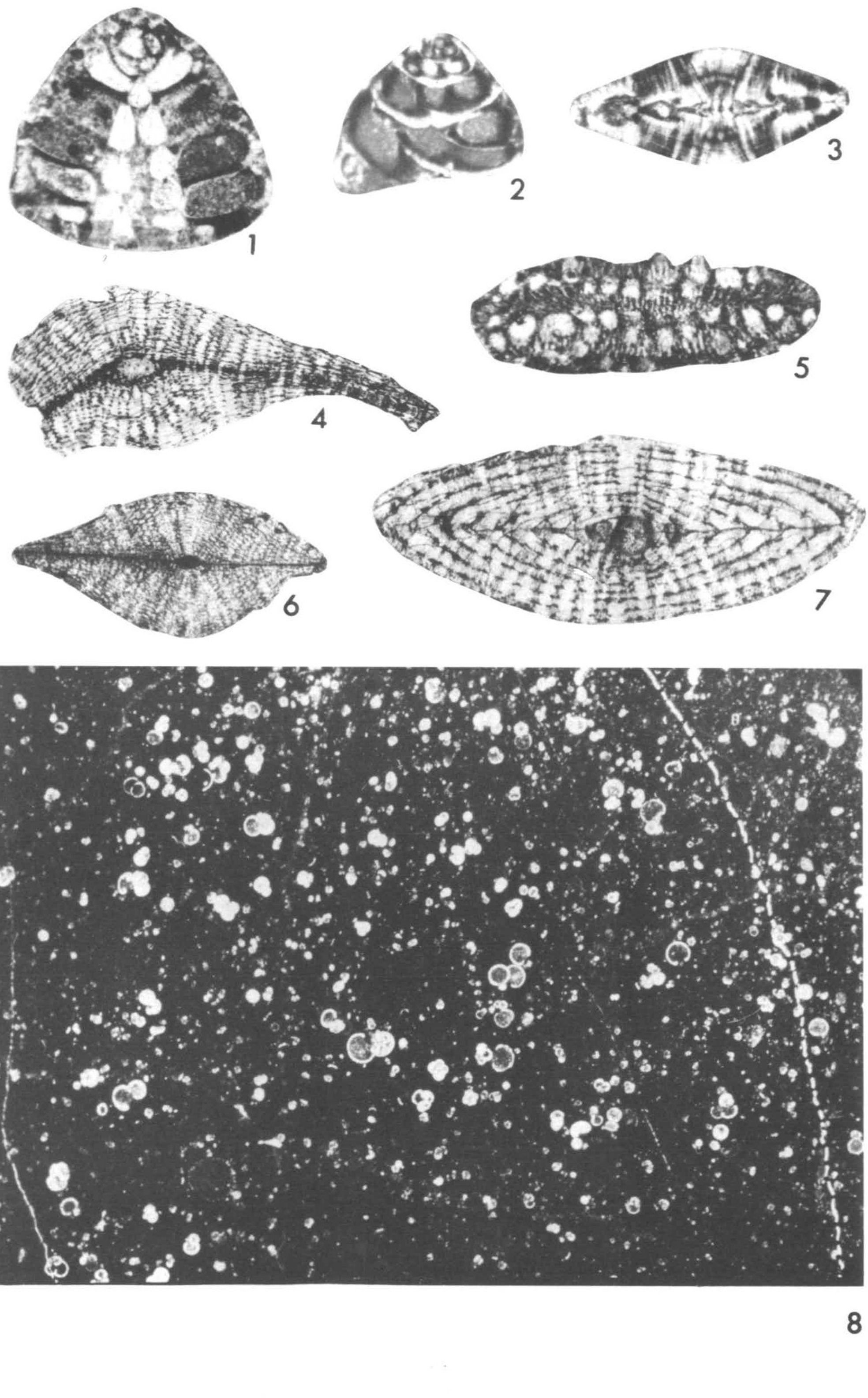
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PLATE 5

(all figures x 80)

Fig. 1-5 *Globigerina praebulloides occlusa* Blow & Banner, 1-3, CPC 13549; sample C17a; 1, ventral view; 2, dorsal view; 3, edge view. 4-5, CPC 13550; sample C17b. 4, ventral view; 5, dorsal view.

Fig. 6-8 *Globigerina venezuelana* Hedberg, CPC 13551; sample C17a. 6, ventral view; 7, dorsal view; 8, edge view.

Fig. 9-14 *Globigerina tripartita* Koch, 9-11, CPC 13552; sample C17a; 9 ventral view, showing reduced final chamber; 10, dorsal view; 11, edge view. 12-14, CPC 13553; sample C17a; 12, ventral view; 13, dorsal view; 14, edge view.

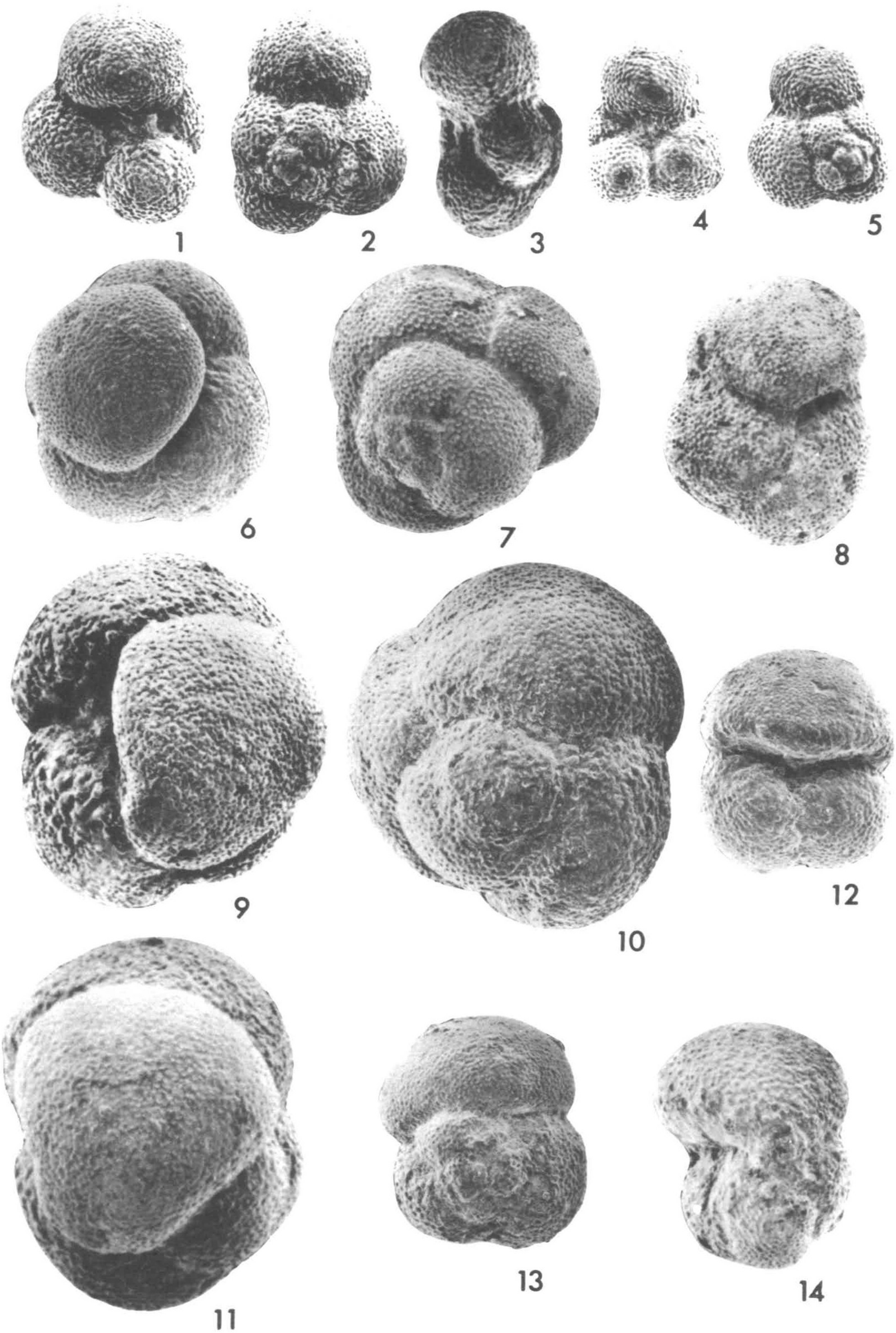

PLATE 6

(all figures x 80)

Fig. 1-8 *Globigerina sellii* (Borsetti), 1-3, CPC 13554; sample C17b; 1, ventral view, showing aperture in re-entrant; 2, dorsal view; 3, edge view; 4-6, CPC 13555; sample C17b; 4, ventral view showing finely reticulate final chamber covering umbilicus; 5, dorsal view; 6, edge view.
7-8, CPC 13556; sample C17a; 7, ventral view; 8, dorsal view.

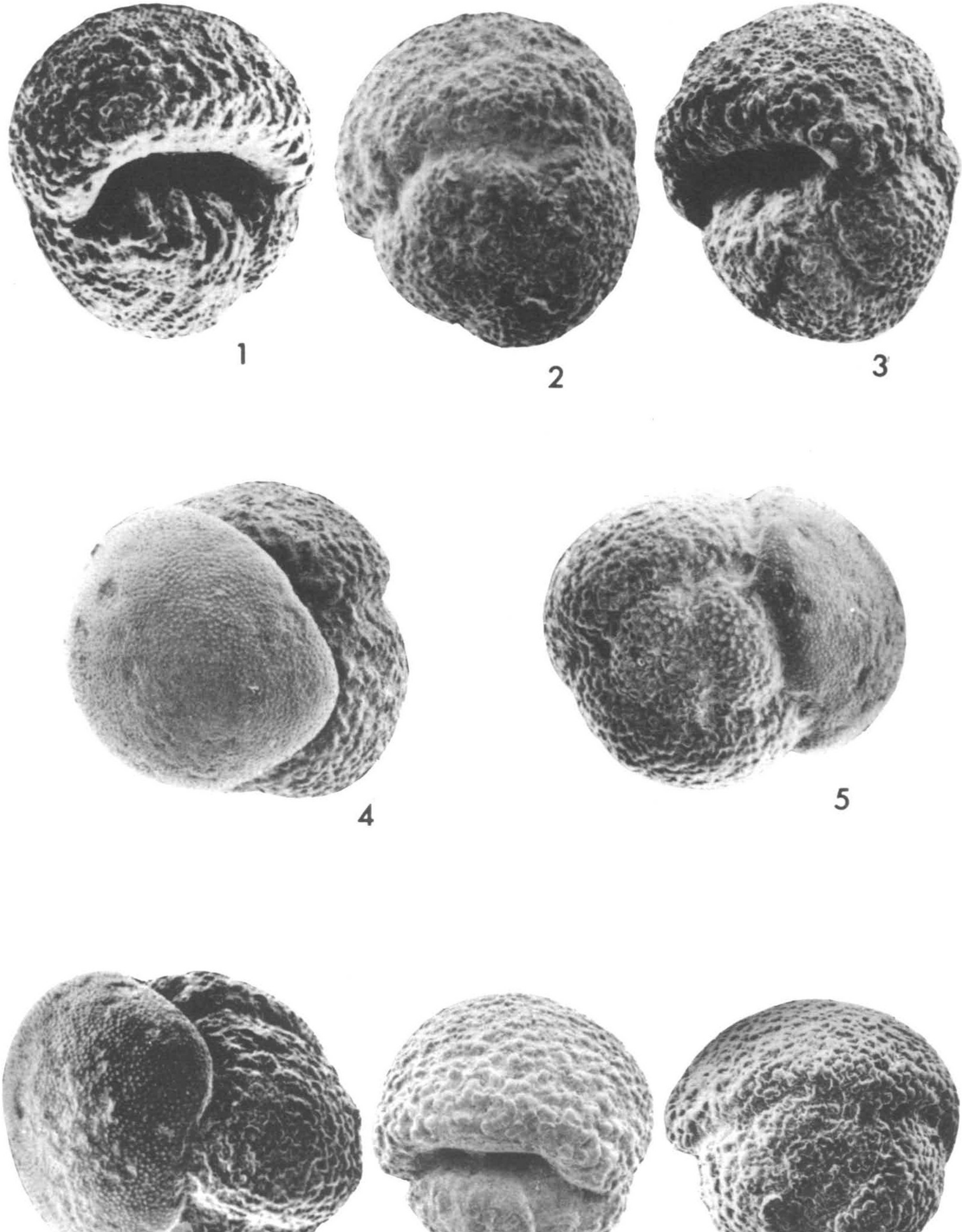
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PLATE 7

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Fig. 1-10 *Globigerina sastrii* Raju.
1-3, CPC 13557; sample C17b; 1, ventral view; 2, dorsal view; 3, edge view.
4-5, CPC 13558; sample C17b; 4, ventral view; 5, dorsal view.
6-8, CPC 13559; sample C17b; 6, ventral view; 7, dorsal view; 8, edge view.
9-10, CPC 13560, young specimen, sample C17b; 9, ventral view, showing low elongate aperture and pustules along apertural face; 10, dorsal view, showing rapid increase in size and degree of overlap of chambers.

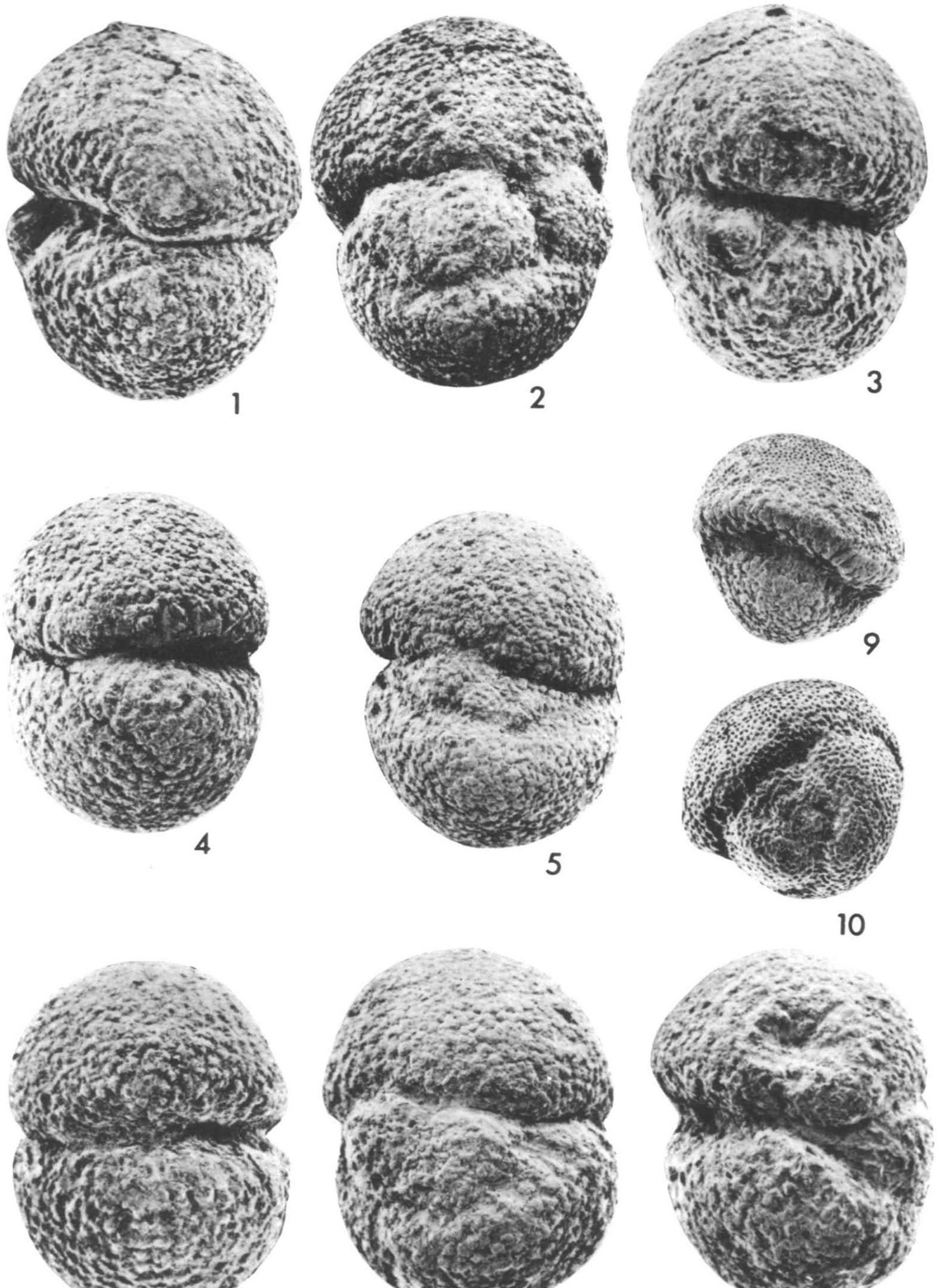
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PLATE 8

(all figures x 80)

Fig. 1-6 *Globigerina gortanii gortanii* (Borsetti).
1-3, CPC 13561; sample C17a; 1, ventral view; 2, dorsal view; 3, edge view.
4-5, CPC 13562; sample C17a; 4, ventral view; 5, edge view.
6, CPC 13563, sample C17a; ventral view.

Fig. 7-12 *Globigerina angustiumbilicata* Bolli.
7-9, CPC 13564; sample C17a; 7, ventral view; 8, dorsal view; 9, edge view.
10-12, CPC 13565; sample C17a; 10, ventral view; 11, dorsal view; 12, edge view.

Fig. 13-18 *Globigerina ouachitaensis ciperoensis* Bolli.
13-15, CPC 13566; sample C17a; 13, ventral view; 14, dorsal view; 15, edge view.
16-18, CPC 13567; sample C17b; 16, ventral view; 17, dorsal view; 18, edge view.

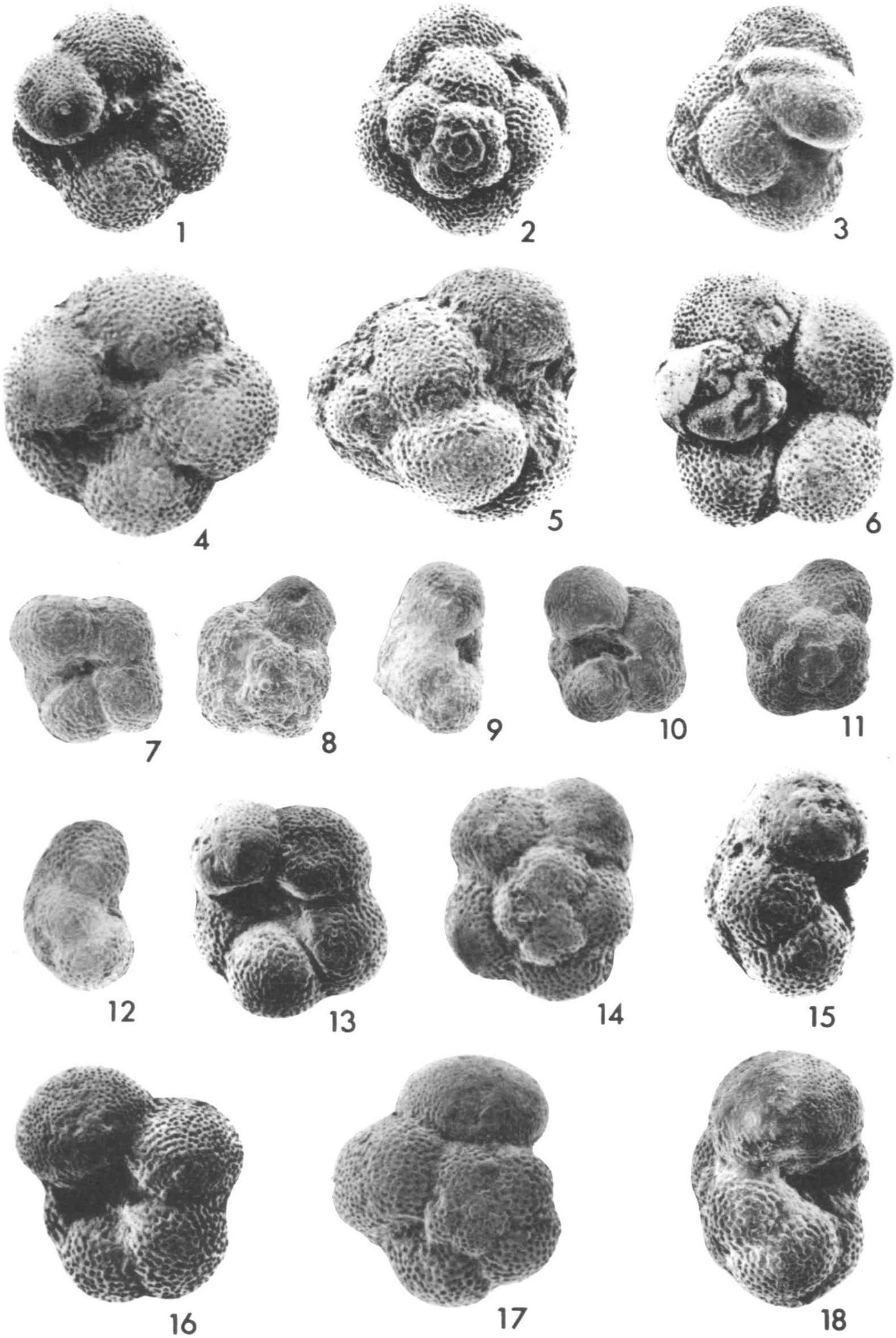
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PLATE 9

(all figures x 80)

Fig. 1-16 *Globigerinoides quadrilobatus primordius* Blow & Banner.
1-2, CPC 13568; sample C17b; 1, ventral view; 2, dorsal view. Small specimen showing development of *primordius* from *Globigerina praebulloides occlusa.*
3-5, CPC 13569; sample C17a; 3, ventral view, showing large arched primary aperture; 4, dorsal view; 5, edge view.
6, CPC 13570; sample C17b; ventral view showing large primary aperture.
7-9, CPC 13571; sample C17b; 7, ventral view; 8, dorsal view; 9, edge view.
10-12, CPC 13572; sample C17b; 10, ventral view; 11, dorsal view; 12, edge view.
13-14, CPC 13573; sample C17b, specimen with large final chamber. 13, ventral view; 14, edge view.
15-16, CPC 13574; sample C17b, specimen with large final chamber. 15, ventral view; 16, edge view.

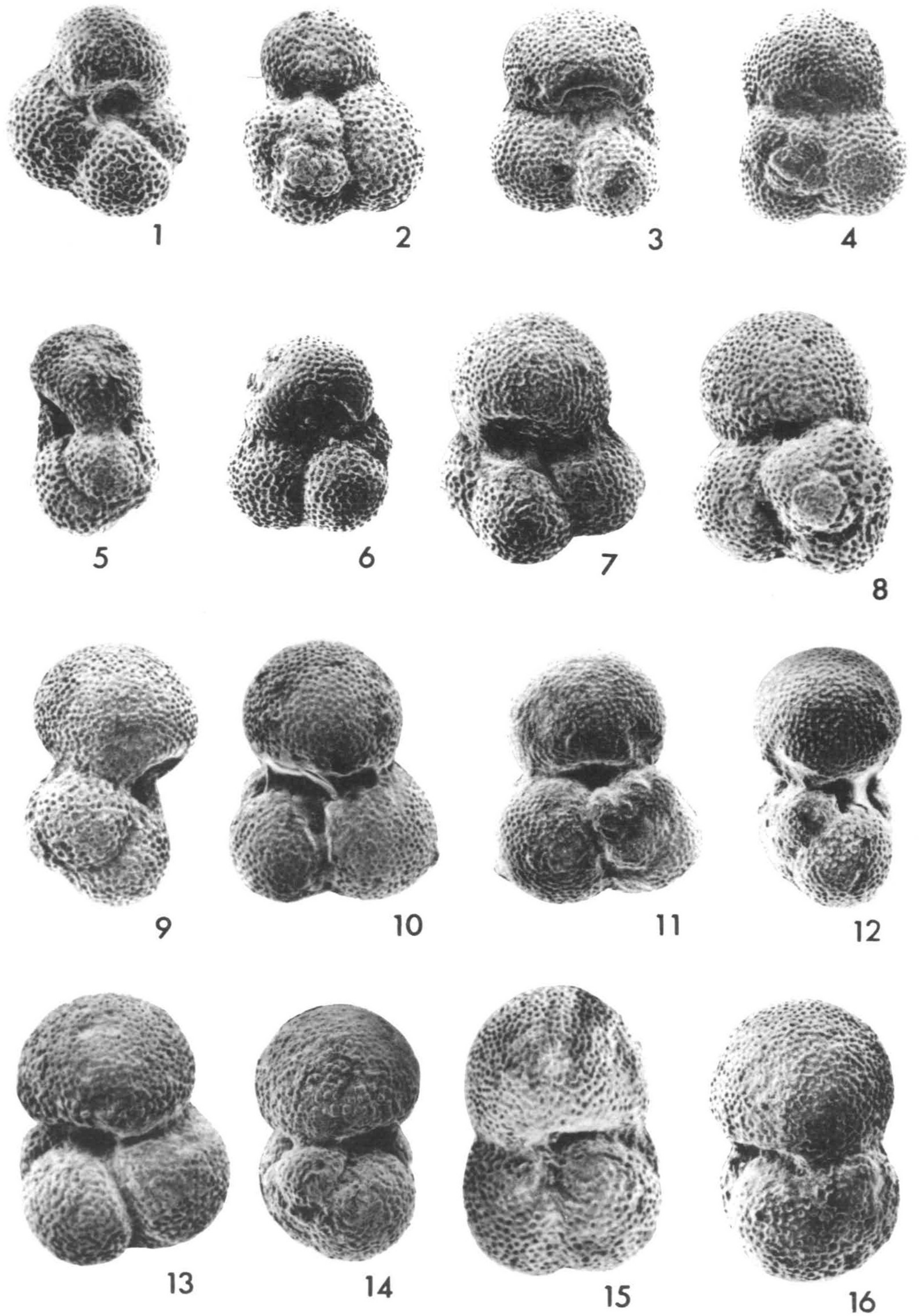
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PLATE 10

(all figures x 80)

Fig. 1-5 *Globigerinoides* sp.
1-3, CPC 13575; sample C17a; 1, ventral view; 2, dorsal view, showing two supplementary apertures; 3, edge view.
4-5, CPC 13576; sample C17a; 4, ventral view; 5, dorsal view, showing two supplementary apertures.

Fig. 6-9 *Globorotalia* (*Turborotalia*) *kugleri* Bolli.
6-8, CPC 13577; sample C17b; 6, ventral view; 7, dorsal view; 8, edge view.
9, CPC 13578; sample C17b, ventral view.

Fig. 10-14 *Globorotalia* (*Turborotalia*) *obesa* Bolli.
10-12, CPC 13579; sample C18b; 10, ventral view; 11, dorsal view; 12, edge view.
13-14, CPC 13580; sample C18b; 13, ventral view; 14, edge view.

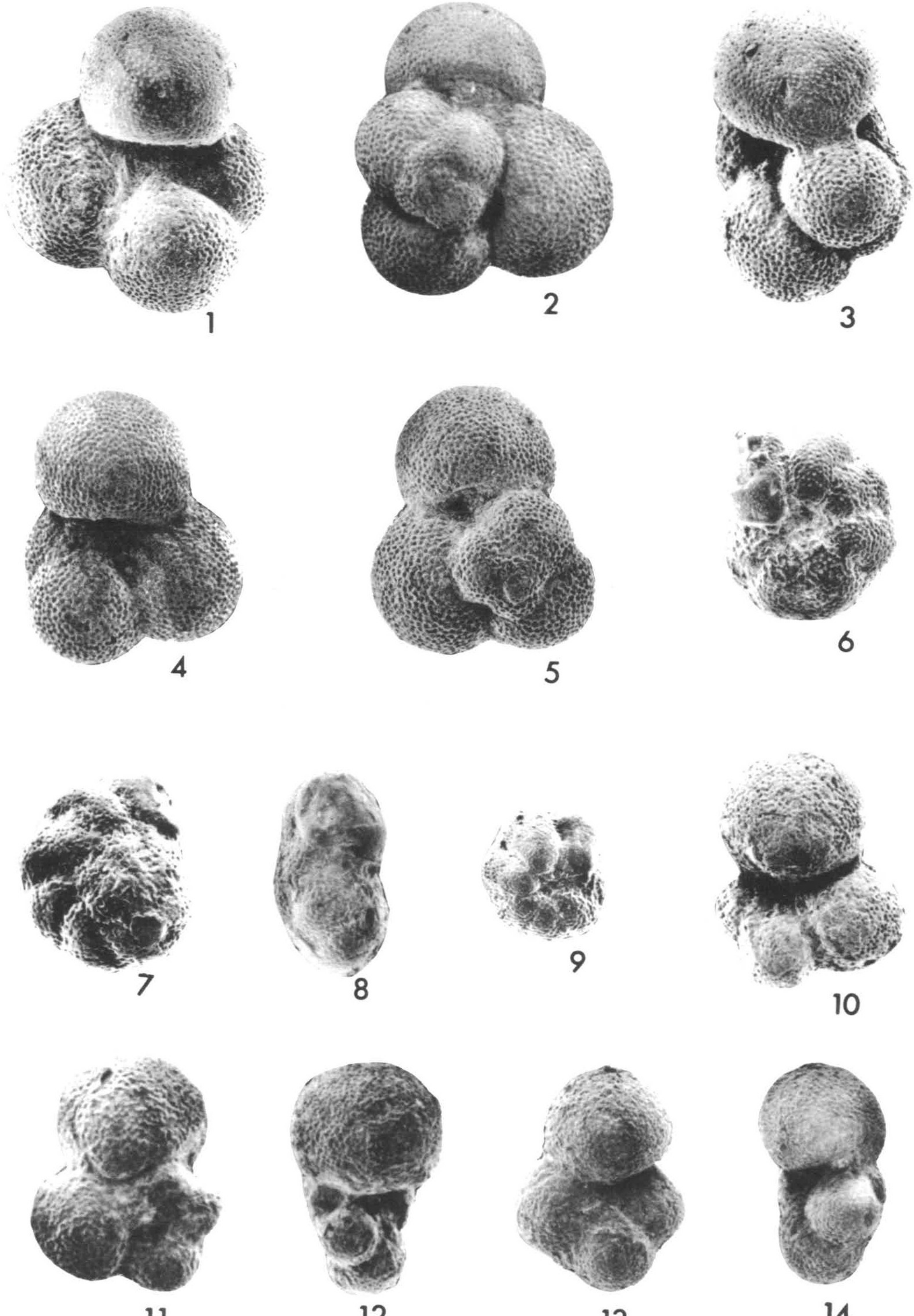
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PLATE 11

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Fig. 1-4 *Globorotalia (Turborotalia) siakensis* (Le Roy).
1-3, CPC 13581; sample C17b; 1, ventral view; 2, dorsal view; 3, edge view.
4, CPC 13582, sample C17b, ventral view.

Fig. 5-9 *Globorotalia (Turborotalia) opima nana* Bolli.
5-7, CPC 13583; sample C17b; 5, ventral view; 6, dorsal view; 7, edge view.
8-9, CPC 13584; sample C17a; 8, ventral view; 9, dorsal view.

Fig. 10-15 *Globorotaloides suteri* Bolli.
10-12, CPC 13585; sample C17a; 10, ventral view; 11, dorsal view; 12, edge view.
13-14, CPC 13586; sample C17a; 13, ventral view; 14, edge view.
15, CPC 13587; sample C17b, ventral view, small specimen showing *Globigerina* stage.

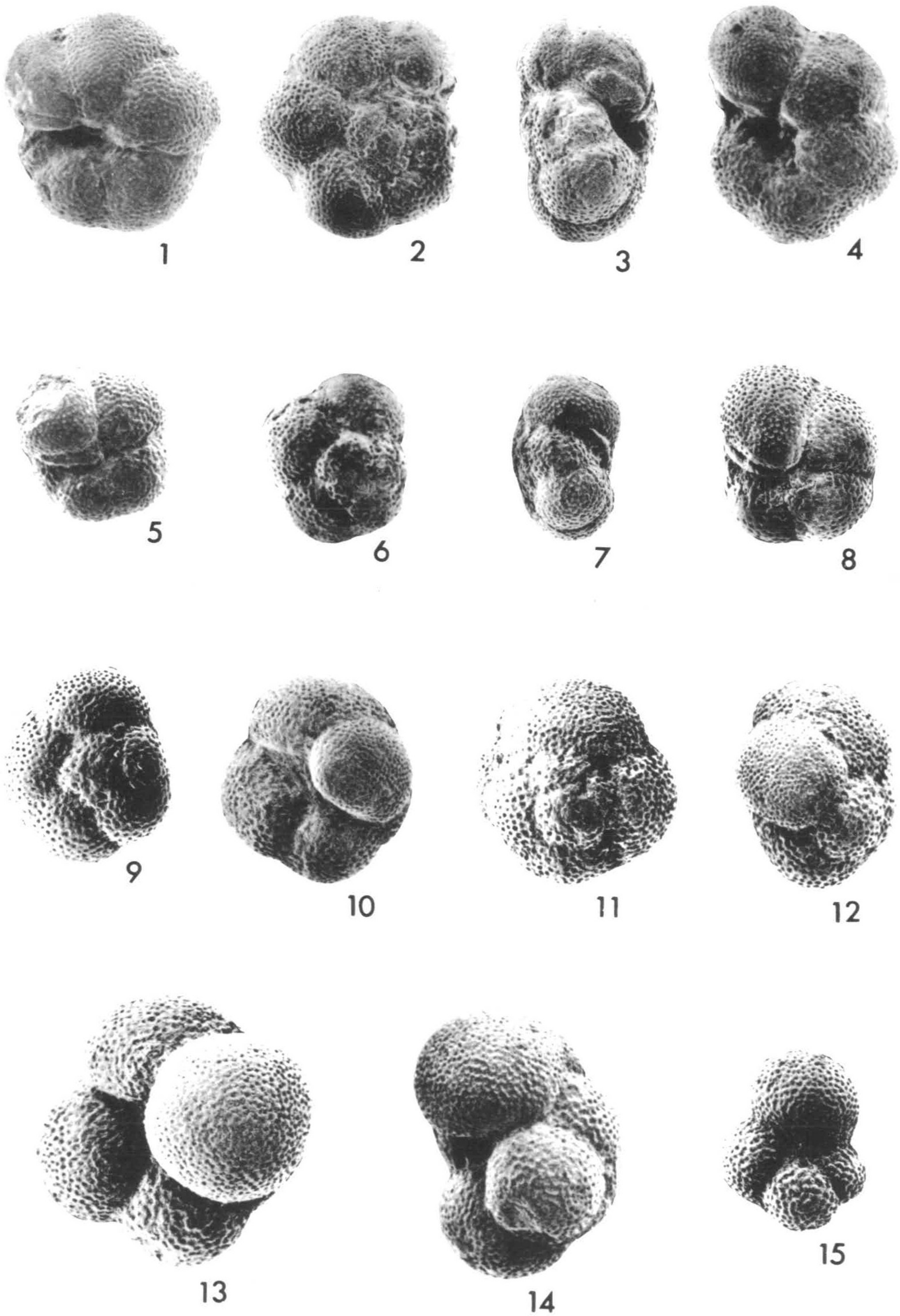
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PLATE 12

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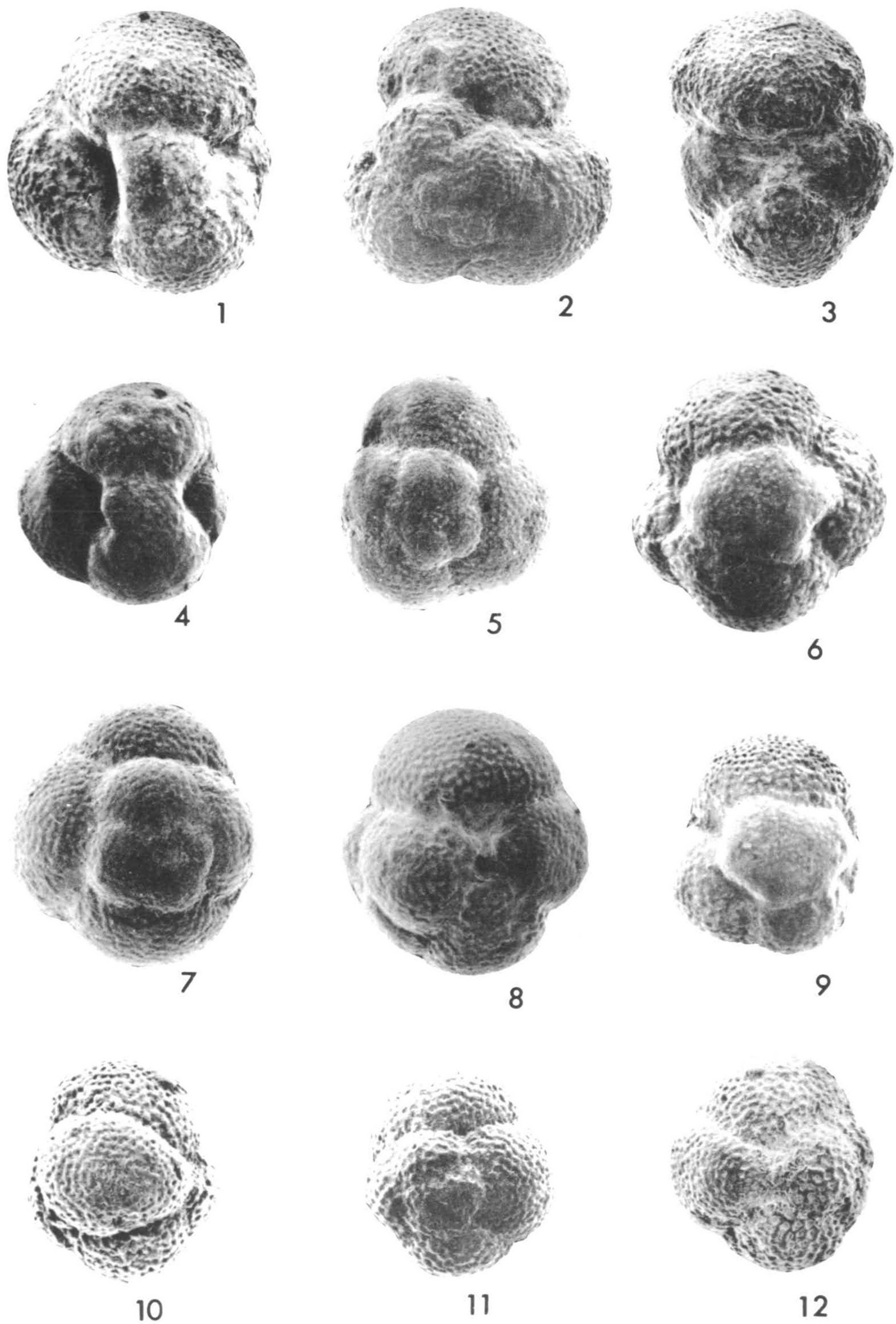
Fig. 1-9 *Globigerinita dissimilis* (Cushman & Bermudez).
1-3, CPC 13588; sample C18b; 1, ventral view; 2, dorsal view; 3, edge view.
4-5, CPC 13589; sample C17b; 4, ventral view; 5, dorsal view.
6-8, CPC 13590; sample C17b; 6, ventral view; 7, dorsal view; 8, edge view.
9, CPC 13591; sample C17b, ventral view.

Fig. 10-12 *Globigerinita unicava unicava* (Bolli, Loeblich & Tappan).
CPC 13592; 10, ventral view; 11, dorsal view; 12, edge view.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PALYNOLOGY OF SUBSURFACE LOWER CRETACEOUS STRATA IN THE SURAT BASIN, QUEENSLAND

by

D. Burger

SUMMARY

This paper discusses the palynology of two boreholes, DRD 27 and GSQ Roma 3, drilled in Lower Cretaceous sediments of the Roma area, Surat Basin. The palynological sequence associated with these sediments includes the *Murospora florida* Zone and part of palynological unit K1b-c. Three Subzones of the *Murospora florida* Zone, formerly described, were recognized. The *Cicatricosisporites australiensis* Subzone, dated as early Neocomian, is associated mainly with the Mooga Sandstone; the *Foraminisporis wonthaggiensis Subzone* of middle Neocomian age, and the *Foraminisporis asymmetricus* Subzone, dated as late Neocomian (Barremian) to early Aptian, are associated with the Bungil Formation. Unit K1b-c, which on faunal evidence is dated as Aptian, is associated with the uppermost part of the Bungil Formation and the lower part of the Wallumbilla Formation.

Statistical analyses of microfloral assemblages from these bores, and a third bore, BMR Roma 1, showed variations in abundance of certain spore-pollen groups in the microfloral record, which presumably reflect major events in the history of the regional vegetation. Variations in relative abundance of microplankton suggest several small local incursions of the sea during the Neocomian, culminating in a major transgression which flooded the entire area in the Aptian.

INTRODUCTION

This paper deals with the palynology of the upper part of a thick sequence of mainly sandstone and siltstone, which was mapped in the northern Surat Basin, Queensland, by Day (1964) and Exon, Milligan, Casey, & Galloway (1967). It forms a complementary study to an earlier work on stratigraphic palynology of the early Cretaceous in the Great Artesian Basin, southeastern and central Queensland (Burger, 1973). The interval examined included the Mooga Sandstone and the Bungil Formation, which consists, in ascending stratigraphic order, of the Kingull Member, Nullawurt Sandstone Member, and Minmi Member. Lithological descriptions and nomenclature are given in Day (1964), Exon et al. (op. cit.), and Exon & Vine (1970).

Recently, the Geological Survey of Queensland undertook a drilling program in the Palaeozoic and Mesozoic of the Bowen and Surat Basins, southeastern Queensland, in order to obtain a reference section for correlation of strata drilled in the search for oil (Gray, 1972). Cores taken in the Mooga Sandstone and Bungil Formation in the Roma area were made available for palynological study. Twelve splits of cores were received from DRD 27 Stratigraphic Bore, and eleven from GSQ Roma 3 Stratigraphic Bore. The locations of these and other bores referred to in this paper are shown in Figure 2.

Macropalaeontological knowledge of this sequence, which was summarized by Burger (1973), is virtually non-existent. Sporadic plant remains in the Mooga Sandstone and Bungil Formation are thought to have Cretaceous affinities (Whitehouse, 1955; Day, 1964; White, 1967). From the few freshwater pelecypods collected in the Roma-Wallumbilla area no age conclusions could be drawn. Of more importance is the occurrence of Cretaceous (early Aptian) marine fossils in the Minmi Member in this area (Day, 1967) and the discovery of a marine Cretaceous (probably Neocomian) fauna in the Nullawurt Sandstone Member, northeast of Mitchell township (Day, 1969).

Palynological study of the interval in subsurface has been very successful. Dettmann (1963) recovered well preserved microfloral assemblages from equivalent sediments in northeastern South Australia. Evans (1966a, b) recovered identical microfloras from the Mooga Sandstone and Bungil Formation and the Hooray Sandstone in the Surat and Eromanga Basins, Queensland. Burger (op. cit.) reviewed much of the material from Queensland, available from drilling by the Bureau of Mineral Resources and various oil exploration companies. This resulted in a subdivision of the contemporaneous palynological interval, based on limited vertical ranges of certain selected species, and serving as a basis for correlation of the associated strata in subsurface. The aim of the present study was fourfold:

1. To record, as completely as possible, the spores, pollen, and microplankton in the samples and thus obtain additional control on the palynological zonation of the early Cretaceous in Queensland.

2. To extract further palynological details from the Mooga Sandstone and Bungil Formation in the Mimosa Syncline; previous drilling in the syncline by the Bureau of Mineral Resources (BMR Roma 8) yielded very little information (Burger, op. cit.).

3. To arrive at a more accurate correlation of the early Cretaceous microfloral sequence in Queensland with palynological schemes described from the Lower Cretaceous of South Australia, Victoria, and Western Australia.
4. To compare environmental and palaeogeographical data based on presence and abundance of microplankton in the microfloral assemblages with those obtained from other palaeontological and field evidence.

More or less successful results were achieved on items 1, 2, and 4. As for item 3, the disappointingly low retrieval of certain zone-indicative species did not offer any possibility of refining the broad correlation of the palynological schemes in eastern Australia as it stands today (see page 33).

METHODS AND TECHNIQUES

Specifications of 23 samples from DRD 27 and GSQ Roma 3, selected for palynological analysis, are given in Table 3; their stratigraphic position in the rock sequence is shown in Figure 3. About 0.5 to 1 cm^3 of each sample was crumbled with pestle and mortar, and treated with Schulze solution (for 10 minutes), hydrofluoric acid solution (15%, for 1 hour), and hydrochloric acid solution (15%). The sludge was then washed and the organic residue was separated from the mineral fraction by means of an alcohol-bromoform mixture (S.G. 1.95). The organic float was decanted and, in most cases, again treated with hydrofluoric acid solution to remove remaining argillaceous matter. From each residue three strew mounts were prepared; these bear the same number (MFP) as the corresponding sample listed in the BMR Palynological Sample Register. Two sets of mounts are at present kept in the BMR Palynological collection, and one set is kept in the Geological Survey in Queensland.

Two slides of each sample were scanned and the presence of fossil species recorded in the distribution charts (Table 3). The occurrence of species in BMR Roma 1, BMR Mitchell 11, and BMR Roma 8 were given in Burger (op. cit.).

No systematic observations have been included in this paper; reference is made to detailed taxonomic and systematic study of Lower Cretaceous spores and pollen grains in eastern Australia by Cookson & Dettmann (1958) and Dettmann (1963). Despite generally poor preservation of the recovered microfossils, illustrations are added of some of the stratigraphically significant species in DRD 27 and GSQ Roma 3 (Pls 13-15). The locations of individual specimens in the preparations are expressed in mechanical stage co-ordinates of Leitz Ortholux binocular microscope No. 741826, currently used by the author.

PALYNOLOGICAL ZONATION

In his palynostratigraphic scheme of the Mesozoic in Queensland, Evans (1966a) placed the basal Cretaceous microfloral succession in the Great Artesian Basin in a broad interval, which he referred to as palynological unit K1a and defined as that part of the sequence where the upper part of the range of *Murospora florida* coincides with the lower part of that of *Cicatricosisporites australiensis*. Outside the Great Artesian Basin the unit was traced in the Papuan Basin (Evans, 1966d) and in the Otway Basin, Victoria (Evans, 1966c). Balme (1957) described equivalent microfloral assemblages from the Perth and Carnarvon Basins, Western Australia. Dettmann (1963) and Dettmann & Playford (1969) described assemblages equivalent to unit K1a as part of their *Crybelosporites stylosus* Zone and *Dictyotosporites speciosus* Zone from the early Cretaceous of Victoria and South Australia.

From its stratigraphic position, and from Balme's and Dettmann's work it could already be assumed that unit K1a was connected with the Neocomian, and that further study perhaps would reveal more data on the Jurassic-Cretaceous boundary in Queensland. Burger (op. cit.) re-examined the material available from the Great Artesian Basin in reference to the unit. Its lower limit indeed appeared to be a significant horizon in the palynological sequence, with the first appearance of *Cicatricosisporites australiensis, Cicatricosisporites hughesii, Couperisporites tabulatus, Cyclosporites hughesii, Triporoletes reticulatus.* Balme (1957, 1964) reported the earliest specimens of *C. australiensis* in the Perth Basin from late Upper Jurassic sediments, so that the lower limit of unit K1a, which in the Surat Basin lies slightly below the base of the Mooga Sandstone, was accepted as a marked horizon in the immediate vicinity of the Jurassic-Cretaceous boundary in Queensland.

Burger (op. cit.) formally designated unit K1a as the *Murospora florida* Zone. He recognized three distinct intervals within the Zone. The first, indicated as the *Cicatricosisporites australiensis* Subzone, contains the species mentioned above, together with forms such as *Murospora florida, Contignisporites multimuratus, Nevesisporites vallatus, Reticuloidosporites arcus, Crybelosporites stylosus, Reticulatisporites pudens, Aequitriradites hispidus, Foveotriletes parviretis,* and *Triporoletes simplex.* In the Surat Basin the Subzone is associated with the upper part of the Orallo Formation and with the overlying Mooga Sandstone.

The second interval, the *Foraminisporis wonthaggiensis* Subzone, contains all these species, but is distinguished by the first appearance of the index species *F. wonthaggiensis*. In addition, it contains *Perotrilites majus, Januasporites spinulosus, Dictyotosporites speciosus, Kuylisporites lunaris,* and *Cicatricosporites ludbrookae.* In the Surat Basin the Subzone is restricted to the Kingull Member of the Bungil Formation.

The third and uppermost interval, the *Foraminisporis asymmetricus* Subzone, contains the species mentioned, except for *Reticuloidosporites arcus* and perhaps *Aequitriradites hispidus*. It is distinguished from the previous Subzone by the first appearance of *F. asymmetricus* and *Pilosisporites notensis.* In addition, it contains *Trilobosporites purverulentus.* In the Surat Basin the Subzone is associated with the Nullawurt and basal Minmi Members of the Bungil Formation.

The sequence in BMR Roma No. 1 Stratigraphic Hole, discussed below, is the standard for the Zone and its Subzones. The *Murospora florida* Zone is preceded by palynological units J5-6 of acceptedly late Jurassic age (Evans, 1966a). Here most of the species mentioned are not yet present. The Zone is succeeded by palynological unit K1b-c, of Aptian age (Evans, loc. cit.; Burger, 1968). This unit contains most of the species mentioned, but lacks *Murospora florida, Nevesisporites vallatus,* and, except perhaps in the basal interval, also *Crybelosporites stylosus.*

The *Cicatricosisporites australiensis* Subzone is of early Neocomian and perhaps late Upper Jurassic age, and is thought to represent mainly the Berriasian. The *Foraminisporis wonthaggiensis* Subzone, dated middle Neocomian, might possibly represent the Valanginian-Hauterivian. The *Foraminisporis asymmetricus* Subzone is thought to be upper Neocomian (Barremian) to early Aptian (Burger, op. cit.).

The relationship of these intervals with Lower Cretaceous palynological schemes referred to above was discussed by Burger (op. cit.), and shown in Figure 1.

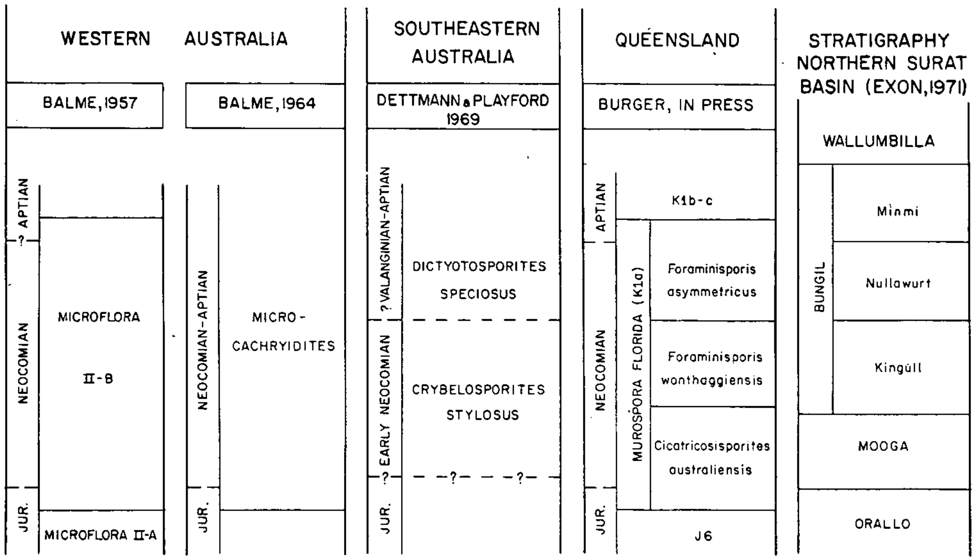

Fig. 1. Correlation of palynological zonal schemes in the early Cretaceous of Australia.

MICROFLORAL SEQUENCES

BMR Roma 1

BMR Roma 1 was drilled northwest of Roma township in order to obtain subsurface information on the Mooga Sandstone and Bungil Formation, and was described by Exon (1972). A total depth of 415 feet (129.5 m) was reached. The top of the Mooga Sandstone was recognized at 360 feet (109.7 m), the top of the Kingull Member at 304 feet (92.7 m), the top of the Nullawurt Sandstone Member at 244 feet (74.4 m), and the top of the Minmi Member at 50 feet (15.2 m). The overlying mudstone interval represents the Doncaster Member of the Wallumbilla Formation.

Eleven core samples selected from more or less regular interspacings were analysed palynologically. Most of these yielded assemblages sufficiently rich and varied for age determination. The *Cicatricosisporites australiensis* Subzone was identified in the 406-377 foot (123.9-115.0 m) interval, the *Foraminisporis wonthaggiensis* Subzone in the 348-307 foot (106.1-93.6 m) interval, and the *Foraminisporis asymmetricus* Subzone between 279 feet (85.1 m) and 185 feet (56.5 m). Palynological unit K1b-c was identified in the 146-55 foot (44.8-16.9 m) interval (Fig. 3).

DRD 27

DRD 27 was drilled west of Roma township to a total depth of 758 feet (231.0 m). The top of the Orallo Formation was penetrated at 681 feet (207.6 m), the top of the Mooga Sandstone at 484 feet (147.5 m), and that of the Bungil Formation at 137 feet (41.7 m). The section above this level was referred to as the Wallumbilla Formation (Gray, 1972). Gray indicated the top of the Kingull Member at 386 feet (117.7 m) and that of the Nullawurt Sandstone Member at 352 feet (107.3 m).

Twelve core samples of this section were palynologically examined. Eleven yielded moderate to rich microfloral assemblages; one was barren. Distribution of microfossils is given in Table 3.

The *Cicatricosisporites australiensis* Subzone was identified at 645 feet (196.6 m) and 584 feet (178.0 m). The presence of *Cyathidites punctatus* at 584 feet corrects Burger's (op. cit.) initial assumption that the species first appears in the *Foraminisporis asymmetricus* Subzone. The presence of one specimen of *Dictyotosporites speciosus* in the same sample is at this moment not taken as reliable. The specimen may be of secondary origin (laboratory contamination); nowhere else has the species been found as early in the sequence as the *Cicatricosisporites australiensis* Subzone. The presence of cf. *Densoisporites velatus* at 645 feet may indicate a slight downwards extension of the range of the species with regard to Burger's earlier assumption.

The *Foraminisporis wonthaggiensis* Subzone occurs between 436 feet (132.9 m) and 393 feet (119.8 m). *Dictyotosporites speciosus* and *Crybelosporites stylosus* were recovered from 393 feet; single specimens and fragments, possibly of the latter species, were also found in the previous Subzone, but identification there was doubtful. Fragments of specimens of *Murospora florida* were found in the strew mounts from both Subzones.

The *Foraminisporis asymmetricus* Subzone was identified at 350 feet (106.9 m) and 294 feet (89.7 m). The assemblages recovered from higher levels are very poorly preserved, and the sediments must have been subjected to an appreciable degree of deep weathering. Only two or three of the assemblages were moderately diverse; the assemblages are therefore dated with caution. The assemblage from 229 feet (69.9 m) is poor in preservation and number of species; but *Crybelosporites stylosus* and Perinatus BMR No. 825 are present. Both species are known from the *Murospora florida* Zone, and do not reach further than the basal interval of unit K1b-c; the microflora therefore very probably represents a horizon in the sequence close to the upper limit of the *Murospora florida* Zone.

The assemblage from 178 feet (54.3 m) is reasonably rich in species, and contains forms such as *Foraminisporis asymmetricus, Dictyotosporites speciosus,* common *Cyclosporites hughesii,* and species BMR No. 825. Species such as *Crybelosporites stylosus* and *Murospora florida* are absent, and *Reticulatisporites pudens* is a rare component. This suggests that the assemblage is part of unit K1b-c. The microfloras from the Wallumbilla Formation are extremely poorly preserved and contain relatively few species. The presence of a single specimen of *Murospora florida* at 117 feet (35.7 m) is very unusual; there is at present only one other observation of the species in the Wallumbilla Formation of the Surat Basin (Burger, *in* Gray, 1972). These occurrences are probably due to recycling of sediments. The microfloras from 117 feet and 67 feet (20.4 m) are therefore regarded as part of unit K1b-c.

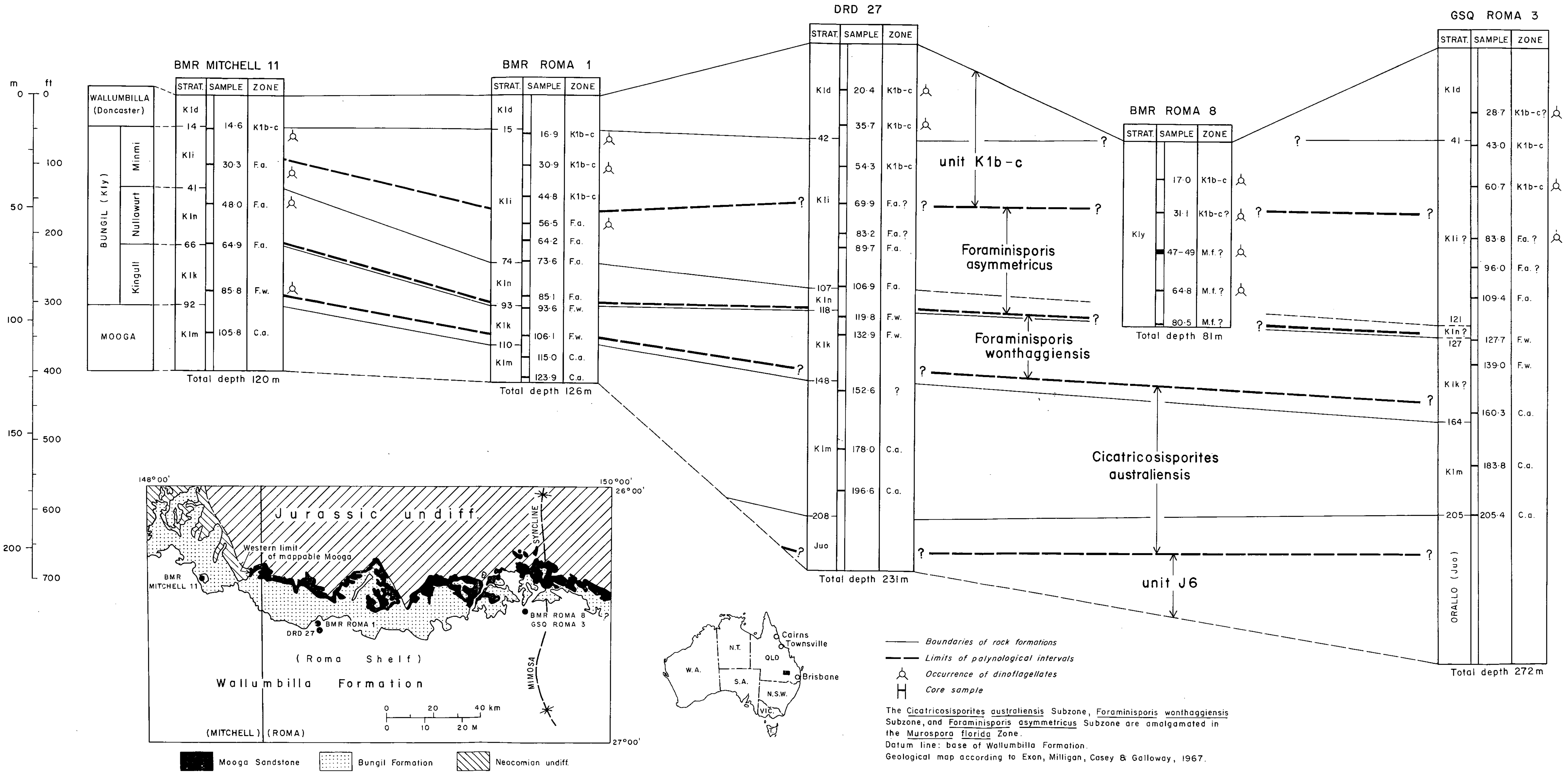

Fig. 2. Palynological correlation of early Cretaceous sediments in southeastern Queensland.

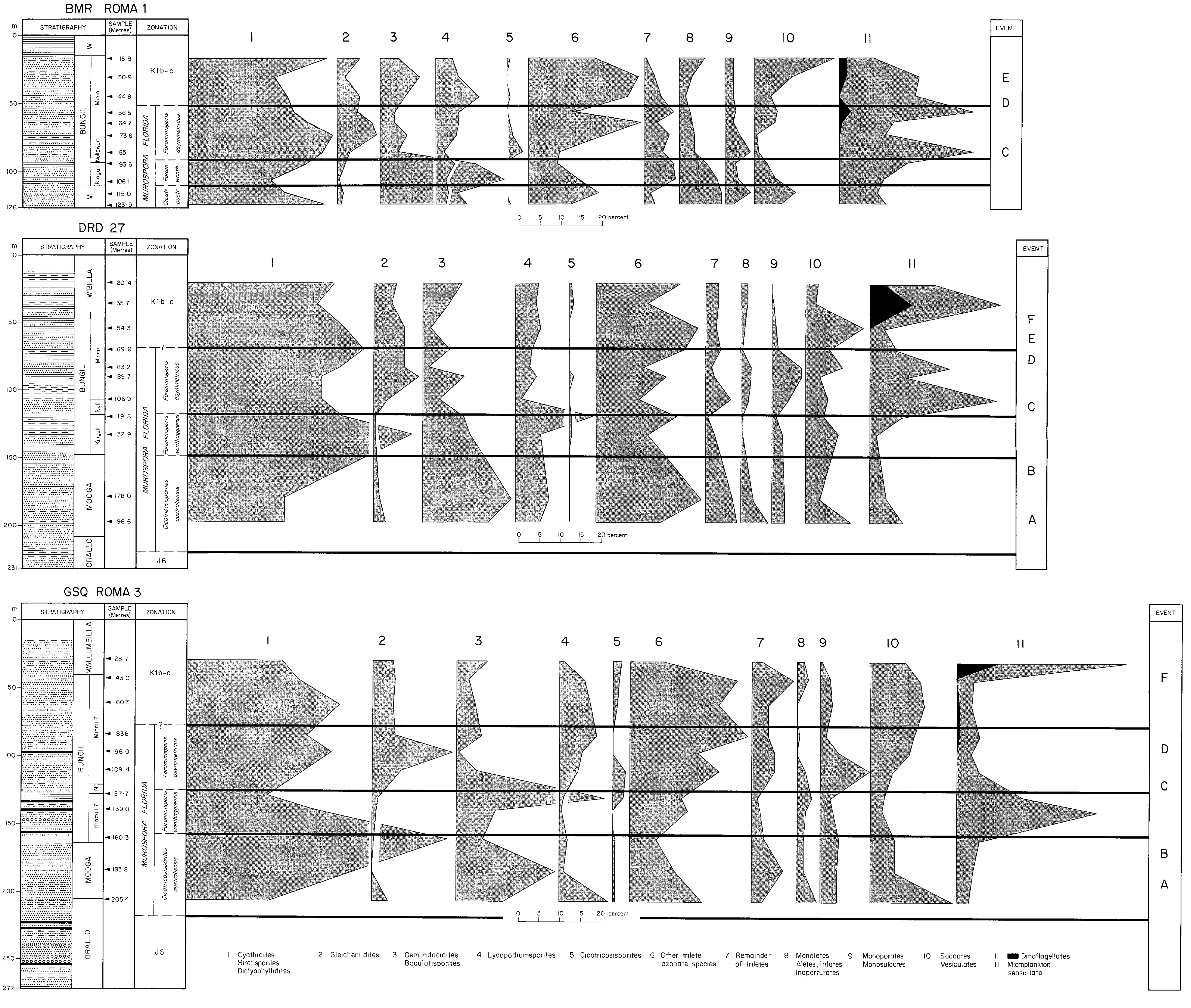

Fig. 3. Lithology and pollen diagrams of the Roma bores, showing fluctuations in relative abundance of selected groups of microfossils.

GSQ Roma 3

GSQ Roma 3 was drilled in the eastern part of the Roma 1:250 000 Sheet area, in the immediate vicinity of BMR Roma No. 8. The section represents the eastern correlate of the rock sequence drilled in DRD 27. The Bungil Formation changes in character towards the east; in the region of GSQ Roma 3 the formation is traceable in outcrop, but consists of Minmi type strata entirely (Exon et al., 1967). BMR Roma No. 8 penetrated the upper part of the Bungil Formation (Exon, 1972), but the palynological data extracted from the five cores were very unsatisfactory (Burger, 1973; see also Fig. 2).

GSQ Roma 3 reached a total depth of 891 feet (271.6 m). Gray (1972) recognized the top of the Orallo Formation at 673 feet (205.1 m), the top of the Mooga Sandstone at 539 feet (164.3 m), and the top of the Bungil Formation at 133 feet (40.5 m). The sequence above this level represents the Wallumbilla Formation. Gray did not formally subdivide the Bungil Formation, but suggested that the 133-398 feet (40.5-121.3 m) interval might be equivalent to the Minmi Member, and the 398-416 feet (121.3-126.8 m) and 416-539 feet (126.8-164.3 m) intervals to the Nullawurt and Kingull Members respectively.

Eleven core samples were selected for palynological analysis; all yielded sufficiently rich microfloral assemblages. Distribution of fossil species is given in Table 3.

The *Cicatricosisporites australiensis* Subzone was recognized in the 674-526 foot (205.4-160.3 m) interval. The presence of *Cyathidites punctatus* in the assemblage at 603 feet (183.8 m) confirms the observation from DRD 27 where the species also occurs in the Subzone. The presence of *Densoisporites velatus* and *Cicatricosisporites ludbrookae* in the same assemblage corrects Burger's (op. cit.) former opinion that they first appear in the *Foraminisporis wonthaggiensis* Subzone.

The *Foraminisporis wonthaggiensis* Subzone was identified at 456 feet (139.0 m) and at 419 feet (127.7 m), although the microfloras from these depths are not very typical; species as *Crybelosporites stylosus, Reticuloidosporites arcus,* and *Dictyotosporites speciosus* were not found.

The *Foraminisporis asymmetricus* Subzone is present at 359 feet (109.4 m). The sediments in the 275-94 foot (83.8-28.7 m) interval have been considerably affected by deep weathering. The microfloras from this interval are poorly preserved and, except for those from 275 feet (83.8 m) and 199 feet (60.7 m), also poor in number of species. The assemblage from 275 feet is very rich in species. Here the presence of *Nevesisporites vallatus, Crybelosporites stylosus,* and the common presence of *Reticulatisporites pudens* are indications that the microflora is part of the Subzone. The assemblage from 199 feet is assigned to unit K1b-c, as it has common *Dictyotosporites speciosus,* and lacks the typical forms of the *Murospora florida Zone.* The assemblages from 141 feet (43.0 m) and 94 feet (28.7 m) cannot be dated confidently; in the regional picture the stratigraphic position of these assemblages suggests that they are part of unit K1b-c.

CORRELATION OF PALYNOLOGICAL SEQUENCES

The stratigraphic position of the palynological zonations discussed is shown in Figure 2 for a number of subsurface sections which penetrated the Mooga Sandstone and Bungil Formation. Because of the excellent stratigraphic control of the analysed samples it is possible to restrict the limits of palynological intervals with considerable precision.

The *Murospora florida* Zone appears to be confined almost entirely to the Mooga Sandstone and the Bungil Formation, although its lower limit occurs in the uppermost part of the Orallo Formation (Burger, op. cit.). The *Cicatricosisporites australiensis* Subzone is associated mainly with the Mooga Sandstone; microfloras attributed to the Subzone have also been recovered from samples of the basal Kingull Member in GSQ Roma 3 and UKA Cabawin No. 1. The *Foraminisporis wonthaggiensis* Subzone is entirely restricted to the Kingull Member in the region of Roma and Mitchell. The lower limit of the *Foraminisporis asymmetricus* Subzone approximately coincides with the base of the Nullawurt Sandstone Member. The upper limit of the Subzone lies almost certainly within the Minmi Member, at least regionally, but deep weathering impedes accurate dating of the critical interval in the spore sequence. Study of the member on the Shelf and in the Mimosa Syncline is continuing, the primary aim being to obtain more accurate data concerning the *Murospora florida* Zone.

Apart from the results of stratigraphic palynology, based on purely qualitative data, additional information on environments and correlation was obtained by quantitative analyses of microfloral assemblages from BMR Roma 1, DRD 27, and GSQ Roma 3. In order to establish approximate abundances of various groups of microfossils in the assemblages, 200 specimens were counted at random in strew mounts from each sample. The results of the counts are listed in Table 1, and relative abundances are plotted in cumulative diagrams for each of the bores (Fig. 3).

Each microfloral assemblage was divided primarily into a group of spores and pollen grains (graphs 1-10) and a group of microplankton 'sensu lato' (graph 11). Changes in relative abundance within these groups and the environmental implications drawn from the composition of the latter group are discussed on page 37.

Within the group of spores and pollen grains variations in abundance of some broad groups are shown in order to examine the degree of resemblance existing in the microfloral records of the bores. It proved impracticable to give abundance curves of each species within a workable scale; instead, separate groups of species were devised, showing, as much as possible, relative abundance of stratigraphically significant genera and the domination in the assemblages of common, widespread species.

More than half of the group of *Cyathidites-Biretisporites-Dictyophyllidites* (1) consists of *Cyathidites minor;* of the remainder, *Dictyophyllidites crenatus* and *Biretisporites spectabilis* are the most common species. They occur in the late Jurassic and Cretaceous throughout eastern Australia. The maxima of abundance in the lower part of the sequence in GSQ Roma 3 and DRD 27 are probably of contemporaneous origin. Their culmination points lie in different Subzones, but this may be misleading; it is possible that the oscillation in DRD 27 is truncated because of the spacing of the samples. There is no common trend in the curves of the group in the remainder of the sequence. Especially in the upper part of each section the effect of deep weathering is probably the main source of the variations in abundance.

The group of *Gleicheniidites* (2), after an initial period of near-absence, increases considerably in the Bungil Formation of all three bores, at the start of the *Foraminisporis asymmetricus* Subzone. The group of *Osmundacidites-Baculatisporites* (3), in which *Baculatisporites comaumensis* is the dominant species, is relatively abundant in the *Cicatricosisporites australiensis* and *Foraminisporis wonthaggiensis* Subzones, and decreases in the remainder of the sequence. The group of

TABLE 1. RELATIVE ABUNDANCES OF MICROFOSSILS IN ASSEMBLAGES FROM THE MOOGA SANDSTONE, BUNGIL FORMATION, AND WALLUMBILLA FORMATION

Numbers 1 to 11 correspond to groups of fossils shown in Figure 3.

BORE	SAMPLE (MFP)	DEPTH metres	feet	1	2	3	4	5	6	7	8	9	10	11
BMR ROMA 1	4321	16.9	55′5″	67	11	9	8	1	32	1	12	4	39	16
	4322	30.9	101′5″	42	4	19	11	—	53	5	6	4	18	38
	4325	44.8	146′11″	48	11	12	21	1	48	8	3	4	8	36
	4326	56.5	185′5″	51	10	7	11	—	22	14	5	5	11	64
	4328	64.1	210′7″	58	17	7	11	1	54	6	6	4	10	26
	4329	73.6	241′6″	70	19	13	10	2	37	12	7	7	1	22
	4330	85.1	279′4″	65	6	9	4	7	15	9	7	12	2	64
	4457	93.6	307′	57	4	46	9	—	14	14	13	5	6	32
	4460	106.1	348′	40	1	60	5	—	24	15	18	6	10	21
	4462	115.0	377′4″	47	3	37	6	—	34	3	20	12	20	18
	4463	123.9	406′5″	66	2	42	5	1	20	5	20	4	13	22
GSQ ROMA 3	5789	28.7	94′	46	10	15	2	4	16	5	3	1	17	81
	5790	43.0	141′	54	11	6	12	3	52	20	5	5	24	8
	5791	60.7	199′	74	10	9	15	2	43	8	—	6	26	7
	5792	83.8	275′	58	11	12	18	—	57	8	1	3	21	11
	5795	96.0	315′	70	39	1	11	—	33	11	—	9	19	7
	5796	109.4	359′	57	14	10	9	6	43	11	4	24	11	11
	5797	127.7	419′	39	3	72	2	5	25	3	7	5	7	32
	5798	139.0	456′	62	2	19	1	—	28	4	4	6	6	68
	5787	160.3	526′	127	1	13	4	1	13	6	3	9	12	11
	5788	183.8	603′	81	—	48	2	1	22	15	3	8	12	8
	5799	205.4	674′	41	8	23	24	1	35	5	9	8	40	6
DRD 27	5800	20.4	67′	71	11	19	11	1	41	6	3	—	6	31
	5801	35.7	117′	63	9	13	10	2	25	6	3	1	5	63
	5802	54.3	178′	76	15	4	12	—	49	5	2	2	28	7
	5803	69.9	229′6″	85	15	13	8	—	43	7	1	3	12	13
	5804	83.2	273′	74	15	3	7	—	23	3	5	14	18	38
	5870	89.7	294′4″	65	22	20	10	2	34	4	5	14	7	17
	6871	106.9	350′11″	65	7	8	3	—	21	12	4	8	11	61
	5805	119.8	393′	75	1	20	37	1	38	1	1	2	9	15
	5806	132.9	436′	109	1	23	12	1	25	4	1	5	16	3
	5807	178.0	584′	47	3	43	16	—	51	13	6	6	7	8
	5808	196.6	645′	47	6	32	12	—	31	15	13	6	22	16

Cicatricosisporites (5), in which *C. australiensis* and *C. ludbrookae* are the most common forms, is relatively abundant at the beginning of the *Foraminisporis asymmetricus* Subzone of BMR Roma 1 and GSQ Roma 3, and shows an increase in the interval of unit K1b-c in DRD 27 and GSQ Roma 3.

Few common elements are detected in the graphs of *Lycopodiumsporites* (4) and other groups of Triletes (6, 7). Group 6, in which *Neoraistrickia truncata* and *Ceratosporites equalis* are the most common species, slightly increases in the *Foraminisporis asymmetricus* Subzone of GSQ Roma 3 and BMR Roma 1. Group 7 and group 8 (Monoletes etc.) are too heterogeneous in composition to show characteristics of component species.

In the group of Monoporates-Monosulcates (9), *Classopollis simplex* is the most common species. A notable increase of the group is shown at the beginning of the *Foraminisporis asymmetricus* Subzone, but its authenticity is uncertain, as the curve of the group may have been influenced considerably by the occurrence of suspected reworked specimens of *Classopollis*. Finally, the group of Saccates-Vesiculates (10) shows maxima of occurrence in the *Cicatricosisporites australiensis* Subzone in GSQ Roma 3 and DRD 27, and at the beginning of unit K1b-c in all three bores. These maxima are caused by increased occurrence of *Alisporites similis* and, to a lesser extent, of *Microcachryidites antarcticus,* two common species in the Lower Cretaceous of Australia. This group has suffered considerably from the destructive effects of deep weathering; the curves in the upper part of each sequence are considered statistically less reliable; the counts of some of the assemblages include many fragmented specimens, particularly of *Alisporites.*

Ideally, the composition of each microfloral assemblage should faithfully represent contemporaneous pollen production in the area and thus reflect to a certain extent the composition of the local vegetation. A pollen diagram of the type shown in Figure 3 is under these circumstances a graphical record of the history of the regional vegetation, and the diagrams of the boreholes could be expected to show a fair degree of similarity. In practice, this picture is very often distorted. Various influences, whose effects cannot be neutralized, have an effect on the pollen diagrams. Recycling of sediments brings in an element of contamination which is not always recognized. Supply of contemporaneous pollen material from more distant areas is often considerable. Aquatic transport over longer distances usually has a winnowing effect, because of differences in density and size of the pollen. This results in concentration of certain pollen forms in a specific rock type, and thus an over-representation in the contemporaneous microflora. Furthermore, deep weathering, which has been mentioned, can reach depths of well over 30 m, and is here probably the largest distorting factor in the upper part of the diagrams. Finally, statistical errors are introduced by retrieving methods and counting procedure. The worst effects of these are on low-percentage groups, such as *Cicatricosisporites* (5) and Monoletes etc. (8).

In spite of these obstacles, and the added element of the distances between the boreholes, broad similarities are apparent in the abundance of various spore-pollen groups. Furthermore, in many of the separate graphs the counts reveal individual oscillations, which occur in similar stratigraphic positions in all three diagrams, and sometimes are of considerable amplitude and vertical measure. Close comparison of the diagrams shows intervals characterized by concurrent changes in certain curves. Six such intervals were recognized, some more pronounced than others; they are here called events, and provisionally lettered A to F. They are specified in Table 2; and their positions in each diagram are marked in Figure 3.

These fluctuations are unlikely to originate from purely statistical irregularities. It is thought that they represent genuine variations in time of the pollen sedimentation, and thus, in fact, reflect major events in the regional history of the parent vegetation.

Too little statistical evidence exists at the present time to assert the significance of this type of representation. Palaeobotanical evidence from the Cretaceous in the Great Artesian Basin is at best only fragmentary, and without the availability of certain basic information, such as abundance and pollen production of various plant species, there is no sound basis for interpretation of the present pollen data in terms of ecology, climate, and evolution. Nevertheless, however empirical, the results of this kind of analysis, even in an initial stage, can yield illustrative details on environment and contribute towards pollen-stratigraphic work. Further data from correlate sediments outside the Surat Basin will perhaps be able to show whether some of the changes specified in Table 2 occurred on a larger geographical scale. Affirmative results might be expected to emerge, if these changes indeed represent long-term manifestations in the floral record.

TABLE 2. SPECIFICATIONS AND OCCURRENCE OF EVENTS IN THE POLLEN DIAGRAMS OF BMR ROMA 1, DRD 27, AND GSQ ROMA 3

Numbers correspond to groups of fossils shown in Figure 3.

	EVENT	BMR ROMA 1	DRD 27	GSQ ROMA 3	ASSOCIATED WITH
F	Increase OSMUNDACIDITES-BACULATISPORITES (3) Increase CICATRICOSISPORITES (5)	—	Minmi/Wallumbilla boundary	Minmi/Wallumbilla boundary	unit K1b-c
E	Minimum CICATRICOSISPORITES (5) Increase SACCATES-VESICULATES (10)	upper Minmi	upper Minmi	not apparent	unit K1b-c
D	Increase OSMUNDACIDITES-BACULATISPORITES (3) Increase AZONATE TRILETES (6)	Minmi		Bungil (Minmi?)	approx. upper limit *Murospora florida* Zone
C	Increase GLEICHENIIDITES (2) Decrease OSMUNDACIDITES-BACULATISPORITES (3) Maximum CICATRICOSISPORITES (5) Increase MONOPORATES-MONOSULCATES (9)	Nullawurt	Nullawurt (not distinct)	Bungil (Nullawurt-Minmi?)	lower *Foraminisporis asymmetricus* Subzone
B	Increase CYATHIDITES etc. (1) Minimum GLEICHENIIDITES (2) Decrease OSMUNDACIDITES-BACULATISPORITES (3)	not drilled	upper Mooga	upper Mooga	*Cicatricosisporites australiensis* Subzone
A	Decrease GLEICHENIIDITES (2) Increase OSMUNDACIDITES-BACULATISPORITES (3) Decrease SACCATES-VESICULATES (10)	not drilled	Mooga	Mooga	*Cicatricosisporites australiensis* Subzone

ENVIRONMENTS OF DEPOSITION

In the statistical analyses of the microfloras from the Roma area bores, a group of micro-organisms is separated, which in Figure 3 is indicated as 'Microplankton sensu lato'. This group includes the dinoflagellates, acritarchs (including common Leiosphaerids, rare *Micrhystridium* spp. and rare *Pterospermopsis* spp.), the (freshwater?) alga *Botryococcus,* and some sporadic Tasmanitids.

Literature dealing with the environmental significance of these groups is scarce. In sediments underlying the marine Cretaceous *Micrhystridium* spp. are sometimes very abundantly associated with 'marine' indicators, such as the oolite beds in the Evergreen Formation. In other parts of the sequence, where the absence of dinoflagellates and other marine fossils casts doubt on the existence of marine or even saline conditions, this group is also present in the assemblages, although in general relatively rare.

Leiosphaerids are common elements in both marine and nonmarine microfloral assemblages from the Great Artesian Basin. The abundance of these organisms in strata from which in outcrop marine fossils have been collected (Nullawurt Sandstone Member, Minmi Member) shows that they are susceptible to salinity changes in the environment. In this context the graphs of Figure 3 are significant, in that the maxima of abundance point to temporary brackish-marine, marginal conditions connected with brief minor incursions of the sea.

The Leiosphaerids are much more abundant in BMR Roma 1 than in the other bores. Two maxima of occurrence were detected, associated with the *Foraminisporis asymmetricus* Subzone. The first occurs in the Nullawurt Sandstone Member (at 85.1 m), the second in the Minmi Member (at 56.5 m); Day (1964, 1967) described marine macrofossils from the Minmi Member in outcrop, but described the Nullawurt Sandstone Member as 'freshwater'. However, marine fossils were later found in the Nullawurt in the Mitchell area (Exon et al., 1967). Considering the presence of dinoflagellates at 56.6 m, the open sea might have reached the immediate vicinity of the bore location during the second oscillation. In DRD 27 two most probably contemporaneous maxima (mainly of Leiosphaerids) occur, although not entirely of equal magnitude. The maxima lie near the top of the Nullawurt Sandstone Member, at 106.9 m, and the Minmi Member at 83.2 m.

Nothing of this is apparent in GSQ Roma 3. Below the Wallumbilla Formation, the picture is dominated by a substantial oscillation associated with the *Foraminisporis wonthaggiensis* Subzone (139.0 m). This was probably connected with an earlier advance of the sea, which was felt at the bore location but not yet farther west. This agrees well with the petrological findings of Exon (1972), who found 'glauconite' (field name for green grains consisting of phyllosilicates and found only in the marine sequence) in older sediments in nearby BMR Roma 8 than on the Roma Shelf. Two subsequent incursions of the sea were felt simultaneously at the location of the two other bores, but apparently had no influence farther east.

The occurrence of Leiosphaerids and *Micrhystridium* and the absence of *Veryhachium,* before the Wallumbilla Formation, may give further indication about the environments at the time. In his microplankton study of Upper Devonian off-reef sediments of Alberta, Canada, Staplin (1961) discussed environmental control of certain morphological groups of microplankton. He found that simple spherical organisms occur in the immediate vicinity of the reefs, whereas thin-spined, thicker-spined, and polyhedral forms were seldom found within miles of the reef front.

TABLE 3. DISTRIBUTION OF PLANT MICROFOSSILS IN DRD27 AND GSQ ROMA 3 STRATIGRAPHIC BORES

	GSQ ROMA 3 STRATIGRAPHIC BORE											DRD 27 STRATIGRAPHIC BORE											
DEPTH OF SAMPLE	205.4	183.8	160.3	139.0	127.7	109.4	96.0	83.8	60.7	43.0	28.7	196.6	178.0	152.7	132.9	119.8	106.9	89.7	83.2	69.9	54.3	35.7	20.4
SAMPLE NO. (MFP)	5799	5788	5787	5798	5797	5796	5795	5792	5791	5790	5789	5808	5807	5872	5806	5805	5871	5870	5804	5803	5802	5801	5800
ROCK UNIT	Orallo	Mooga	Bungil	Bungil	Bungil	Bungil	Bungil	Bungil	Bungil	Bungil	Wallumbilla	Mooga	Mooga	Mooga	Kingull	Kingull	Minmi	Minmi	Minmi	Minmi	Minmi	Wallumbilla	Wallumbilla
PALYNOLOGICAL ZONATION	Cic. austral.	Cic. austral.	Cic. austral.	Foram. wonthagg.	Foram. wonthagg.	Foram. asymm.	Foram. asymm?	Foram. asymm?	unit K1b-c	unit K1b-c	unit K1b-c?	Cic. austral.	Cic. austral.	?	Foram. wonthagg.	Foram. wonthagg.	Foram. asymm.	Foram. asymm.	Foram. asymm?	Foram. asymm?	unit K1b-c	unit K1b-c	unit K1b-c
SPORES AND POLLEN GRAINS																							
AEQUITRIRADITES SPINULOSUS (Cookson & Dettmann, 1958) Cookson & Dettman, 1961		•			+										•	•							
A. VERRUCOSUS (Cookson & Dettmann, 1958) Cookson & Dettman, 1961					•	•									•	•							
ALISPORITES GRANDIS (Cookson, 1953) Dettmann, 1963	•	•		o		•		o	•	•	•	o									•		•
A. SIMILIS (Balme, 1957) Dettmann, 1963	•	•	•	•	•	•	•	•	•	•	•	•					•	•	•	•	•		
ARAUCARIACITES AUSTRALIS Cookson, 1947	•	•			•	•			•			•	•		•	o	•	•	•	o			
BACULATISPORITES COMAUMENSIS (Cookson, 1953) Potonie, 1956	•	•	•	•	•	•		•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
BIRETISPORITES POTONIAEI Delcourt & Sprumont, 1955		•			•	•			•	o						•	•		•	o	o		•
B. SPECTABILIS Dettmann, 1963	•	•	•		•	•		•	•	•		•	•		•	•	•	•	•	•	•		o
CALLIALASPORITES DAMPIERI (Balme, 1957) Dev, 1959	•	•	•		•	•	•	•		•	•	o					•	•	•			•	
C. TRILOBATUS (Balme, 1957) Dev, 1959	•		•				•	•				•			•	•				o			
CERATOSPORITES EQUALIS Cookson & Dettmann, 1958	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
CICATRICOSISPORITES AUSTRALIENSIS (Cookson, 1953) Potonie, 1956		•	•		•	•		•	•	•	•	•	•		•	•	•	•	•		•	•	•
C. HUGHESII Dettmann, 1963		•	o	•		o						•	•		•		•		o				
C. LUDBROOKAE Dettmann, 1963		•	•	•	•	•			•	•		o	•		•	•	•	•	•	•	•		o
C. SPP. INDET.	•	•				•	•		•		•												
CINGUTRILETES CLAVUS (Balme, 1957) Dettmann, 1963					•		•	•		•								o	•	•	•	•	
CLASSOPOLLIS SIMPLEX (Danze-Corsin & Laveine, 1963) Reiser & Williams, 1969	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•
CONCAVISSIMISPORITES SP. (BMR Species Catalogue no. 487)													•										
CONTIGNISPORITES COOKSONAE (Balme, 1957) Dettmann, 1963	•	•	•		•	•	•					•	•		•	•	•			•			
C. FORNICATUS Dettmann, 1963	o	•	o			o		•				•	•		•	o	•						
C. MULTIMURATUS Dettmann, 1963	•	•				o			•	•			•				•		•				
CORONATISPORA PERFORATA Dettmann, 1963					•				•			•	•				•	•		•			
COUPERISPORITES TABULATUS Dettmann, 1963					•																		
CRYBELOSPORITES STYLOSUS Dettmann, 1963								•				o	o			•	o			•	o		
CYATHIDITES AUSTRALIS Couper, 1953	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•
C. ASPER (Bolchovitina, 1953) Dettmann, 1963		•						•								o							
C. MINOR Couper, 1953	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
C. PUNCTATUS (Delcourt & Sprumont, 1955) Delcourt, Dettmann & Hughes, 1963		•		•	•	•							•			•	•		o				
CYCLOSPORITES HUGHESII (Cookson & Dettmann, 1958) Cookson & Dettmann, 1959	•	•	•	•		•	o	•	•	•		•	•		•	•				•	•		
DENSOISPORITES VELATUS Weyland & Krieger, 1953 emend. Krasnova, 1961		•										o			o		•			•			
DICTYOPHYLLIDITES CRENATUS Dettman, 1963		•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	o	•		•
DICTYOTOSPORITES COMPLEX Cookson & Dettmann, 1958	•	•		•				•	•	•	•	•	•		•	•		•	•	•	•		o
D. SPECIOSUS Cookson & Dettmann, 1958							•	o	•				•			•		o		•	•		•
FORAMINISPORIS ASYMMETRICUS (Cookson & Dettmann, 1958) Dettmann, 1963																	•	•			•	o	
F. DAILYI (Cookson & Dettmann, 1958) Dettmann, 1963		•	•	•	•	o	•		•			o	•		•	•	•	•			•		
F. WONTHAGGIENSIS (Cookson & Dettmann, 1958) Dettmann, 1963				•	o	•			•						•	•			•	o			
FOVEOSPORITES CANALIS Balme, 1957								•	•	•		•	•				o	•	•	•	•		
GLEICHENIIDITES CIRCINIDITES (Cookson, 1953) Dettmann, 1963	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
INAPERTUROPOLLENITES TURBATUS Balme, 1957	•	•				•						•			•		•						
ISCHYOSPORITES PUNCTATUS Cookson & Dettmann, 1958		•			•	•		o		•		•	•		•	•	o	•	•		o		
JANUASPORITES SPINULOSUS Dettmann, 1963																•							
KLUKISPORITES SCABERIS (Cookson & Dettmann, 1958) Dettmann, 1963					•			o	•		•	•	o		o	•	o				o	•	•
KUYLISPORITES LUNARIS Cookson & Dettmann, 1958						o									•	•							
LAEVIGATOSPORITES SP. (BMR Species Catalogue no. 824)												•	•										
LEPTOLEPIDITES MAJOR Couper, 1958		•				•	•	•		•			•			•		•					
L. VERRUCATUS Couper, 1953	•			•				•	•	•	•		•		•	•			•	•	•	•	•
LYCOPODIACIDITES AMBIFOVEOLATUS Brenner, 1963	•	o	•	•			o	•	•	•		•	•		•		•	•	•	•	o		
LYCOPODIUMSPORITES AUSTROCLAVATIDITES (Cookson, 1953) Potonie, 1956	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•		•		•
L. CIRCOLUMENUS Cookson & Dettmann, 1958	•	•	•	•		•		•	•	•	•	•	•			•	•	•	•	•	•		•
L. EMINULUS Dettmann, 1963				•				•		o					•	•					•		
L. FACETUS Dettmann, 1963									•	•		o	o			•	•	•	•	•	•		
L. NODOSUS Dettmann, 1963	o					o	•	•	•	•		o				•	•			•	•		•
L. ROSEWOODENSIS (De Jersey, 1959) De Jersey, 1963	•	•	•	•		•	•	•	•	•		•	•		•	•		•		•	•		•
MATONISPORITES COOKSONAE Dettmann, 1963	•	•	•		•	•				•		•			•	•	•	•			o		•
MICROCACHRYIDITES ANTARCTICUS Cookson, 1947	•	•		•			•	•	•			•					•	•	•		•	•	
MONOLETE GRANULATE SPECIES (BMR Species Catalogue no. 1096)		•	•	•	•				•	o			•										
MONOSULCITES MINIMUS Cookson, 1947	•	•	•	•	•		•	•	•		•	•					•	•				•	•
MUROSPORA FLORIDA (Balme, 1957) Pocock, 1961	•	•			o	+							+			o	+	•				▸	
NEORAISTRICKIA TRUNCATA (Cookson, 1953) Potonie, 1956	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•
NEVESISPORITES VALLATUS De Jersey & Paten 1964						•		•					•		•	•	o						
OSMUNDACIDITES WELLMANII Couper, 1953	•	•	•	•	•		•	•	•	•		•			•	•	•			•			
PERINATE INAPERTURATE SPECIES (BMR Species Catalogue no. 1073)		•	•	•																			
PERINATE TRILETE SPECIES (BMR Species Catalogue no. 825)								•							•	•			o	•	•		
PEROTRILITES LINEARIS (Cookson & Dettmann, 1958) Evans, 1970		o			o	o			•		o		•				•	•		•	•	o	
P. MAJUS (Cookson & Dettmann, 1958) Evans, 1970																•							
PILOSISPORITES NOTENSIS Cookson & Dettmann, 1958						•		•		•							•	o					•
PODOCARPIDITES ELLIPTICUS Cookson, 1947						•			•		•		•										
P. MULTESIMUS (Bolchovitina, 1956) Pocock, 1962		•				•	o	o	o	o		•					o						
RETICULATISPORITES PUDENS Balme, 1957		•		•			•	•	•	•			•				•	•	•	•	•		•
RETICULOIDOSPORITES ARCUS (Balme, 1957) Dettmann, 1963		•	•					o				o											
SESTROSPORITES PSEUDOALVEOLATUS (Couper, 1958) Dettmann, 1963	•	•	•			•		•	•		•	•						o					•
STEREISPORITES ANTIQUASPORITES (Wilson & Webster, 1946) Dettmann, 1963	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
TRILITES cf. T. TUBERCULIFORMIS Cookson, 1947	o	•	o	•	o	•		•	•	•			•		•	•		•	•				•
TRILOBOSPORITES ANTIQUUS Reiser & Williams, 1969		•					•	•	•			•			•		•		•				
TRIPOROLETES RETICULATUS (Pocock, 1962) Playford, 1971		o			•										o	•				•			
T. SIMPLEX (Cookson & Dettmann, 1958) Playford, 1971		o							o								o	•					
TRISACCITES MICROSACCATUS (Couper, 1953) Couper, 1960							•										•	•					
VELOSPORITES TRIQUETRUS (Lantz, 1958) Dettmann, 1963			•					•	•				•			•		•		•	•		
VITREISPORITES PALLIDUS (Reissinger, 1950) Nilsson, 1958		•	•	•				•		•	•	•					•					•	
DINOFLAGELLATES																							
CANNINGIA COLLIVERI Cookson & Eisenack, 1960																							•
CHLAMYDOPHORELLA NYEI Cookson & Eisenack, 1958											•						•					•	
CYMATHIOSPHAERA PTEROTA Cookson & Eisenack, 1958																						•	
DEFLANDREA ACUMINATA Cookson & Eisenack, 1958															•								
DINGODINIUM CERVICULUM Cookson & Eisenack, 1958							o	•	•		•							o	•			•	o
ODONTOCHITINA OPERCULATA (Wetzel, 1933) Deflandre & Cookson, 1955						+			+	+													•
TRICHODINIUM INTERMEDIUM Eisenack & Cookson, 1960						o																o	•
OTHER MICROFOSSILS																							
BOTRYOCOCCUS SPP.						•						•	•				•						
"GEN. ET SP. INDET. FORMA A" Eisenack & Cookson, 1960													•				•						
LEIOSPHAERIDS	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
MICRHYSTRIDIUM SPP.				•	•						•						•				•	•	
PALAEOSTOMOCYSTIS SP.		o			•	•	•	o	•		•					•			o	•			•
PTEROSPERMOPSIS AUSTRALIENSIS Deflandre & Cookson, 1955																			o				
SCHIZOSPORIS PARVUS Cookson & Dettmann, 1959							•																
VERYHACHIUM REDUCTUM Deunff, 1958											•												•

Depth in metres

- • species present in situ
- + only fragments of species present
- ▸ species probably of secondary (recycled) origin
- o identification of species not positive

Wall (1965) examined microfossil assemblages from the Lower Jurassic of England and South Wales. He found that forms such as *Micrhystridium* (thin-spined) preferred inshore, partly enclosed environments, whereas forms such as *Veryhachium* (thick-spined) were found mainly in open-sea environments.

If the presence of these organisms in the Roma bores is interpreted in analogy with the results of Wall's and Staplin's work, an environmental picture emerges which ties in very well with field evidence, according to which the sediments of the Bungil Formation were accumulated in lowland, sheltered, lacustrine, partly near-shore conditions (see Day, 1964; Exon et al., 1967).

It is not certain where at these times the connexion with the open ocean existed. During Mooga deposition, drainage appears to have been to the southeast (Exon, pers. comm.). Day (1969) thought that at a later stage a passage might have opened to the east. The final invasion of the sea in unit K1b-c times is clearly shown by a sudden increase of dinoflagellates in DRD 27 and GSQ Roma 3 at the onset of the Wallumbilla Formation. It was shown that the transgression originated from a northwesterly direction (Burger, 1973).

ACKNOWLEDGMENTS

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PLATE 13

(all figures approximately x 750)

Fig. 1	*Dictyophyllidites crenatus* Dettmann. GSQ Roma 3, 526 feet; Bungil Formation. MFP 5787-2; coord. 328/1010 (CPC 13593).
Fig. 2	*Cyathidites punctatus* (Delcourt & Sprumont). GSQ Roma 3, 603 feet; Mooga Sandstone. MFP 5788-2; coord. 394/1168 (CPC 13594).
Fig. 3	*Ceratosporites equalis* Cookson & Dettmann. GSQ Roma 3, 94 feet; Wallumbilla Formation. MFP 5789-2; coord. 344/1048 (CPC 13595).
Fig. 4	*Leptolepidites verrucatus* Couper. GSQ Roma 3, 456 feet; Bungil Formation. MFP 5798-2; coord. 468/1175 (CPC 13596).
Fig. 5	*Neoraistrickia truncata* (Cookson). DRD 27, 393 feet; Bungil Formation. MFP 5805-1; coord. 300/1084 (CPC 13597).
Fig. 6	*Cicatricosisporites australiensis* (Cookson). GSQ Roma 3, 359 feet; Bungil Formation. MFP 5796-1; coord. 465/1068 (CPC 13598).
Figs 7, 8	*Cicatricosisporites ludbrookae* Dettmann. 7. DRD 27, 584 feet; Mooga Sandstone. MFP 5807-1; coord. 259/1079 (CPC 13599). 8. GSQ Roma 3, 456 feet; Bungil Formation. MFP 5798-1; coord. 351/1036 (CPC 13600).
Fig. 9	*Lycopodiumsporites circolumenus* Cookson & Dettmann. DRD 27, 645 feet; Mooga Sandstone. MFP 5808-1; coord. 272/1148 (CPC 13601).
Fig. 10	*Cyclosporites hughesii* (Cookson & Dettmann). DRD 27, 393 feet; Bungil Formation. MFP 5805-1; coord. 348/1003 (CPC 13602).
Fig. 11	*Pilosisporites notensis* Cookson & Dettmann, GSQ Roma 3, 359 feet; Bungil Formation. MFP 5796-2; coord. 302/1212 (CPC 13603).
Fig. 12	*Lycopodiumsporites rosewoodensis* (de Jersey). DRD 27, 393 feet; Bungil Formation. MFP 5805-1; coord. 287/1060 (CPC 13604). a—proximal face; b—distal reticulum.

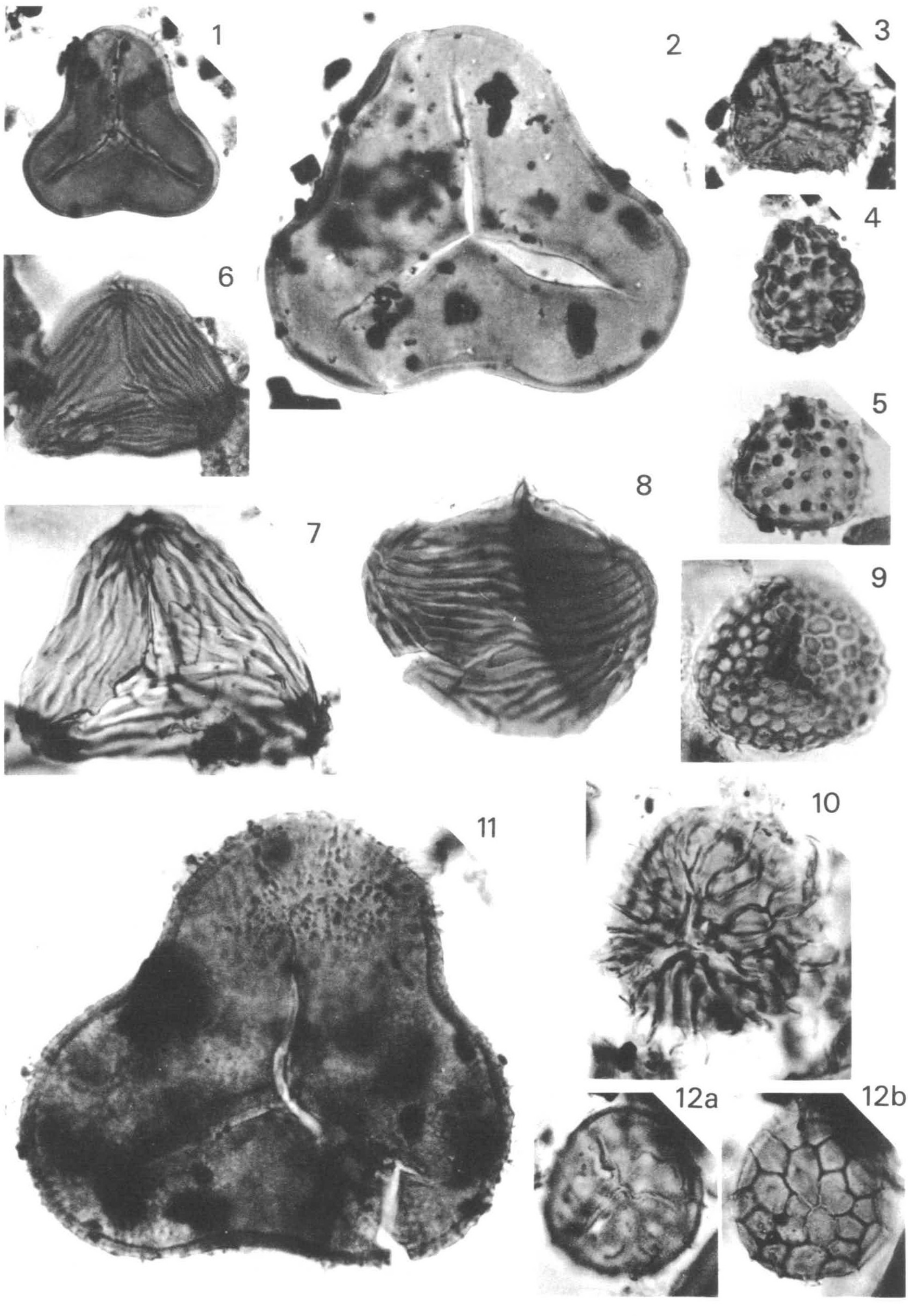
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PLATE 14

(all figures opproximately x 750)

Fig. 1	*Crybelosporites stylosus* Dettmann. GSQ Roma 3, 275 feet; Bungil Formation. MFP 5792-2; coord. 392/1190 (CPC 13605).
Fig. 2	*Dictyotosporites speciosus* Cookson & Dettmann. DRD 27, 178 feet; Bungil Formation. MFP 5802-1; coord. 355/1135 (CPC 13606). a—proximo-equatorial aspect; b—distal sculpture.
Fig. 3	*Lycopodiumsporites nodosus* Dettmann. GSQ Roma 3, 199 feet; Bungil Formation. MFP 5791-2; coord. 415/1135 (CPC 13607). a—proximal face; b—distal sculpture.
Figs 4, 5	*Klukisporites scaberis* (Cookson & Dettmann). 4. DRD 27, 393 feet; Bungil Formation. MFP 5805-1; coord. 319/1193 (CPC 13608). Proximal face. 5. Same preparation; coord. 433/1185 (CPC 13609). Distal face.
Fig. 6	*Dictyotosporites complex* Cookson & Dettmann. DRD 27, 393 feet; Bungil Formation. MFP 5805-1; coord. 312/1060 (CPC 13610).
Fig. 7	*Couperisporites tabulatus* Dettmann. DRD 27, 436 feet; Bungil Formation. MFP 5806-2; coord. 321/1064 (CPC 13611).
Fig. 8	*Stereisporites antiquasporites* (Wilson & Webster). GSQ Roma 3, 199 feet; Bungil Formation. MFP 5791-1; coord. 330/1189 (CPC 13612).
Fig. 9	*Matonisporites cooksonae* Dettmann. DRD 27, 393 feet; Bungil Formation. MFP 5805-2; coord. 407/1169 (CPC 13613).
Fig. 10	*Foraminisporis dailyi* (Cookson & Dettmann). GSQ Roma 3, 603 feet; Mooga Sandstone. MFP 5788-1; coord. 458/1080 (CPC 13614).
Fig. 11	*Foraminisporis wonthaggiensis* (Cookson & Dettmann). GSQ Roma 3, 199 feet; Bungil Formation. MFP 5791-2; coord. 377/1003 (CPC 13615).
Fig. 12	*Foraminisporis asymmetricus* (Cookson & Dettmann). DRD 27, 294 feet; Bungil Formation. MFP 5870-4; coord. 360/1082 (CPC 13616).
Fig. 13	*Januasporites spinulosus* Dettmann. DRD 27, 393 feet; Bungil Formation. MFP 5805-1; coord. 301/1160 (CPC 13617).

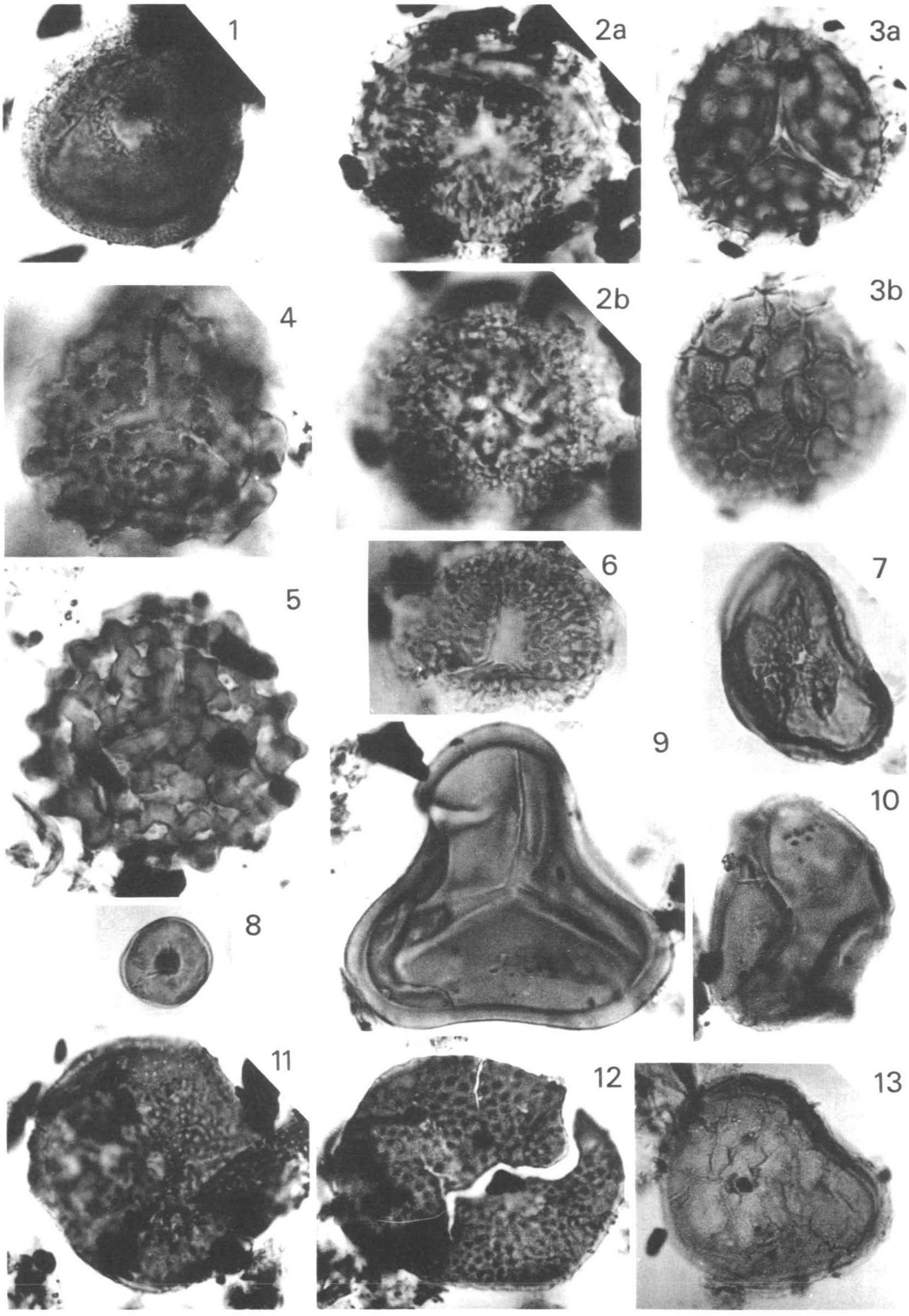
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PLATE 15

(all figures, except 10 and 11, approximately x 750)

Fig. 1 — *Aequitriradites spinulosus* (Cookson & Dettmann). DRD 27, 436 feet; Bungil Formation. MFP 5806-2; coord. 321/1064 (CPC 13618).

Fig. 2 — *Aequitriradites verrucosus* (Cookson & Dettmann). GSQ Roma 3, 359 feet; Bungil Formation. MFP 5796-1; coord. 299/1207 (CPC 13619).

Figs 3, 4 — *Contignisporites multimuratus* Dettmann. 3. GSQ Roma 3, 603 feet; Mooga Sandstone. MFP 5788-2; coord. 292/1118 (CPC 13620). a—proximal face; b—numerous distal striae. 4. Same preparation; coord. 320/1082 (CPC 13621). a—proximal face; b—distal face.

Fig. 5 — *Contignisporites cooksonae* (Balme), GSQ Roma 3, 603 feet; Mooga Sandstone. MFP 5788-2; coord. 354/1106 (CPC 13622). a—proximal face; b—distal face.

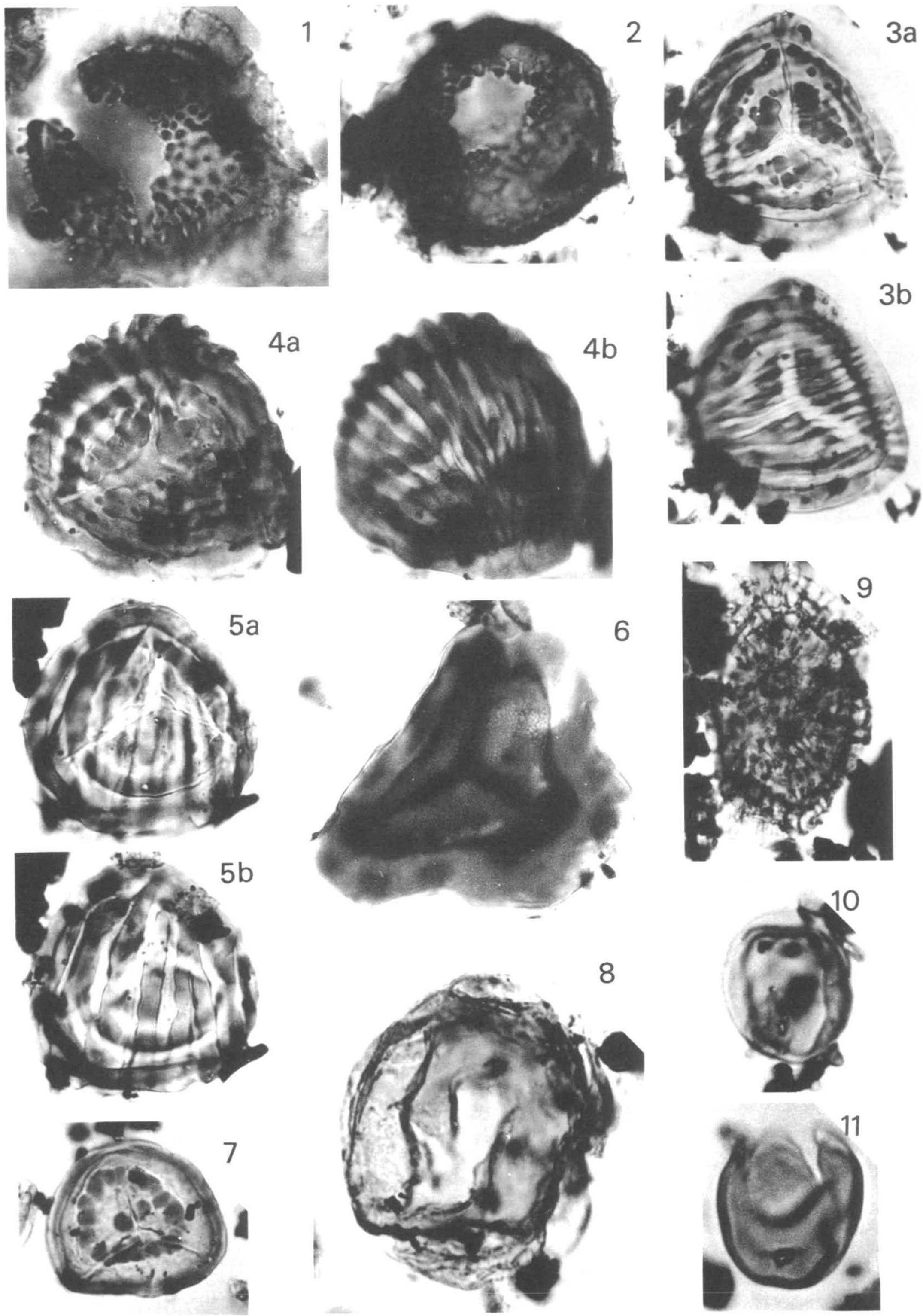
Fig. 6 — *Murospora florida* (Balme). DRD 27, 393 feet; Bungil Formation. MFP 5805-1; coord. 254/1062 (CPC 13623).

Fig. 7 — *Cingutriletes clavus* (Balme). DRD 27, 178 feet; Bungil Formation. MFP 5802-2! coord. 339/1160 (CPC 13624).

Fig. 8 — aff. *Palaeostomocystis* sp. DRD 27, 393 feet; Bungil Formation. MFP 5805-2; coord. 407/1169 (CPC 13625).

Fig. 9 — *Chlamydophorella nyei* Cookson & Eisenack. DRD 27, 117 feet; Wallumbilla Formation. MFP 5801-3; coord. 260/1096 (CPC 13626).

Figs 10, 11 — *Leiosphaeridium* spp. 10. GSQ Roma 3, 456 feet; Bungil Formation. MFP 5798-1; coord. 379/1117 (CPC 13627). 11. Same preparation; coord. 343/1121 (CPC 13628). Both figures approximately x 2 500.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SOME ORDOVICIAN GRAPTOLITES FROM THE CANNING BASIN, WESTERN AUSTRALIA

2: GRAPTOLITES FROM THE GOLDWYER No. 1 WELL

by

S. K. Skwarko

SUMMARY

Of ten cores recovered from the Goldwyer Shale, Goldwyer No. 1 Well, six yielded graptolites on digestion with hydrofluoric acid. The forms present are *?Didymograptus artus,* previously described from the neighbouring Willara No. 1 Well, *'Didymograptus gracilis* Törnquist', *Tetragraptus* sp. indet., dichograptid stipes, *Pterograptus* sp., the locally very abundant *Amplexograptus confertus* (Lapworth), and its less abundant but still common mutant. All, apart from the diplograptid mutant and the *Pterograptus* sp., responded well to the bleaching solution and allowed scrutiny of the microstructures. Some scolecodonts and Chitinozoa were also separated from the shaly matrix.

The cores are of Llanvirnian age.

INTRODUCTION

The paper on *Didymograptus artus* Elles & Wood from Willara No. 1 Well, Canning Basin, published in 1968 (Skwarko, 1967) was the first of a series dealing with graptolites from stratigraphic wells drilled in the Canning Basin, Western Australia, by the West Australian Petroleum Company. The reader is referred to it for general comments regarding the occurrence of graptolites in Australia and their preservation, and particularly regarding the type of preservation, methods of extraction, and approach to study of the graptolites occurring in the Willara Well. These comments apply also to the graptolites described in the present paper from the neighbouring Goldwyer No. 1 Well. A more detailed locality map (Fig. 1) is here appended to show the positions of the Willara and the Goldwyer Wells and their geographical relationship to other graptolite-bearing wells in the Canning Basin, to be discussed in the future.

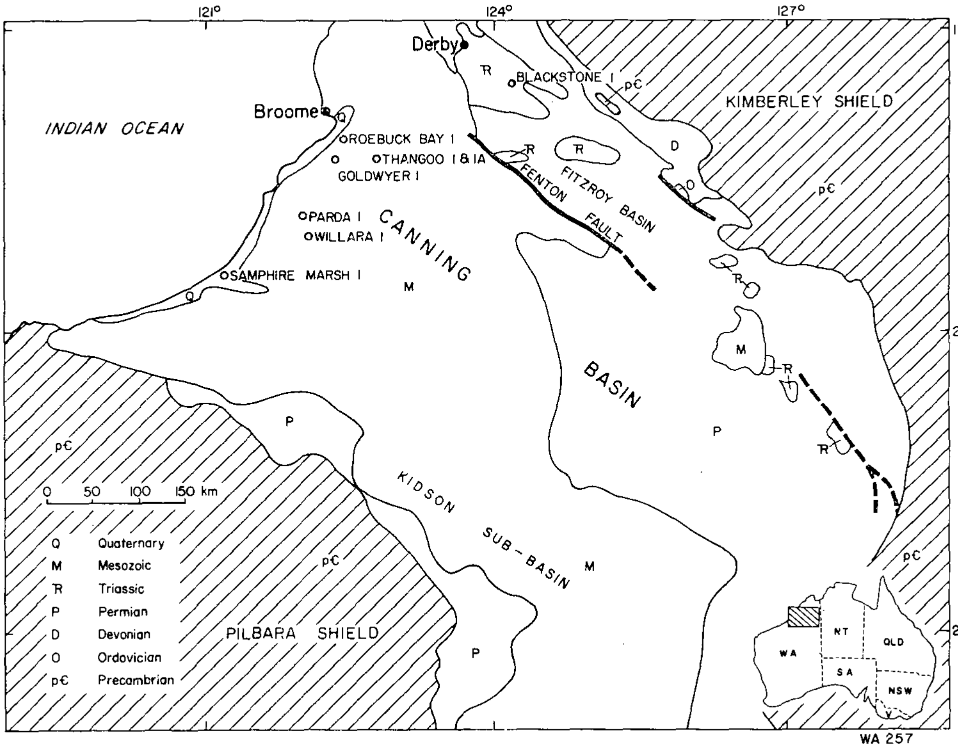

Fig. 1. Distribution of graptolite bearing wells in the Canning Basin.

The application of the graptolites to both the broader and the detailed correlation of the Canning Basin wells, and in dating of the individual cores, will be discussed in the final paper of this series.

AGE

Goldwyer No. 1 Well was drilled by the West Australian Petroleum Company between 17 August and 22 November 1958, in the Canning Basin, Western Australia, at lat. 18°22′47″S and long. 122°22′58″E. Drilling ceased at 4720 feet (1439 m) in 18 m of Precambrian granite. Above this basement rock are 1125 feet (343 m) of the Lower Ordovician Thangoo Limestone, which in turn underlies 752 feet (229 m) of Lower-Middle Ordovician Goldwyer Shale. The remaining 2843 feet (848 m) of drilled strata consists of Permian, Jurassic, and Cretaceous sediments.

Ten cores were recovered from the Goldwyer Shale. Table 1 shows the position of six of those from which graptolites were recovered and identified and their fossil content. The position of other wells in the Canning Basin which intercept graptolite-bearing sediments is shown on Fig. 1.

	GOLDWYER I					
CORE NUMBER	10	9	8	7	5	1
Didymograptus artus		?				
"Didymograptus gracilis"	•	?		•	•	?
Tetragraptus sp. indet.				•		
Dichograptid stipes indet.	•	•	•	•	•	•
Amplexograptus confertus	•	•	?	•	•	•
Amplexograptus confertus mut.				•	•	
Pterograptus sp. indet.		•	•		?	
Graptolite frags. indet.	•	•	•	•	•	
Scolecodonts				•	•	
DEPTH (in feet)	3215 3227	3201 3215	3191 3201	3002 3011	2985 2994	2367 2876

Table 1. Distribution of graptolites in the Goldwyer No. 1 Well.

The macrofossils from Goldwyer No. 1 Well were identified by Gilbert-Tomlinson (1958, unpubl.) who wrote:

> 'In the upper part of the sequence (Cores 1 to 7), brachiopods are the most persistent fossils. Three groups are present—inarticulate (phosphatic) brachiopods (more than one genus), a strophomenacean (cf. *Sowerbyella;* immature), and a plicate orthid (fragmentary). Undetermined ostracods and cystid fragments are also present. Except in Cores 1 and 7, trilobites are too fragmentary for determination. Core 1 contains an immature asaphid resembling *Megalaspis* Angelin, and Core 7 contains a different *Megalaspis* (with an extended front resembling *M. extenuata* (Wahlenberg)). The lower part of the sequence (Cores 8 to 10) is characterized by trilobites. Brachiopods are very rare in this part of the sequence and are represented by inarticulate forms only. Three genera of trilobites are present—a larger asaphid resembling *Megalaspis,* the olenid *Triarthrus* Green, and the raphiophorid *Ampyx* Dalman. *Ampyx* is confined to Core 8; the other two trilobites are present in all three cores.'

Gilbert-Tomlinson dated the upper part of the sequence as late Llanvirnian to Llandeilian on the presence of *Amplexograptus.*

The following graptolites were identified from the Goldwyer cores in the course of the present study:

Pterograptus sp. indet.

Didymograptus artus Elles & Wood, 1901

'Didymograptus gracilis Törnquist, 1890'

Tetragraptus sp. indet.

Amplexograptus confertus (Lapworth, 1875)

Amplexograptus confertus (Lapworth, 1875) mut.

The age in the Canning Basin of *D. artus* is Llanvirnian (Skwarko, 1967).

As discussed below, *'D gracilis',* which occurs in the Goldwyer cores 10, ?9, 7, 5, and ?1, is identical neither with *D. gracilis* Törnquist from northern Europe nor with specimens identified with it from southern Australia. Its distinguishing feature is the similar level of divergence of th 1^1 and th 1^2 from the sicula, and in this respect it resembles *D. gracilis* Törn. mutant Holm described by Bulman in 1936. The age of the Victorian *D. gracilis* is Chewtonian and lower Castlemainian (Ch1, Ch2, Ca1) viz. *nitidus* and lower *gibberulus* zones, the age of the mutant prepared by Holm and described by Bulman is Yapeenian (Ya1, Ya2) (D. Skevington, pers. comm.). However, Holm's mutant and our mutant might not be identical for reasons given below, and the presence of *'Didymograptus gracilis* Törnquist' cannot in my opinion be used as evidence for any particular age of cores in which it occurs.

The stratigraphical range of both *Tetragraptus* and *Pterograptus* has been extended from Arenig into Middle Ordovician (Bulman, *in* Moore, 1970), so their value in dating is negligible at the generic level.

Lapworth's typical material of *A. confertus* in Wales came from the *bifidus* Zone; in Scandinavia it makes its appearance in the *bifidus* Zone and extends right through the *murchisoni* Zone. The range of *A. confertus* in terms of the British Ordovician graptolite zonal sequence is the *bifidus* and *murchisoni* Zones, i.e. Llanvirnian (viz. MO. 1-4 of the Victoria sequence) (Skevington, pers. comm.). The presence of the mutant of *A. confertus* described below in association with *A. confertus* cannot be used there as evidence for or against any particular age for Cores 7 and 5.

In this paper the age of Cores 1-10 is thus regarded as Llanvirnian mainly on the presence of *A. confertus.*

SYSTEMATIC DESCRIPTIONS

Family Dichograptidae Lapworth, 1873

Section Goniograpti

Genus Pterograptus Holm, 1881

Type species: *Pterograptus elegans* Holm, 1881

Pterograptus sp. indet.
(Pl. 17, figs 1-12)

Material: A broken but complete sicula with bud and crossing canal; two specimens of metasiculae with both initial stipes attached; several fragments of stipes showing method of branching; two fragments of mature stipes.

Description: The length of the complete sicula (CPC 11468; Pl. 17, fig. 1) together with nema and virgella is 3.2 mm, of which the incomplete nema measures 0.6 mm and the virgella at least 0.44 mm.

The nema is robust, 0.06 mm thick, and of unknown but probably considerable length.

The prosicula is 1.44 mm long and 0.2 mm wide, parallel-sided for most of its length, though with a gently conical apex. It is strengthened throughout with nine or ten longitudinal riblets.

The main body of the metasicula is 0.82 mm long, 0.22 mm wide at its proximal end, and 0.4 mm wide at the aperture. The dorsal process is moderately well developed. The ventral spine or virgella is prominent and extends 0.44 mm into the body of the metasicula.

The initial bud is given off from the dorsal side of the metasicula, close to its junction with the prosicula. The bud continues down the metasicula for about 0.3 mm closely adpressed to it before giving off the first theca, th 1^1, and the crossing canal which on further growth develops into th 2^1. The crossing canal is about 0.14 mm wide at its origin; theca th 2^1 is about 1.2 mm long, straight or curved downwards, and reaches its greatest width of 0.18 mm at its distal extremity.

Figures 9-17 in Plate 17 illustrate the overall appearance of the individual primary branches, while figures 5-8 of the same plate show the detail. Each theca on the primary branch gives off two thecae: one on one side as its direct continuation on the dorsal side, and the other by lateral budding from the obverse side of the theca, at a distance of over 0.2 mm from its aperture.

Occurrence: Goldwyer Cores No. 9, 8, ?5.

Discussion: In spite of the fact that several multiramous forms such as *Pterograptus, Pseudobryograptus, Nemagraptus* and *Trichograptus* occur in the Llanvirnian, that neither the detailed structure of the sicula nor the detail of method of branching of these genera is known, and that no sicula similar to the one described above has hitherto been described, it is suggested that the specimens illustrated in Plate 17 represent fragments of Pterograpti. This is because, of the multiramous genera occurring in the Llanvirnian, *Pterograptus* alone contains the combination of a large sicula with a large number of lateral branches. Our largest specimen, which unfortunately was irretrievably lost before it could be properly drawn, was of a single incomplete branch with six to eight lateral stipes given off.

Section Didymograpti

Genus Didymograptus M'Coy, in Sedgwick & M'Coy, 1851

Type species: *Graptolithus murchisoni* Beck, 1839

'Didymograptus gracilis Törnquist, 1890'

(Pl. 16, figs 1-7)

Material: Several early growth stages, some of which are illustrated on Plate 16 as figures 1-4; three mature or near-mature specimens of sicula with attached fully grown theca or thecae (Pl. 16, figs 6, 7); several broken stipes (Pl. 16, fig. 5).

Description: Two of the three measured siculae are 0.72 mm long, the third 0.85 mm long. The nema is strongly attached, and is at least 0.44 mm long. It is just over 0.02 mm thick at its junction with the prosicula.

The prosicula is 0.30-0.32 mm long, with a conical apex and parallel distal walls. The spiral thread is present, but there is no evidence of the longitudinal strengthening riblets.

The metasicula is 0.42 to 0.54 mm long, and up to 0.20 mm broad. It consists of about 35 fuselli which, though irregular in any part of the metasicula, are almost invariably thinner in its proximal than in its distal part, and never exceed 0.018 mm. The fuselli appear to be absent in the proximal 0.1 mm of the metasicula in one specimen (Pl. 16, fig. 1). Both ventral and dorsal apertural processes are present, the ventral being longer than the dorsal, but neither is really well developed.

The initial bud seems to be given off from the distal portion of the prosicula, and on its ventral side. It proceeds distally in close contact with the sicula, broadening gradually, and departs from it at a high angle slightly before the sicular aperture. It proceeds to the left, immediately after giving off th 1^2 to the right.

The length of th 1^1 is 1.32 mm; its proximal thickness is 0.1 mm and the thickness of its aperture a little less than 0.2 mm; its overlap is just under 1/4 proximally but possible 1/5 to 1/6 distally. The branches are given off at about the same level and very close to the mouth of the metasicula; they seem to be slightly declined for at least the initial distance from the sicula. The density of thecae is possibly 9 or 10 to a centimetre. The total size of the rhabdosome is not known.

Occurrence: Goldwyer Cores 10, ?9, 7, 5, ?1.

Discussion: The slender Didymograpti from the Goldwyer cores are closely related to two previously described forms, *Didymograptus gracilis* Törnquist, and *D. gracilis* Törnquist mut. Holm, and may be identical with one of them. The mutant form was more recently discussed by Bulman (1932). The close similarity shared by the three forms is reflected in the small size of the sicula, the mode of branching (i.e. the *bifidus* stage), the thinness of stipes, the negligible thecal overlap, and the thecal density. In Törnquist's specimens, however, the stipes leave the sicula at strikingly different levels. The preservation of the mutant did not allow Bulman to define the position of the point of origin of the initial bud (Bulman, op. cit., p. 26), but he was inclined to interpret it as having originated low down in the metasicula. If so, this is the only obvious difference between his and our specimens, and the Goldwyer forms should be considered as intermediate between the mutant and *D. gracilis* s. str.

Occurrence in Australia: In Australia *D. gracilis* s. str. has been reported only from Ordovician strata in Victoria. Hall (1899, p. 448) identified it from an unlocalized collection at Bendigo; and (1914a, p. 105; 1914b, p. 299) from the 'upper Bendigonian' of the same district. Harris & Thomas (1942, p. 366) identified *D. gracilis* from Chewtonian (Ch2) of the Parish of Campbelltown. Thomas (1960, table on p. 17), however, in his summary of the zonal distribution of graptolites in Australia, showed the range of *D. gracilis* in Australia as Chewtonian and lower Castlemainian. Both the descriptions and the detailed drawings leave no doubt that the Victorian form is *D. gracilis* s. str., and not one of the mutants.

Section TETRAGRAPTI

Genus TETRAGRAPTUS Salter, 1863

Type species: *Fucoides serra* Brongniart, 1828

TETRAGRAPTUS sp. indet.
(Pl. 16, figs 8-10)

Material: Three siculae with incipient and slightly advanced proximal development.
Description: The mature sicula is at least 1.54 mm long, and consists of a small prosicula and a relatively large and well developed metasicula. The nema is invariably present but was not observed to exceed 0.12 mm in length.

The prosicula is about 0.3 mm long, conical, somewhat inflated, and strengthened by at least a dozen thin longitudinal riblets. The distal aperture, when flattened, measures about 0.2 mm across.

The rapidly expanding metasicula is large compared with the prosicula: at least 1.2 mm long and 0.6 mm across its digital (flattened) aperture. The total number of its fuselli exceeds 70. The fuselli are very narrow in the proximal portion of the metasicula, but gradually increase in breadth to a maximum of about 0.03 mm at or near its distal aperture. A well developed broadly rounded ventral apertural process is present.

The pore is positioned on the prosicula and close to its aperture. The initial bud begins to grow probably before the metasicula attains its maturity; it grows down the metasicula, closely adhering to it, increasing in breadth fairly constantly and rapidly to a maximum breadth of about 0.5 mm, which is then maintained for a short distance. The overall length of the initial bud is probably about 1.4 mm.

Figure 10 in Plate 16 shows the initial portion of the crossing canal which is the incipient th 1^2, and the lower and smaller swelling—and a consequent protrusion—of the fusellar half-rings, which presumably is the incipient th 2^{1b}.

Occurrence: Goldwyer No. 1, Core 7.

Discussion: Although the collection includes only the very early stages of development of this form, viz. sicula plus proximal portion of th 1^1 and the very beginning of th 1^2, the very small prosicula relative to the metasicula suggests that the genus represented is probably *Tetragraptus*. Skevington (1965) recently described siculae of several Tetragrapti from Öland; although in these the ratio of the size of prosicula to metasicula is also invariably low, all early stages differ from those in our possession. The closest is probably the sicula of *T. bigsbyi* in which the pore occurs on the prosicula and close to its junction with the metasicula.

Family DIPLOGRAPTIDAE Lapworth, 1873

The only previous record of the occurrence of graptolites in the Goldwyer No. 1 Well was by Thomas, who listed *Amplexograptus arctus* or *A.* cf. *arctus* from Core 1 (Thomas, 1960, p. 15, 43 see errata) and *A. perexcavatus* probably from Core 6 (2995'-3002'; Thomas, op. cit., p. 43, and pl. 14, fig. 202). Earlier in an unpublished report, Öpik (*in* Gilbert-Tomlinson, 1958 unpubl.) identified *Amplexograptus modicellus* Harris & Thomas, from Cores 1, 7, and possibly 5. Neither Thomas's nor Öpik's specimens were freed from matrix by acid before identification.

The present study confirmed the presence of two different diplograptids in the Goldwyer cores. They have a number of important morphological features in common, some typically amplexograptid in character, others of climacograptid type. The main difference between the two forms is that only one has an unusually robust and long virgella. This spinose form was probably the one identified by Thomas as *A. arctus,* although our specimens came from Core 7 and are definitely absent from Core 1, from which Thomas' material was apparently derived. Thomas probably identified as *A. perexcavatus* the diplograptids with three short proximal spines particularly abundant in Core 1. The presence of more than one proximal spine on all specimens with proximal ends preserved examined excludes the presence of *A. modicellus* in the Goldwyer No. 1 Well.

The genus *Amplexograptus* has received a fair amount of attention in the last few years (Walker, 1953; Barrass, 1954; Bulman, 1962, and *in* Moore, 1970; Jaanusson & Skoglund, 1963), and, as a result of Bulman's re-examination of the type species *A. perexcavatus* and the redefinition of the genus, the features whose combination is supposed to characterize this rather difficult genus are particularly well known.

It will be apparent from the detailed descriptions of the species that the diplograptids from Goldwyer No. 1 Well proved particularly difficult to identify: they were found to possess obvious structures usually found in the Amplexograpti, but close scrutiny showed hardly less important morphological features usually associated with the Climacograpti.

They have the following features not associated by Bulman with the *Amplexograptus:*

i. Subcircular or circular cross-section, as inferred from the random orientation of rhabdosomes to the bedding plane.

ii. Rather shallow thecal excavations, which only appear to be deeply incised in specimens compressed obliquely by compaction of sediments.

iii. The presence of a median septum which, as can be judged by the species listed by Bulman as belonging to *Amplexograptus,* does not usually occur in this genus, though some species (e.g. *A. coelatus*) do possess it.

However, as the description below shows, our specimens have a considerable number of features usually associated with *Amplexograptus;* consequently the Goldwyer diplograptids are referred to this genus.

Family DIPLOGRAPTIDAE Lapworth, 1873

Subfamily DIPLOGRAPTINAE Lapworth, 1873

Genus AMPLEXOGRAPTUS Elles & Wood, 1907

Type species: *Diplograptus perexcavatus* Lapworth, 1876

AMPLEXOGRAPTUS CONFERTUS (Lapworth, 1875)

(Pl. 18, figs 1-9; Pl. 19, figs 1-4; Pl. 20, figs 8-17; Text-fig. 2)

Material: Numerous specimens in all stages of development.

Description: The rhabdosome is up to 12 mm long, approximately round in cross-section, about 1 mm wide at th 1^2, and widening gradually to 1-2 mm distally.

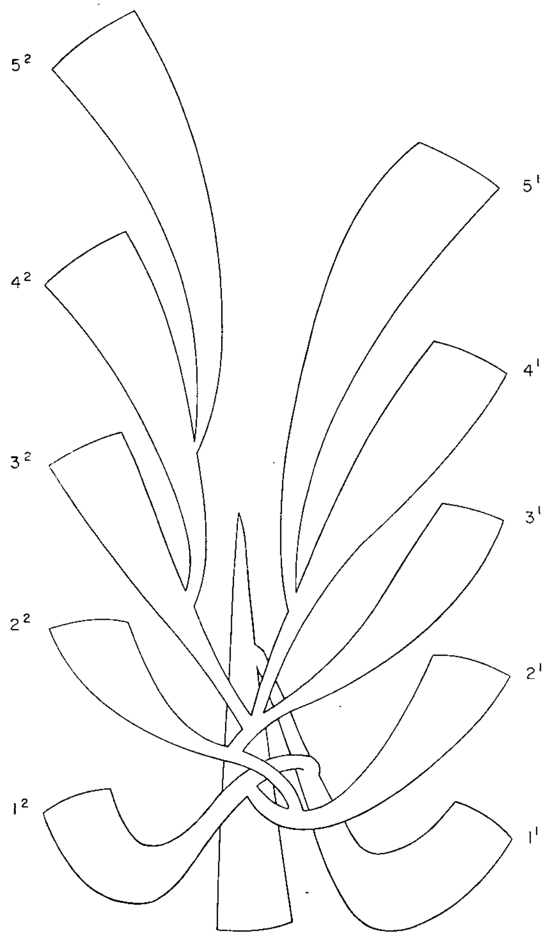

Fig. 2. ***Amplexograptus confertus*** **Lapworth, 1875. Reconstruction thecal diagram showing the medium septum originating between th 3^2 and th 4^1, at the place of their origin. The interpretation of the nature of th 3^1 is partly tentative.**

Thecae number about 16 in 10 mm, are sharply geniculate, with a straight supragenicular wall only slightly inclined to the longitudinal axis of the rhabdosome, and a little longer than the infragenicular wall. The selvage round the infragenicular wall is confluent with the apertural selvage. Apertural margins are commonly undulate. The thecal excavations are moderately wide and deep. Mesial spines are present on th 1^1 and th 1^2 only.

In specimens preserved in subscalariform view (perhaps the most common preservation) the thecal excavations appear to be particularly deep, as in *Amplexograptus,* this being due in part to the considerable breadth of the thecal excavations resulting from the circular or near-circular cross-section of the rhabdosomes. The two proximal-most thecae bear spines similar to those found in *Amplexograptus.* The near-circular cross-sectional shape of the rhabdosome, the very low inclination of the supragenicular wall to the longitudinal axis of the rhabdosome, the presence of the median septum, are features usually found associated with Climacograpti, not Amplexograpti.

Sicula: The sicula is up to 1.2 mm long. The prosicula is short, up to 0.32 mm, slender, conical in shape, initially rapidly widening to 0.1 mm and then very gradually to 0.16 mm. Though reinforced with longitudinal ribs the periderm of the prosicula is in many specimens wrinkled, broken, or collapsed. The metasicula is also conical, up to 0.84 mm long, about 0.16 mm across at its proximal end, and up to 0.33 mm across at its distal end. Although strengthened with up to seven annular rings it is somewhat irregular in shape and does not seem to be very robust. Its dorsal process is inconspicuous, but the ventral spine is robust and originates about 1/3 the distance from the prosicula.

Initial bud: The circular foramen forms on the metasicula, on or very close to the virgella and near its point of origin. The initial bud grows down the metasicula, closely adhering to it (Pl. 18, fig. 5), and then upwards away as th 1^1 before reaching the sicular aperture. The crossing canal forms early on the initial bud, crosses diagonally downwards over to the dorsal side of the sicula still adhering to it, and then upwards and away from it on a slightly higher level than th 1^1, giving rise to th 1^2.

Thecae th 1^1 and th 1^2, and the succeeding thecae: Thecae th 1^2 and th 1^1 resemble each other in their overall shape and in the presence on each of a prominent spine up to 0.4 mm long, which may or may not be the continuation of the outer lip of the thecal aperture.

In the succeeding thecae the supragenicular wall is slightly inclined to the longitudinal axis of the rhabdosome at least in its proximal portion; it is also slightly longer than the infragenicular wall. The mesial flanges are only occasionally visible and never prominent. The apertural margins generally show rather weakly developed low rounded lappets. There is a selvage around the infragenicular wall.

Theca th 2^1 buds off the right side of th 1^2 and proceeds across the sicula to occupy a position above th 1^1; th 2^2 and th 3^1 follow the same pattern of formation and emplacement (Pl. 19, fig. 1). The pattern changes at th 3^1, which seems to give off two buds, one crossing the sicula and giving rise to th 3^2, the other remaining on the same side as th 3^1 by swinging to the right and occupying position above it (Pl. 19, fig. 4).

The average length of the supragenicular wall is about 0.3 mm, though individual thecae might exceed this (th 2^1 is 0.44 mm) while the gaps between them average about 0.15 mm. There are about 2 thecae in 10 mm.

Median Septum: The median septum originates most probably between th 3^2 and th 4^1, permanently separating the two sides of the rhabdosome; from this point onwards the crossing of thecae ceases, with successive thecae on each side of the septum giving rise to thecae which remain on that side of the rhabdosome. This mode of development is rather unusual (Bulman, 1932, pl. 10) in that the change from non-septate to septate mode is somewhat delayed in the development of the rhabdosome.

Occurrence: Goldwyer No. 1 Cores 10, 9, ?8, 7, 5, 1.

AMPLEXOGRAPTUS CONFERTUS (Lapworth, 1872) mut.
(Pl. 20, figs 1-7)

Cores 5 and 7 yielded a number of diplograptids obviously differing from the very numerous *A. confertus* by a robust and prominent virgella. No particular difficulty was experienced in separating the specimens from the shaly matrix by digesting with hydrofluoric acid, but attempts at bleaching with oxidizing solution to allow examination of the internal structures were unsuccessful.

Close examination of external structures and their comparison with those of *A. confertus* confirmed that the only basic difference between them is the lack of extremely well developed virgella on *A. confertus*. In addition as mentioned above in contrast to *A. confertus* none of the extremely spinose specimens responded to bleaching solutions.

It is concluded that the specimens with strongly developed virgella represent a mutant of *A. confertus* (Lapworth, 1872).

ACKNOWLEDGMENTS

I wish to thank Mr G. M. Furnival, Managing Director of the West Australian Petroleum Co., for his permission to extract from his company's cores material for this study.

I particularly wish to thank Professor Adam Urbanek, Palaeontology Department, Warsaw University, without whose guidance and generous help the study here summarized would not have been possible.

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PLATE 16

Figs 1-7 *'Didymograptus* aff. *gracilis* Törnquist, 1890'

1.Prosicula with nema and proximal portion of metasicula. Note strengthening rods on prosicula. CPC 11459. x 50.

2. Sicula with initial bud and proximal portion of th 1^1. CPC 11460. x 50.

3, 4. Complete sicula in reverse and obverse view with initial bud, th 1^1 and proximal part of crossing canal. CPC 11461. x 50.

5. Portion of stipe in ventral view. CPC 11462. x 25.

6. Portion of sicula with initial bud, crossing canal, and th 1^2. CPC 11463. x 25.

7. Sicula with ?th and ?th 2^2. CPC 11464. x 25. Goldwyer No. 1, Core 7.

Figs 8-10 *Tetragraptus* sp. indet.

8. Sicula in obverse view with proximal portion of th 1^1. CPC 11465. x 25.

9. Sicula in obverse view with th 1^1 and incipient th 1^2. CPC 11466. x 50.

10. Sicula in obverse view with th 1^1 and th 1^2. Note resorption foramen. CPC 11467. x 33. Goldwyer No. 1, Core 7.

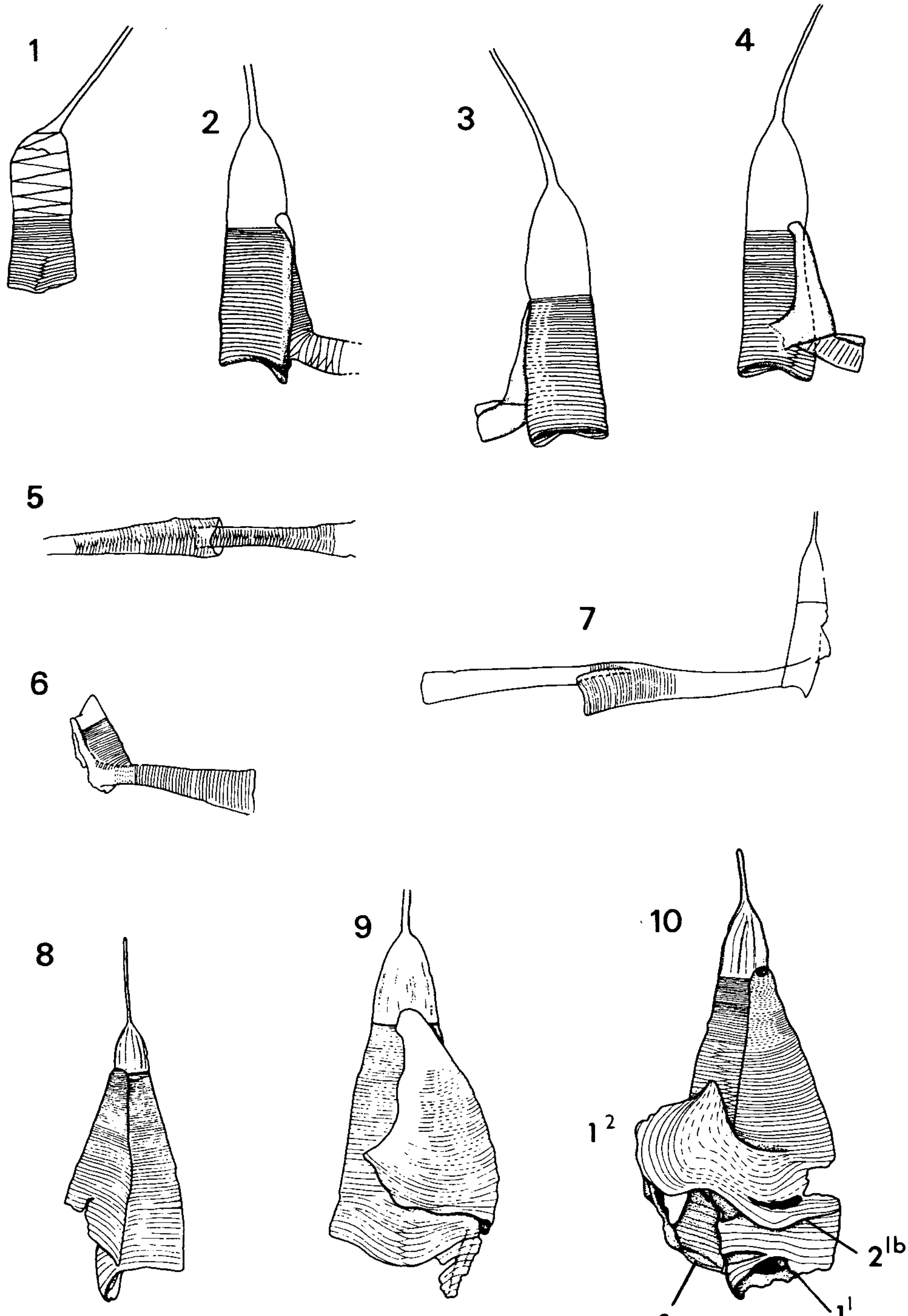
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PLATE 17

Figs 1-12 *Pterograptus* sp. indet.

1. Outline of sicula in obverse view, with proximal portion of th 1^1 and complete crossing canal. Major portion of prosicula broken off together with virgella. CPC 11468. x 25. Goldwyer No. 1, Core 9.

2. Detail of metasicula showing its structure as well as proximal portion of th 1^1 and crossing canal. CPC 11469. x 50. Goldwyer No. 1, Core 9.

3. Specimen of proximal portion of rhabdosome in obverse view. Note metasicula, initial bud, th 1^1, crossing canal, th 1^2 with lateral bud. CPC 11470. x 25. Goldwyer No. 1, Core 9.

4. Specimen of fragment of stipe probably from proximal portion of rhabdosome in reverse and obverse view showing method of branching. CPC 11471. x 25. Goldwyer No. 1, Core 9.

5, 6. Specimen of fragment of stipe in reverse and obverse views probably from proximal portion of rhabdosome showing method of branching. CPC 11472. x 25. Goldwyer No. 1, Core 9.

7, 8. Specimen of fragment of stipe in reverse and obverse views showing method of branching. CPC 11473. x 25. Goldwyer No. 1, Core 9.

9, 10. Fragment of stipe, CPC 11474, viewed from both sides. Note ?lateral buds (lb). Goldwyer 1 Core 7.

11, 12. Fragments of stipes CPC 11475 and CPC 11476. Note ?lateral bud (lb) on proximal end of fig. 12. x 25. Goldwyer No. 1, Core 7.

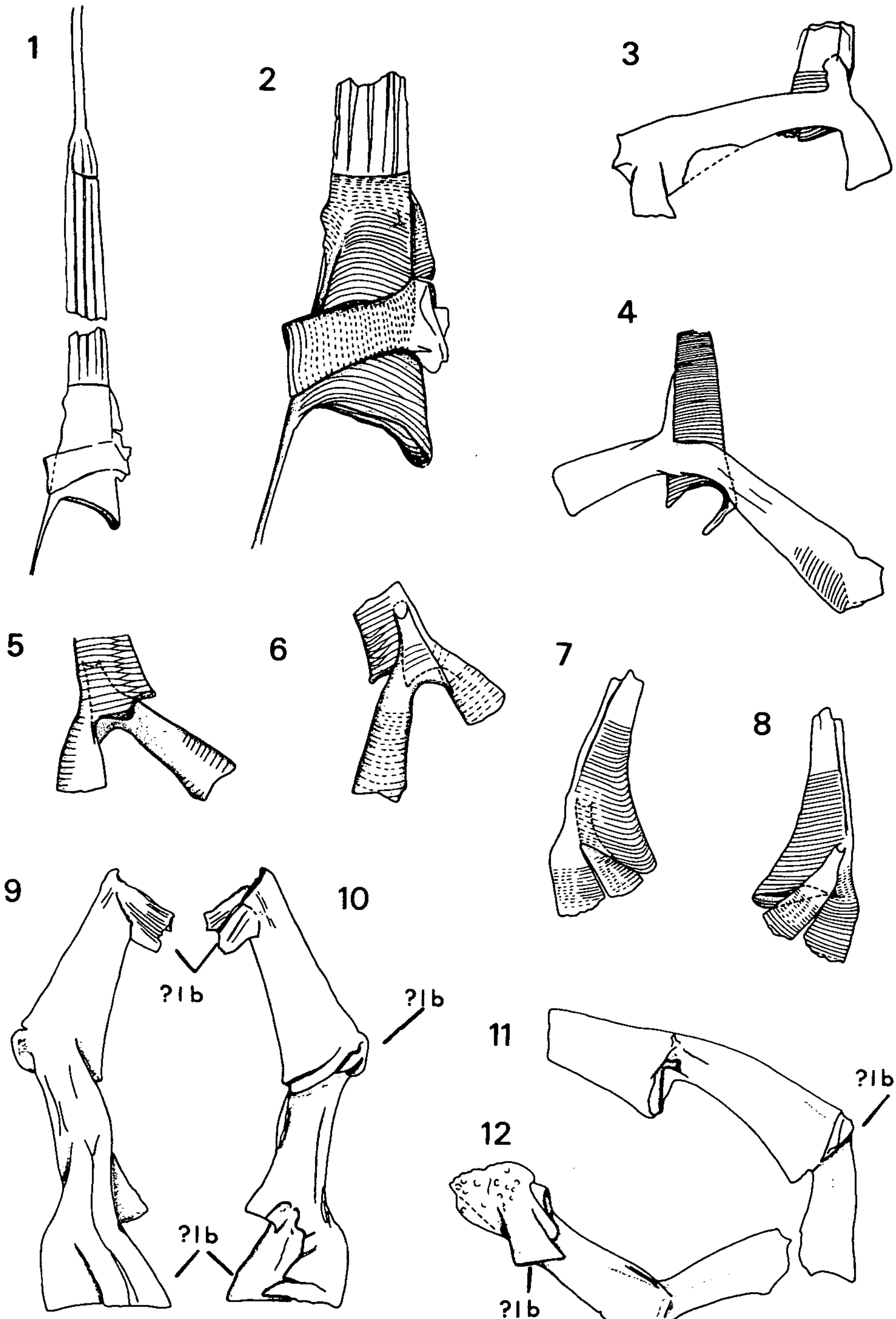
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PLATE 18

Figs 1-9 *Amplexograptus confertus* (Lapworth, 1875).

1. Prosicula with virgella and strengthening rods. CPC 11477. x 50.
2. Metasicula with spine, in obverse view. Note somewhat degenerate prosicula. CPC 11478. x 50.

3, 4. Specimens of sicula in obverse view with fully developed pore. CPC 11479 and CPC 11478. x 50.

5. Metasicula in reverse view with incipient initial bud. Fusellar rings on metasicula omitted to show annular rings. CPC 11481. x 50.

6, 7. Metasicula in obverse and reverse view, with theca 1^1 extending along it and adhering to it. Note incipient th 1^2 in fig. 7. Fusellar rings on sicula omitted to accentuate annular rings. CPC 11482. x 50.

8, 9. Distal portion of metasicula in reverse and obverse view with fully developed th 1^1 and incompletely developed th 1^2. CPC 11483. x 50. Goldwyer 1 Core 1.

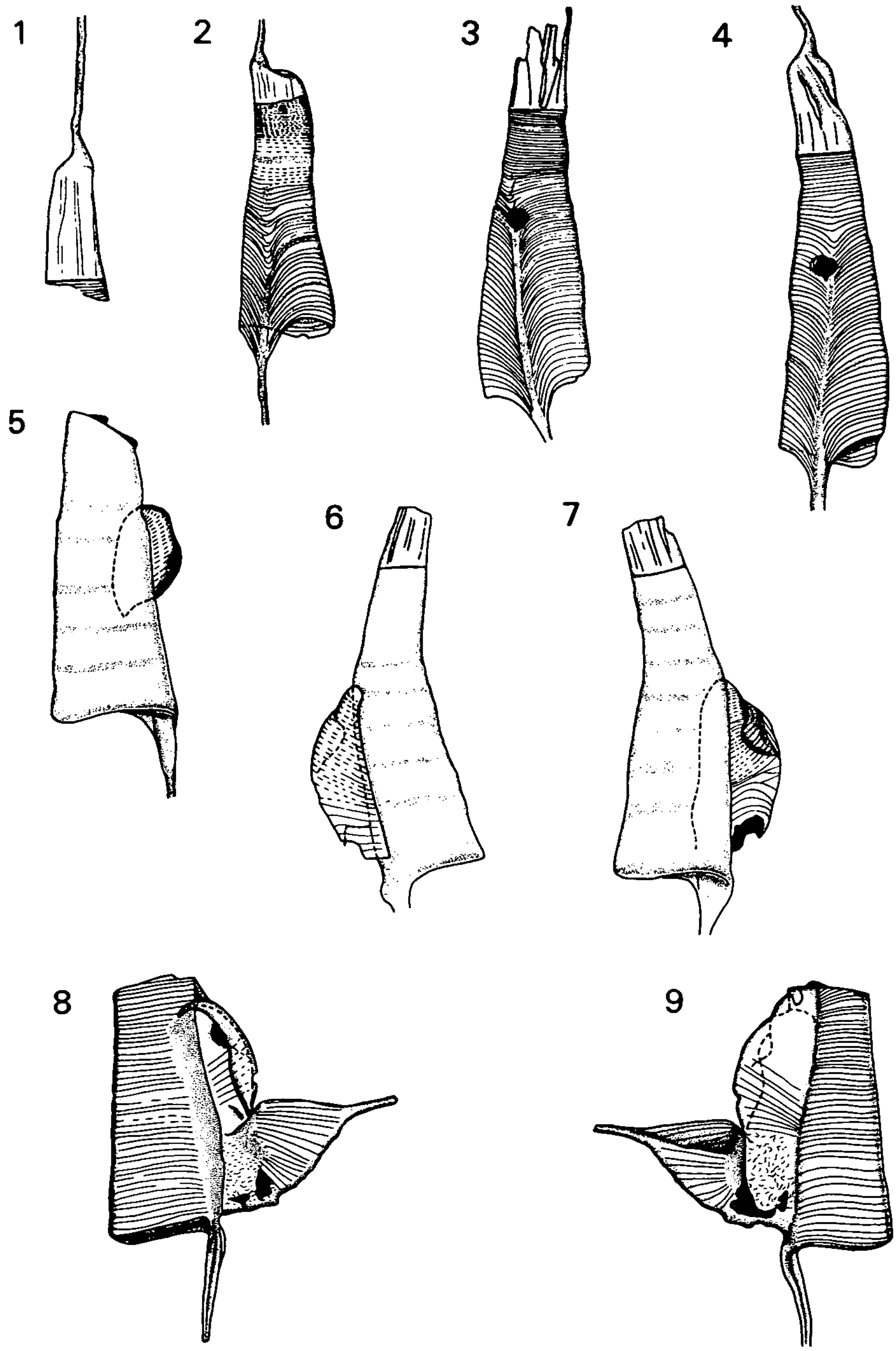
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PLATE 19

Figs 1-4 *Amplexograptus confertus* (Lapworth, 1875)

1. Proximal portion of rhabdosome with thecal development up to th 2^2. Note th 2^1 branching off from th 1^2 and foramen in th 1^2 from which th 2^2 originates. CPC 11484. x 50.
2. Advanced stage of development of proximal portion of specimen in obverse view, showing clearly the median septum in end-on view. CPC 11485. x 25.
3. Oblique view of broken off proximal portion of rhabdosome with clearly visible median septum. CPC 11486. x 25.
4. Proximal portion of specimen in reverse view showing progressing development of thecae up to th 4^1, and beginning of development of median septum between thecae 3^2 and 4^1. Note the dicalycal type of th 3^1. CPC 11487. x 50. Goldwyer 1 Core 1.

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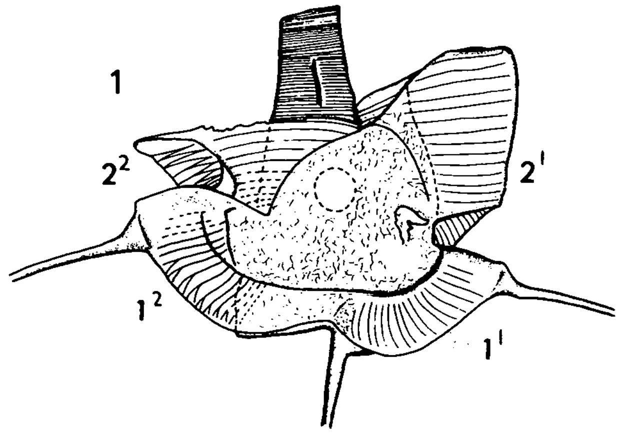

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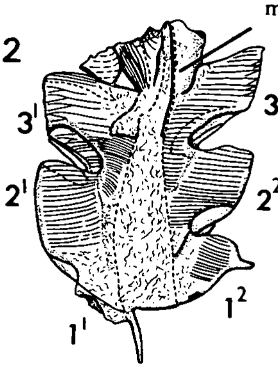

median septum

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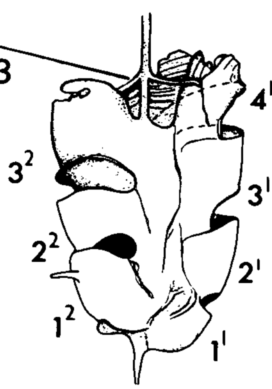

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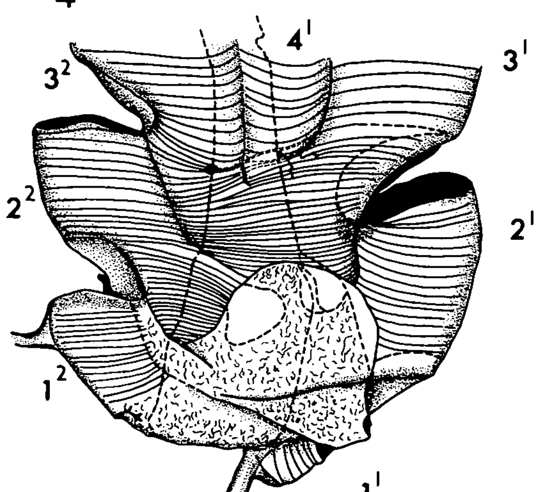
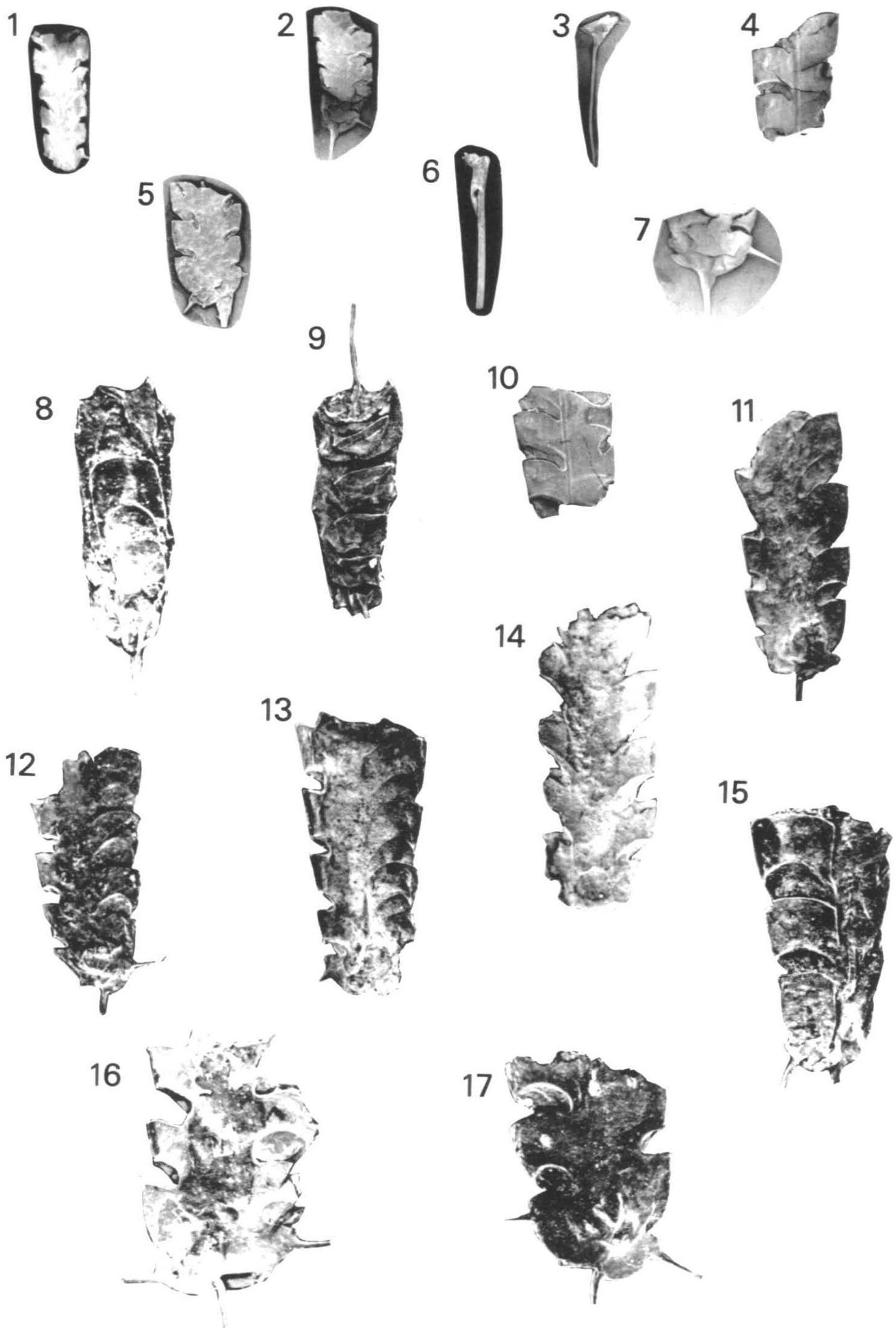


PLATE 20

Figs 1-7 *Amplexograptus confertus* (Lapworth, 1875) mut.
1. Well developed specimen in obverse view. x 6. CPC 13954.
2. Broken specimen with moderately developed ventral spine, in obverse view; proximal-most part broken off. x 6. CPC 13955.
3. Well developed virgella. x 6. CPC 13956.
4. Broken off fragment compressed in subscalariform view. x 9. CPC 13957.
5. Specimen in obverse view with broken off ventral spine. x 9. CPC 13958.
6. Robust virgella broken off at both ends. Note sheath-like structure enveloping proximal portion of virgella. x 5.3. CPC 13959.
7. Enlarged proximal portion of Pl. 20, fig. 2. x 11. Goldwyer No. 1, Core 7. CPC 13955.

Figs 8, 9, 11-17 *Amplexograptus confertus* (Lapworth, 1875)
8. Specimen CPC 13960 in scalariform view. x 19.
9. Specimen CPC 13961 in scalariform view. x 13.
11. CPC 13962 in subscalariform view. x 15.
12. CPC 13963 in subscalariform view. x 14.
13. CPC 13964 in subscalariform view. x 14.
14. CPC 13965 in subscalariform view. x 15.
CPC 13966 in subscalariform view. x 26.
16. CUC 13967 in subscalariform view. x 23.
17. CPC 13968 in subscalariform view. x 21. Goldwyer No. 1, Core 7.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JURASSIC FOSSILS OF WESTERN AUSTRALIA

1. BAJOCIAN BIVALVIA OF THE NEWMARRACARRA LIMESTONE AND THE KOJARENA SANDSTONE

by

S. K. Skwarko

SUMMARY

The bivalve fauna of the Newmarracarra Limestone and the Kojarena Sandstone, here revised, contains at least 32 different bivalves, 27 of which are named specifically and subspecifically. Of these, 24 are endemic to Australia; only three represent or probably represent European Middle Jurassic forms.

Ten new species are described: *Grammatodon* (*Indogrammatodon*) *carnarvoni*, *Cucullaea geraldtoni*, *Propeamussium* (*Parvamussium?*) *geelvinki*, *Camptonectes greenoughi*, *C. waggrakinensis*, *Chlamys enantyi*, *Plagiostoma championi*, *Astarte* (*A.*) *tibraddeni*, *Tancredia* (*T.*) *sandspringi*, and *Tancredia* (*Isotancredia*) *kojarena*. There are also two new subspecies: *Lopha marshii australiensis* and *L. marshii newmarracarraensis*.

Of the previously identified or established species in the area, *Cucullaea inflata* Moore, 1870 is retained for lack of conclusive evidence that it is—as suspected—an aberrant form; *C. tibraddonensis* Etheridge, 1910 is placed in synonymy with *C. semistriata* Moore, 1870; the reported presence by Moore of *C. oblonga* Sowerby is not substantiated; *Camptonectes* cf. *rigidus* is certainly similar to the European species but material is not well enough preserved for definite comparison: *Pecten cinctus* J. Sowerby is a new species *'C'. waggrakinensis;* past identification of *C. pectiniformis* and *Pseudavicula duplicata* is confirmed. but *Ostrea marshii* is represented by its subspecies *australiensis* and *newmarracarraensis*.

The genera identified were of worldwide distribution and attest to the presence of sea connexions between Western Australia and Europe and the Americas. However, the environmental conditions in the Geraldton area were such as to favour evolution of a mainly endemic fauna—at least at the specific level.

INTRODUCTION AND ACKNOWLEDGMENTS

Marine bivalves were among the earliest Jurassic fossil invertebrates to be described from Western Australia, but although their discovery created and maintained considerable interest for a number of years, they have not been intensively studied since 1910, when Etheridge described a large collection from Greenough River area.

Interest seems to have dwindled recently. Although Jurassic bivalves continue to be encountered in boreholes drilled in the search for oil, and they are occasionally mentioned in private company reports, they seem to be supplanted by smaller fossils in the dating of cores and environmental studies. Their potential value, however, is considerable, and is one of the reasons why revision was undertaken.

Of all Western Australian Jurassic faunas, those of the Newmarracarra Limestone, and to a lesser extent the Kojarena Sandstone, are the most prolific and easiest of access. The strata which yield the Newmarracarra and the Kojarena faunas in abundance crop out commonly around Geraldton (Fig. 1) on the west coast of Western Australia. The material for revision was obtained on loan from institutions throughout the country. Some of the early type specimens were located at the British Museum (Natural History) in London, which generously submitted plaster duplicates. The loaned collections were supplemented by personal collections on behalf of the Bureau of Mineral Resources.

I wish to thank the Director of the British Museum (Natural History) for the opportunity to do comparative work in the museum and Messrs N. Morris, P. Palmer, and R. Cleevely, also of the British Museum, for their help and cooperation during my stay there and after my return to Canberra. Thanks are due to the heads of the following institutions which have loaned their material for study: Australian Museum, Sydney; Geological Survey of Western Australia; University of Tasmania Geology Department; University of Western Australia Geology Department; Western Australian Museum. I wish to express particular thanks to the West Australian Petroleum Company for the use of maps of the Geraldton area; also to Mr G. W. Kendrick, Department of Palaeontology, Western Australian Museum.

HISTORY OF INVESTIGATION OF THE CHAMPION BAY GROUP

The first report of the presence of Jurassic fossils from the State of Western Australia was by Gregory (1861), when he listed Mesozoic specimens of *Trigonia* and *Ammonites* from the Moresby Range, an ammonite from Mount Albert, and a *Pecten* from east of Wizard Peak. Some of these specimens may have been exhibited in London in the following year, and in the next few years several additional collections were made and sent to England.

Clarke (1867) in his brief resumé on the discovery of Secondary fossils in Australia listed Moore's as yet unpublished as well as his own identification of all the Mesozoic (viz. Bajocian) fossils collected in Western Australia. These determinations were either on generic level or reflected supposed affinities with species already described in Europe. He regarded them as of Inferior Oolite age on the basis of the supposed presence of *Avicula munsteri, Ostrea marshii, Ammonites moorei, Nautilus sinuatus,* and *Trigonia costata.*

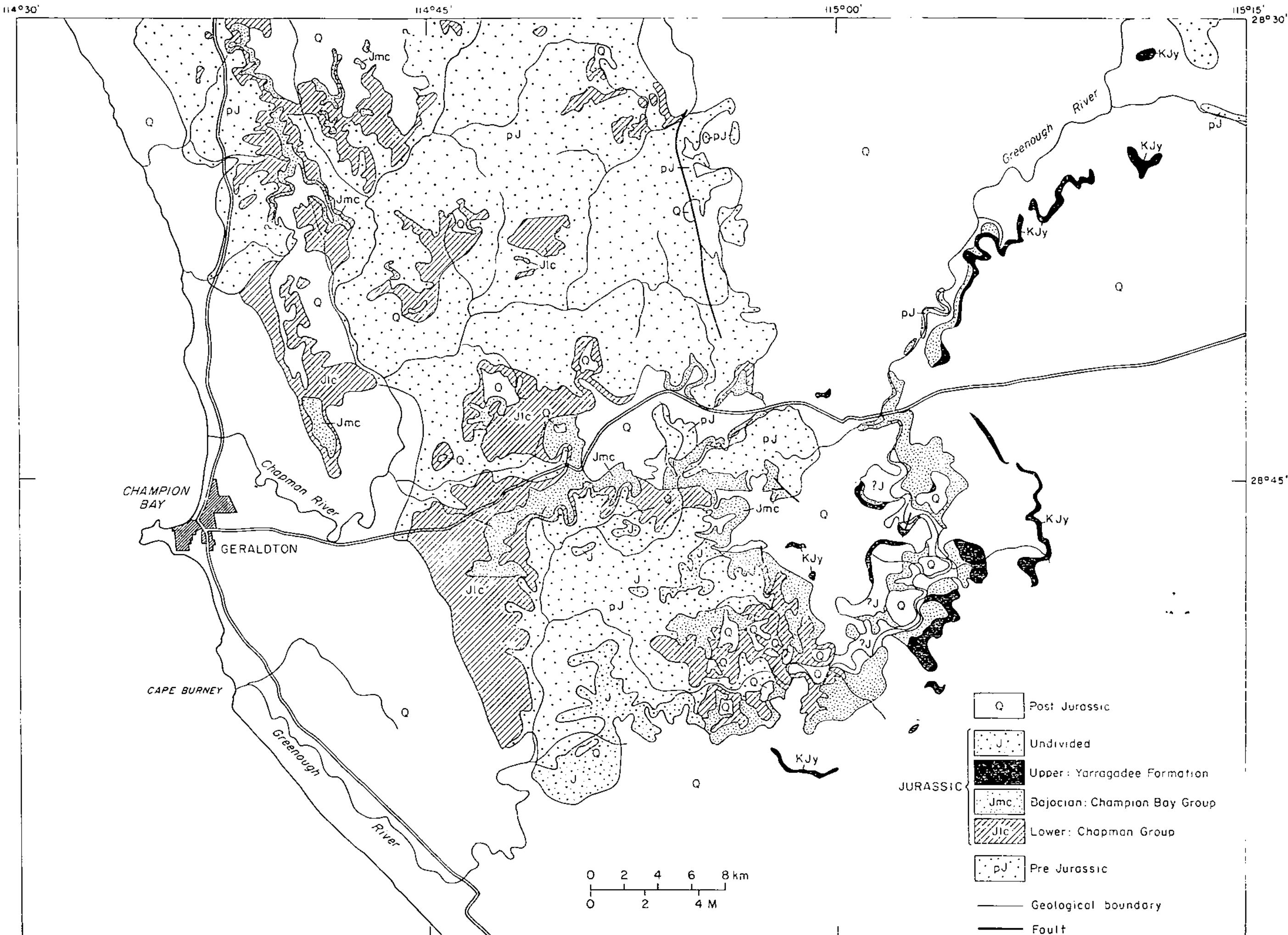


Fig. 1. Geological map of the Geraldton district, showing among others, outcrops of the Chapman Group, Champion Bay Group, and the Yarragadee Formation (modified after WAPET map).

Moore (1870) published the first systematic description of Australian Mesozoic fossils, listing 57 determinations from the Jurassic of Western Australia. Twenty of these, including four ammonites which he figured and assigned to Toarcian, Bajocian, and Callovian species, were regarded as specifically identical with the Ooolitic or Upper Liassic European forms, and ten were described as new: *Pecten greenoughensis, Astarte cliftoni, Cucullaea inflata, C. semistriata, Cucullaea* sp., *Myacites sanfordii, Trigonia moorei, Cerithium greenoughensis, Rissonia australis, Turbo australis.* Moore's material was not, however, systematically collected, and because of this he dated it broadly as Middle and Upper Lias and the Inferior Oolite.

Etheridge (1878) listed the following fossils from the Jurassic of Western Australia: *Rhynchonella variabilis* Schlotheim, *Avicula echinata* and *A. inaequivalvis* J. Sowerby, *A. munsteri* Bronn, *Cucullaea oblonga* J. Sowerby, *Gresslya donaciformis* Phillips, *Lima duplicata* J. de C. Sowerby, *L. proboscida* and *L. punctata* J. Sowerby, *Myacites liassianus* Quenstedt, *Ostrea marshii* J. Sowerby, *Pecten calvus,* Goldfuss, *P. cinctus* J. Sowerby, *Pholadomya ovulum* L. Agassiz, *Turbo laevigatus, Ammonites aalensis* and *A. brocchii* J. Sowerby, *A. macrocephalus* and *A. radians* Schlotheim, *A. walcotti* J. Sowerby, *Belemnites canaliculatus* Schlotheim, *Nautilus semistriatus* d'Orbigny, and *N. sinuatus* Clarke. These were in addition to the species described earlier by Moore.

Neumayr (1885) figured a new species of ammonite, *Stephanoceras leicharti,* and some fragments of ammonites supposedly from the Glenelg River, Kimberley district, from which he dated the limestone from which it came as middle Bajocian, *humphriesianum* Zone.

Crick (1894) overlooked Neumayr's publication, and in his two short papers described as *Belemnites* sp., *Ammonites (Sphaeroceras) woodwardi, A. (Perisphinctes) championensis, A. (P.) robiginosus,* and *A. (Sphaenoceras)* sp. He revised Moore's earlier determination of ammonites and described as new *Nautilus perornatus* from material previously identified by Moore as *N. semistriatus* d'Orbigny, *A. (Dorsetensia) clarkei* (previously identified as *A. radians* Schlotheim), *A. (Stephoanceras) australe* (previously *?A. macrocephalus* Schlotheim) and *A. (Sphaeroceras) semiornatus* (previously *A. brocchi* J. Sowerby). He dated the fauna as Bajocian on the supposed presence of *Normannites* and *Dorsetensia.*

Redlich (1896) reviewed Crick's paper, and remarked upon the similarity between his and Neumayr's species, particularly between Neumayr's *Stephanoceras leicharti* and Crick's *Perisphinctes championensis.*

Etheridge (1901) redescribed specimens identified by Moore as *'Lima proboscidea* J. Sowerby' as *Ctenostreon pectiniformis* Schlotheim.

In the course of his description of the Jurassic fauna of Cutch, Kitchin (1903) remarked upon the close similarity between his *Trigonia dhosaensis* and the *T. moorei* from Western Australia.

Chapman (1904) commented upon a number of species which he identified from a collection made by Gregory from the Greenough River District. He referred Crick's *Ammonites* (*Stephanoceras*) *australe* to *Normannites* and dated the assemblage as Inferior Oolite.

Maitland (1907) in his presidential address briefly discussed Jurassic strata around Geraldton and listed their fossil content.

Etheridge (1910) described a large collection of Jurassic fossils from the Greenough River district. He identified *Serpula conformis* Goldfuss and *Radula duplicata* J. de C. Sowerby, and described the following new species: *Ostrea tholiformis, Modiola maitlandi, Cucullaea tibraddenensis, Pleurotomaria greenoughensis.* He refigured one of Crick's species, *Dorsetensia clarkei,* from the new material .

Glauert in 1910 (pp. 97-106) listed systematically all the Jurassic fossils in Western Australia, their areas of occurrence, bibliographical references, and places where they were exhibited. The areas of occurrences listed were Shark Bay, Moresby Range, Greenough River, Tibradden, Moonyoonooka, Sandspring, Woolanooka, Shark Farm, and Mount Hill.

Uhlig (1911, p. 409) gave the opinion that closer examination of the stephanoceratids figured by Neumayr and Crick from Western Australia diminished their apparent similarity with European forms and underlined their local aspect.

In his textbook on Australian fossils, Chapman (1914, pp. 105, 181-2, 197, 208-9) listed and illustrated with rather poor drawings some bivalves, gastropods, ammonites, and brachiopods from the Jurassic of Western Australia.

In 1924 Whitehouse treated systematically a small collection of fossils from 30 km east of Geraldton. From it he described for the first time the following: *Cidaris* sp., *Berenicea* cf. *archiaci* Haime, a variety of *Trigonia moorei* Lycett, a new ammonite *Otoites depressus, Otoites* sp., *Sonninia* spp., some indeterminate ammonitic forms, and a *Belemnopsis.* He also remarked on *T. moorei,* renamed *Avicula echinata* as *Pseudomonotis echinata* (J. Sowerby), and renamed and redescribed *Avicula munsteri* Bronn as *Oxytoma decemcostata.* He also renamed Etheridge's *Dorsetensia clarkei* as *D. etheridgei* and regarded it as generically distinct from Crick's, which he assigned to *Sonninia.* The presence of *Otoites* was regarded by Whitehouse as evidence for the middle Bajocian age *(sauzei* Zone) of the assemblage.

In 1926 Glauert brought up to date his earlier list.

Maitland (1919, pp. 39-42) summarized available data on the Jurassic sediments and fossils of Western Australia. The Jurassic sediments were known to be at least 1000 m thick, and to consist of limestone, clay, sandstone, grit, conglomerate, and lignite. They were thought to be flat-lying or gently undulating and to stretch from Moore River in the south to Shark Bay in the north. He listed the fossiliferous localities and gave fossil lists for some of them. Maitland discounted the possibility that fossils described by Neumayr were derived from Glenelg River in the Kimberley, and suggested that they were probably collected in the Glenelg District, northeast of Perth.

'Spath (1939) described a small collection of ammonites from the Geraldton District and considered that they were referable to the Sauzei or Sowerbyi Zones (Middle Bajocian) of the European succession. . . . [He] reproduced Neumayr's figures of *Stephanoceras leicharti* and founded on it a new genus, *Pseudotoites,* and refigured the holotype fragment of *Dorsetensia clarkei* Crick, which he reaffirmed to be a *Dorsetensia* in opposition to Whitehouse's opinion, and placed *D. etheridgei* Whitehouse in synonymy. Spath also figured an *?Emileia* sp., which is now considered to be the inner whorls of a *Pseudotoites,* and a *'Normannites'* which he identified as *'N.' woodwardi* (Crick), but which is now believed to be another species and not a *Normannites.* He also discussed the affinities and age of the fauna, which he considered to be of the *sowerbyi* and *sauzei* Zones.' (Arkell & Playford, 1954, pp. 551, 559).

In 1939 Teichert postulated continuation of sedimentary conditions, based on minor faunal similarities, between the Timor-East Celebes Geosyncline on the one hand and his Westralian Geosyncline on the other. His thesis was based partly on evidence from the endemic faunas near Geraldton, and partly on the discovery of Jurassic fossils on the Minilya River and near Broome.

Pia (1940) described *Parachaetetes megalocytus,* a Jurassic alga, from Minilya River, northern Carnarvon Basin.

Teichert (1940) discussed a small Jurassic fauna from the Minilya River, consisting of *Parachaetetes megalocytus* Pia, *Ostrea tholiformis* Etheridge, and a new species *Echinotis sinuata* (Moore's *Avicula echinata* and Whitehouse's *Pseudomonotis echinata*). He correlated this assemblage with marine Bajocian faunas of the Geraldton district, 650 km to the south, thereby considerably extending the area of marine inundation of Western Australia in Jurassic time. His was the first report of marine Jurassic sediments and fossils in the Carnarvon Basin.

In 1946 and 1947 Teichert summarized the knowledge of the Jurassic strata and fossils of Western Australia. He grouped them under their origin and areas of occurrence, one being a narrow coastal belt of plant-bearing or unfossiliferous sandstone and shale of lacustrine origin and over 300 m thick, which probably underlies the whole of the coastal strip between Perth and Mingenew and which is probably Lower to early Middle Jurassic in age. Another area consisted of a few hundred metres of strata east and southeast of Geraldton with a rich marine molluscan fauna, which was dated on ammonites as lower Bajocian *(sauzei* and *sowerbyi* Zones) by Spath (1939). A third was a small inlier of sandstone with pelecypods and algae, less than 8 m thick, cropping out on Minilya River in the northern part of the Carnarvon Basin.

David (1950) briefly summarized the Jurassic stratigraphy of Western Australia. He included further data on the Perth-Geraldton area, and suggested that the southernmost terrestrial beds, which crop out at Bullsbrook 40 km north of Perth, may be Lower Cretaceous rather than Upper Jurassic, as they are higher stratigraphically than beds underlying the Cretaceous strata at Gingin. The latter are older and underlie marine Bajocian beds at Mount Hill, southeast of Geraldton. David gave the thickness of the Jurassic beds at Geraldton as at least 900 m.

In his address to the Gondwana Symposium in 1952 Teichert briefly discussed the small outcrop of Jurassic sandstone on the Minilya River which formed the basis for his paper of 1940. He formally named the sandstone the Curdamuda Sandstone and revised his earlier determinations of bivalves found in it. He decided that the shells which he originally identified as *Echinotis sinuata* — actually *Meleagrinella sinuata,* the name *Echinotis* being a subjective synonym of *Meleagrinella*—were a new species and not the *M. sinuata* of the Geraldton district. Specimens of this new species were also found in the Desert Basin near Mount Alexander in 1948, in beds below strata with *Buchia subspitiensis* of Oxfordian or slightly older age. Thus Teichert interpreted the age of the Curdamuda Sandstone as either Middle Jurassic or earliest Upper Jurassic. Revision of the Curdamuda fauna also revealed the possible presence of a *Lima,* and threw doubt on the original determination of *Ostrea* as *O. tholiformis* of the Geraldton area.

Fairbridge (1953) brought up to date Teichert's summary of Western Australian stratigraphy and palaeontology. His summary is based in part on earlier resumés discussed above, in part on the then unpublished manuscript of Arkell & Playford—particularly for the Geraldton area (see below)—and partly on other, mostly new sources. He formalized such names as 'Monksleigh Sandstone', for the non-marine outcrops north of Mingenew; 'Yarragadee Beds' with a rich Upper Jurassic flora of East Indian affinities, also in this area; 'Desert Sandstone' and 'Misery Shale' and 'Dandaragan Sandstone' in the Jurassic succession in the Hill River/Dandaragan/ Gingin area; the subsurface 'Claremont Sandstone' in the Perth metropolitan area; and 'Callawa Beds' with *Otozamites* 300 km southwest of Broome.

Arkell & Playford (1954) described in detail the stratigraphy and ammonites of the Jurassic of the Geraldton area. The Jurassic sequence was subdivided into two groups: the lower, non-marine, plant-bearing Chapman Group, and the overlying marine Champion Group. The Chapman Group consists at the base of 85 m of Greenough Sandstone, overlain by 36 m of Moonyoonooka Sandstone. The disconformity between the Chapman Group and the Champion Group is regarded as representing a short time interval. The bottom unit of the marine sequence is the Colalura Sandstone, which contains fossil wood as well as *Astarte cliftoni, Astarte* sp., *Lopha* cf. *marshii* (J. Sowerby), *Ctenostreon pectiniformis, Trigonia moorei, Ostrea sp., Oxytoma* sp., and *Belemnopsis* sp. Overlying the Colalura Sandstone is up to 2.5 m of Bringo Shale, with dwarf bivalves including *Meleagrinella* occurring at several levels. Above it is the Newmarracarra Limestone, with a rich fauna of bivalves and ammonites, from which all the previously described fossils have been collected. The Newmarracarra Limestone varies in thickness from 4.8 to 11.6 cm. The highest unit is Kojarena Sandstone, over 25 m thick, with rare marine fossils such as *Trigonia moorei, Isognomon* sp., *Belemnopsis* sp. The following new species were described: *Sonninia playfordi, Withellia australica (Dorsetensia* sp. ind. of Spath), *Fontannesia fairbridgei, F. whitehousei, Otoites antipodus, Pseudotoites fasciculatus, P. emiloides, P. brunnschweileri, P. spitiformis, Zemistephanus corona,* and *Z. armatus;* and the following species were redescribed or discussed: *Fontannesia clarkei* (Crick) (previously *Dorsetensia clarkei), Fontannesia* spp. indet. (previously *Sonninia* spp.), *Otoites woodwardi* (Crick) (previously *Normannites woodwardi* of Spath and *Sphaeroceras woodwardi* of Crick), *Otoites (?Trilobiticeras) depressus* Whitehouse (formerly *Normannites depressus* of Spath and *Otoites depressus* of Whitehouse), *?Otoites australis* (Crick) (formerly *Normannites australe* of Chapman and *Sphaenoceras australe* of Crick), *Pseudotoites leicharti* (Neumayr), *P. championensis* (Crick), *P. robiginosus* (Crick) (previously *P, robiginosus* and *Emileia?* sp.juv. of Spath), *P. semiornatus, Pseudotoites* n.spp.indet., *Stephanoceras (Stemmatoceras)* cf. *subcoronatum* (Oppel), and *S. (S.)* aff. *triptolemus* (M. & L.). Thus, *Dorsetensia,* one of the genera characterizing the *humphriesianum* Zone in Europe, is absent in Western Australia, but *Fontannesia,* a genus of the *sowerbyi* Zone is present. The previously reported *Teloceras,* a genus characteristic of the upper part of the *humphriesianum* Zone, turned out to be a much earlier homeomorph of *Teloceras,* a cadicone relative of *Pseudotoites.* Forms referred to *Normannites,* which overwhelmingly belong to the *humphriesianum* Zone in Europe, turned out to be more closely related to *Otoites,* an ancestral form to the true *Otoites* of the *sowerbyi* Zone and close to the dwarf subgenus *Trilobiticeras* of the early *sowerbyi* Zone. Arkell & Playford concluded on the basis of these reassignations that: 'the main Newmarracarra Limestone fauna is of the age of the *sowerbyi* Zone, possibly but doubtfully including the *sauzei* Zone . . . In addition there are a few species . . . from the haematitic uppermost layer . . . which suggests the presence of patches of the *humphriesianum* Zone'. (p. 559). The two authors inferred from the presence of *Pseudotoites* and *Zemistephanus* that in middle Bajocian time Western Australia was in free communication, through the

Moluccas, with the Americas; this in addition to free marine connexions along the Papuan Geosyncline.

P. E. Playford's paper of 1959 is the most important and up to date summary of the geology of the Geraldton area. Apart from an exhaustive treatment of topography, stratigraphy, lithology, and sedimentary environments he also quotes full lists of fossils, both large and small, identified earlier from each of the Jurassic units occurring in the area. His lists of fossils are not revised and are identical to those quoted above.

Stevens (1965, p. 146) found Whitehouse's *Belemnopsis* sp. a typical early *Belemnopsis* of the Bajocian-Bathonian, very similar to specimens of *B. bessinus* from the Bajocian of the Calvados Chain and Normanby Island, but possibly a different species. Specimens of *Belemnopsis* apparently identical with Whitehouse's species occur in the Colalura Sandstone, Bringo Shale, Kojarena Sandstone and Cadda Formation.

Skwarko (*in* Coleman & Skwarko, 1967) identified *Fontannesia clarkei* and the nine bivalves *Cucullaea* sp., *Meleagrinella sinuata, ?Oxytoma decemcostata, Chlamys?* sp.nov.aff. *C. splendens, Camptonectes* sp.nov.aff. *C. lens, Pseudolimea* sp.cf. *P. duplicata, Trigonia moorei, ?Astarte apicalis* and *Pleuromya? sanfordii* from the Mingenew area, about 75 km southeast of Geraldton, and correlated it with the Newmarracarra Limestone. Most of the identifications carried qualifications in view of the forthcoming revision of the Newmarracarra bivalve fauna.

STRATIGRAPHICAL POSITION OF THE NEWMARRACARRA LIMESTONE AND THE KOJARENA SANDSTONE

The position of the Newmarracarra Limestone and the Kojarena Sandstone in the Western Australian Jurassic stratigraphic sequence and their relation to other Jurassic units in Western Australia is shown diagramatically in Table 1.

In the Geraldton area (Fig. 1) the Jurassic succession begins possibly with the Greenough Sandstone, a fluviatile sandstone whose only fossil remains are rare wood fragments. Conformably overlying it is the Moonyoonooka Sandstone, also probably a continental deposit with similar fossil content, and also tentatively regarded as of Early Jurassic age. The Colalura Sandstone is the first sediment laid down here by the advancing sea. Its fossil content is limited to *Astarte, Ctenostreon, Lopha, Trigonia, Ostrea, Isognomon, Belemnopsis,* an assemblage similar to, but more limited than, that of the overlying Newmarracarra Limestone; the Colalura Sandstone is consequently assigned to the Bajocian, though it must obviously be slightly older than the unit overlying it. The Bringo Shale is also of Bajocian age, and probably at least in part synchronous with the Newmarracarra Limestone, but is lithologically distinct and has a much more limited dwarf fauna of *Meleagrinella, Belemnopsis,* and gastropods. Overlying the Newmarracarra Limestone and marking the end of the marine inundation in the area is the Kojarena Sandstone, with fossils still of the Newmarracarra type, viz. *T. moorei, Cucullaea, Isognomon, Belemnopsis,* and wood fragments. The next higher unit, the Yarragadee Formation, is a non-marine deposit containing leaf impressions in addition to the wood fragments.

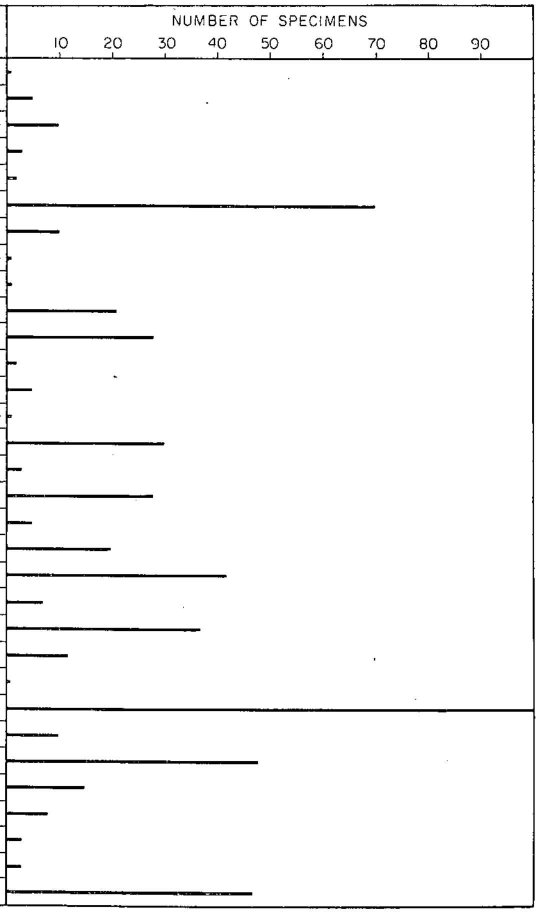
South of Geraldton, towards the Perth-Gingin area, and in the Hill River area (Fig. 2), the Newmarracarra Limestone is represented by its lateral correlative, the

TABLE 1. CORRELATION CHART OF JURASSIC STRATIGRAPHIC UNITS IN WESTERN AUSTRALIA

	PERTH BASIN			CARNARVON BASIN			CANNING BASIN
	PERTH GINGIN AREA	HILL RIVER & CENTRAL-NORTH OF BASIN	GERALDTON AREA	SOUTHEAST PART OF BASIN	EXMOUTH GULF	BARROW ISLAND	
UPPER JURASSIC	CLAREMONT SST 170	YARRAGADEE FORMATION 1080	YARRAGADEE FORMATION		WOGATTI SANDSTONE ? ? DINGO CLAYSTONE 880	TITHONIAN SANDSTONE WITH *BLANFORDICERAS* MARINE SANDSTONE AND SHALE IN BARROW OIL WELLS	JOWLAENGA FORMATION JARLEMAI SILTSTONE 90 ALEXANDER FORMATION 70 JURGURRA AND WALLAL SANDSTONE CALLAWA FM
MIDDLE JURASSIC	YARRAGADEE FORMATION CADDA FORMATION 35 (BAJOCIAN)	CADDA FORMATION 35 (BAJOCIAN)	CHAMPION BAY GROUP: KOJARENA SANDSTONE 10 NEWMARRACARRA LIMESTONE (BAJOCIAN) 12 BRINGO SHALE COLALURA SANDSTONE 8		LEARMONTH BEDS 680		
LOWER JURASSIC	CATTAMARRA COAL MEASURES MEMBER COCKLESHELL GULLY FORMATION 680	CATTAMARRA COAL MEASURES MEMBER COCKLESHELL GULLY FORMATION 680	CHAPMAN GROUP: MOONYOONOOKA SANDSTONE 40 GREENOUGH SANDSTONE 80 ? ?	WOODLEIGH BEDS 90 ? ?	DINGO CLAYSTONE 880 ? ?	? ?	

TABLE 2. RELATIVE ABUNDANCE OF INDIVIDUAL BIVALVE GENERA AND SPECIES IN THE NEWMARRACARRA LIMESTONE (NL) AND THE KOJARENA SANDSTONE (KS).

	NL	KS
"Nuculid" indet	—	
Parallelodontidae spp.	—	
Grammatodon (I.) carnarvoni		—
Cucullaea geraldtoni	—	
"Cucullaea inflata"	– –	– –
Cucullaea semistriata	—	
Modiolus (M.) maitlandi	—	
Falcimytilus sp.		—
Isognomon (I.) sp. indet.	—	
Oxytoma (O.) decemcostata	—	
Meleagrinella sinuata	—	
Propeamussium (P.?) geelvinki	—	
Camptonectes greenoughi	—	
Camptonectes cf. rigidus		—
Camptonectes waggrakinensis	—	
Chlamys enantyi	—	
Ctenostreon pectiniformis	—	
Plagiostoma championi	—	
Pseudalimea duplicata	—	
Amphidonta tholiformis	—	
Amphidonta cf. tholiformis	—	
Lopha marshii australiensis	—	
Lopha marshii newmarracarraensis	—	
Gryphaea sp. indet.	—	
Trigonia moorei	—	—
Astarte (A.) apicalis	—	—
Astarte (A.) cliftoni	—	
Astarte (A.) tibraddeni	—	
Tancredia (T.) sandspringi	—	
Tancredia (T.) kojarena		—
Martesia (P.) australis	—	
Gresslya sanfordii		



Cadda Formation. Though composed of ferruginous and calcareous sandstone and siltstone grading into limestone, and so lithologically somewhat different from the Newmarracarra Limestone, it contains similar fossils—*Pseudotoites emilioides, P. semiornatus, M. sinuata, Oxytoma decemcostata, T. moorei, Ostrea* sp., and *Belemnopsis.* Beneath it is the Lower Jurassic non-marine Cockleshell Gully Formation, and above it the Yarragadee Formation.

In the Exmouth Gulf area the Dingo Claystone contains the middle Bajocian to middle Kimmeridgian ammonites *Perisphinctes, Kossmatia, Macrocephalites, Pseudotoites?,* and *Otoites?,* the belemnites *Belemnopsis alfurica* and *B. callovien-sis,* and bivalves *Inoceramus galoi, Meleagrinella, Posidonia,* and *Quenstedtia.* The underlying 1000 m thickness is also grouped with the Dingo Claystone, which may range down to the Lower Jurassic. The Learmonth Beds are probably a condensed paralic facies equivalent of part of the Dingo Claystone. The beds contain a poor marine macrofauna (fragments of belemnites and brachiopods, indeterminate ammonites, and a species of *Trigonia*). Microfossils and spores indicate Middle to Late Jurassic age.

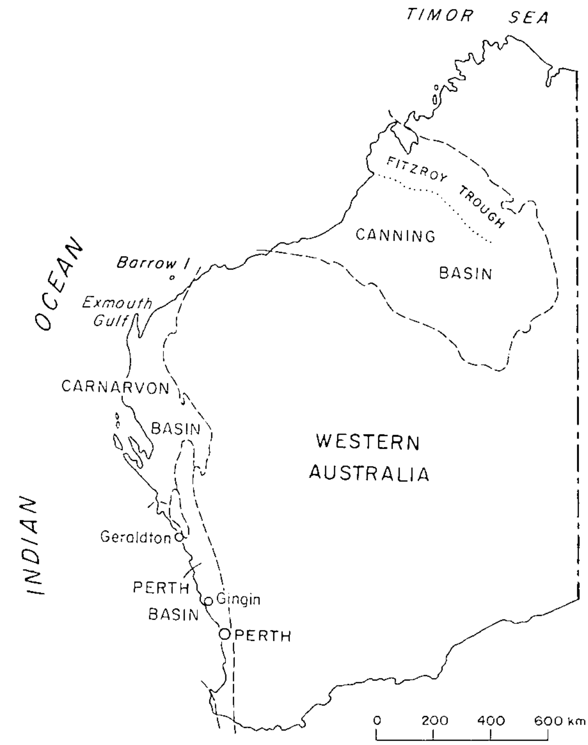


Fig. 2. Locality map showing the position of the individual areas of Jurassic sedimentation in Western Australia.

The age of the Canning Basin Jurassic units is not definitely known, despite contained marine faunas mostly of moderately varied content.

The basal units such as the Jurgurra Sandstone and Wallal Sandstone (?and the Callawa Formation) may be Lower or Middle as well as Upper Jurassic in age (McWhae et al., op.cit., pp 87-89, 108, 109; Brown et al., op.cit., pp. 252, 253). The Alexander Formation contains *Virgatosphinctes* cf. *communis, Kossmatia, Inoceramus* cf. *everesti, Maccoyella* cf. *corbiensis, Meleagrinella maccoyelloides* Brunnschweiler, 1960, *Quenstedtia, Lingula,* and Ophiuroidea, and has lately been regarded as upper Oxfordian (McWhae et al., 88; Brunnschweiler, 1960, pp. 39-41). The Jarlemai Siltstone contains *Perisphinctes* (*P?*) aff. *cautisignare* Arkell, *Buchia* cf. *extensa, Buchia* cf. *spitiensis, Meleagrinella* sp., and *Lima* sp., and has been regarded as upper Oxfordian or Kimmeridgian (McWhae et al., 88, 89; Brown et al., 262). Both the Langey Beds and the Jowlaenga Formation are regarded as 'late Upper Jurassic'. The Jowlaenga Formation contains *Hibolites* cf. *subfusiformis* (Raspail), *Meleagrinella* sp.nov.aff. *curta* (Hall), *M.* cf. *superstes* (Spitz), *Quenstedtia* sp.nov.aff. *rodborensis* (Lycett), and bivalves indet. (Skwarko, 1970, p. 232). The Langey Beds contain *Belemnopsis* cf. *aucklandica* (Hochstetter), *B.* cf. *alfurica* (Boehm), *Kossmatia* aff. *tenuistriata* (Gray) or a *?Substeueroceras, K.* cf. *tenuistriata, 'Buchia' malayomaorica* (Krumbeck), *Calpionella* cf. *undelloides* Colom, and *C. schneebergeri* Brunnschweiler, 1960 (Brunnschweiler, op.cit., p. 37).

PALAEOGEOGRAPHIC IMPLICATIONS

The marine macrofossil fauna of the Newmarracarra Limestone is prolific, and is represented by several groups of fossils of which the richest and now best known are the ammonites and the bivalves.

The ammonites have been recently revised in detail by Arkell (*in* Arkell & Playford, 1954) and have thrown light on the precise age of the Newmarracarra fauna, its overseas affinities and correlations, and palaeogeographic implications.

As revealed by similarities on the generic level, active sea connexions must have existed, between Western Australia on the one hand and both Europe and the western coast of America on the other, to permit the presence in the Geraldton area of ammonite genera previously described from those parts of the world. On the other hand, however, out of some 21 species described by Arkell only two were compared — with reservations — with European species, and one other was later identified from Tibet; this must mean that despite the outside migratory links with both Europe and the Americas, in the main the Geraldton area was rather sheltered, favouring the evolution of a mainly endemic fauna.

The study of the contained Bivalvia tends to support this interpretation. The genera occurring near Geraldton are well known from many parts of the world, but of the 27 species now known 24 are endemic and only 3 represent or might represent European Jurassic forms.

The concept of the Geraldton area as a quiet embayment with limited access to outside influences also finds support in the recent portrayal of palaeogeographic configuration of the western part of Australia during the Jurassic times by Veevers, Jones, & Talent (1971) and Veevers (1971), who picture it in close juxtaposition with eastern peninsular India, with a relatively narrow tongue of Jurassic sea penetrating southwards to various distances between the two parts of Gondwanaland during Jurassic time.

SYSTEMATIC DESCRIPTIONS

BIVALVIA

?Family NUCULIDAE Gray, 1824

'NUCULID' indet.

(Pl. 25, figs 3, 7)

Only one specimen of the type illustrated has been found. What is preserved of its dentition is unmistakably nuculid, and its large size and subquadrate shape are reminiscent of *Nucula* s. str. There is a prominent though narrow welt in front of the rear muscle scar, aligned subparallel to the posterior cardinal margin. The presence of radial lineation of the exterior surface cannot be verified, and no *Nucula* s. str. is known from rocks older than Cretaceous. It is possible that the specimen is an unusual *Nuculoma* or *Palaeonucula*.

Occurrence: Newmarracarra Limestone.

Family PARALLELODONTIDAE Dall, 1898

PARALELLODONTIDAE spp.
(Pl. 23, figs 1-9)

Parallelodontids are rare in the Newmarracarra Limestone; as their preservation on the whole is poor no attempt was made to subdivide them into individual species.

Three of the four illustrated specimens, WAM 67.473, 67.492, and GSWA F5041 (Pl. 23, figs 2-8) may belong to the same species, of which specimen 5910/9 (Pl. 23, fig. 1) is a somewhat aberrant form differing from the others in its very small area. Specimens in figures 2-6 are almost certainly one species, characterized, among other things, by very attenuated hinge-plate. Their description is as follows:

The species is at least 27 mm high, 18 mm thick, and about 60 mm long. It is well inflated, but its anteriorly placed umbo, which is broad and slightly curved over the area, has a wide shallow centrally situated sinus. The sinus extends diagonally across the shell, offsetting the concentric growth-lines and rugae and giving rise to an indentation in the ventral shell margin. Apart from the growth-lines, the surface of the shell is lined with very thin and closely set linear radiating riblets. The umbo is situated in the anterior fifth of the cardinal margin. The post-umbonal carina is broad and ill defined. The area is broad anteriorly, where it is 6 mm wide, gradually tapering and finally wedging out posteriorly. It is striated with about 20 sinuous chevron-shaped striae. The hinge-plate seems to be narrowest a little behind the umbo, where it is more than 1 mm wide. From that point forwards it rapidly increases in breadth to 3 mm, while posteriorly it broadens almost imperceptibly until it rapidly increases in breadth the posterior third. There are three short oblique sinuous teeth in the anterior swelled portion of the hinge-plate on the mature specimen, and behind the umbo probably two elongate teeth close to the rear extremity of the shell. In addition there are short transverse teeth similar to those found in *Arca* along the margin of the area.

In specimen F5041 the detailed structures are clearly preserved, but the specimen is unfortunately incomplete so that they cannot be used to supplement the description above. Its description is as follows:

The specimen is 31 mm high, 14 mm thick, and of unknown length. It is moderately well inflated, with depressed and incurved prosogyrous umbo, which is invaginated by a broad, well developed sulcus. The exterior surface of the shell is lined with fairly prominent irregularly spaced concentric rugae whose concentration increases distally, and with thin inconspicuous but numerous radial striae absent from the anteriormost part of the shell. The ligament area is only 4 mm wide at its widest, and striated with up to eight irregular and weak grooves which may not cover the whole of the area. In front of the umbo the hinge-plate is widest anteriorly, where it measures almost 7 mm across. There are six oblique elongate fluted teeth which increase in breadth frontwards, gently flexing at the same time, their upper surfaces convex. The anterior adductor scar is located directly beneath the front end of the hinge-plate. It is vertically oval.

Occurrence: Newmarracarra Limestone.

Subfamily GRAMMATODONTINAE Branson, 1942

Genus GRAMMATODON Meek & Hayden, 1861

Type species: *Arca* (*Cucullaea*) *inornata* Meek & Hayden, 1859

Subgenus INDOGRAMMATODON Cox, 1937

Type species: *Cucullaea virgata* J. de C. Sowerby, 1840; by original designation of Cox

Indogrammatodon, a subgenus of *Grammatodon* Meek & Hayden, was established by Cox in 1937 who assigned four species to it: *G.* (*L.*) *virgatus* J. de C. Sowerby, from the Bathonian to Diversian of India, *G.* (*I.*) *egertonianus* (Stoliczka) from the Argonian to Portlandian of East Africa, Spiti Shales of India, and possibly New Zealand; *G.* (*I.*) *irritans* (Henning) from the Kimmeridgian of East Africa; and *G.* (*I.*) *stockleyi* Cox from the ?Callovian of Tanganyika.

In his description of the Jurassic lamellibranch fauna of Kuchh (Cutch), Cox (1940) redescribed in greater detail *G.* (*I.*) *virgatus* and described four new *Indogrammatodons, blakei* from the ?Callovian of India; *iddurghurensis, kantkotensis,* and *G.* (*Indogrammatodon*) sp. indet., all from the Argovian of India. To this subgenus he also referred, though somewhat hesitantly, *Parallelodon guibali* of Cossman from the Toarcian of France and *Grammatodon parallelus* (Conrad) from the Upper Cretaceous of Palestine. He suggested that the Australian bivalve *Cucullaea robusta* Etheridge Snr may also be an *Indogrammatodon.*

More recently Fleming (1966) redescribed *C. robusta* as *G. (I.) robusta* from the Lower Cretaceous of Queensland.

Thus the hitherto known time range of the *Indogrammatodon* is Bathonian — possibly Toarcian — to Early Cretaceous, possibly Late Cretaceous.

The Bajocian Newmarracarra Limestone has yielded nine specimens of Parallelodontidae whose subgeneric morphological features — the large inflation, the characteristically dissimilar ornamentation on the left and the right valves, the obtuse postumbonal carina, the numerous and closely spaced chevron-shaped ligament grooves on the areas, and the type of dentition — allow them to be placed with confidence in *Indogrammatodon.*

GRAMMATODON (INDOGRAMMATODON) CARNARVONI sp. nov.
(Pl. 23, figs 10-14)

Material: Nine specimens — eight of which are incomplete — from locality SKS7, are external impressions of the left valve, an incomplete external impression of the right valve, and a right valve dentition. There is an additional specimen, GSWA F406.

Holotype: GSWA F406 (Pl. 23, fig. 14)

Paratypes: CPC 11376 (Pl. 23, fig. 10) and CPC 11377 (Pl. 23, fig. 11).

Diagnosis: The combination of the moderately large size, rather narrow and well defined umbo in immature specimens, few if any ribs on the posterior part of the shell, and the area lined with numerous and wavy chevron-shaped striae, is regarded as diagnostic.

Comparison with other species: The Australian species can be readily distinguished from *G.* (*I.*) *stockleyi, kantkotensis,* and *blakei* by its considerably more elongate outline, and from *iddurghuensis* by its smaller size and finer ribbing; from *virgatus* it can be separated by its finer and less numerous ribs and possibly larger size; from the widespread and variable *egertonianus* by its more centrally situated umbo and possibly narrower posterior portion of the hinge; from *irritans* by narrower umbones, fewer ribs on the posterior part of the shell, and less regular spacing of ribs — even on the left valve.

Description: The largest specimen is 7 cm long, 4½ cm high, and each valve is 5 cm deep. It is strongly inflated, slightly inequivalve, asymmetrical, produced to the front and more strongly to the rear. The umbo is well defined, prosogyrous, incurved, and bounded on its posterior side by a post-umbonal carina which is sharply angular proximally but becomes obtuse and indistinct distally.

The dorsal cardinal margin is straight or almost straight; the ventral margin is slightly convex; the anterior and the posterior shell margins parallel each other near the dorsal shell margin; away from it the anterior margin merges into the ventral margin through a broad arch, while the posterior margin is concave before taking a tight turn which joints it with the ventral portion of the periphery.

Exterior sculpture consists of concentric fairly distinct growth-lines and prominent growth-rugae, both of which parallel the periphery of the shell, and of thin radial ribs which depart from the tip of the umbo and proceed — diverging slightly and increasing in breadth very slightly — to meet the distal shell margin. The distribution of the radial ribs is not uniform so that the wide flat interspaces vary in width. On the left valve the ribs number between 19 and 26, are of one order only, and are concentrated in front of the post-umbonal carina. Behind the carina the ribs, if present, are weak and tend to disappear about the middle of the post-umbonal region, but reappear strongly near the posterior portion of the ligamental margin. On the right valve, ribs are much more numerous and are of two orders, the interspaces between the primary ribs being in part occupied by pairs of finer secondary riblets. The distribution of ribs is more irregular than on the left valve and they tend to disappear near to and on the post-umbonal carina.

The ligamental area is low, crescentic, and concave in profile. In mature specimens it is almost 10 mm high and probably about 60 mm long. It is striated with about 20 chevron striae which, though straight and parallel to each other in young specimens, tend to become wavy and subparallel with age. They are absent from near the ligamental margin, but occupy most of the ligament area.

There are about 15 teeth on the hinge-plate. They radiate out from the ventral part of the hinge-plate beneath the umbo, their length rapidly increasing with distance from the umbo, with the corresponding decrease of the angle of inclination to the cardinal margin.

Occurrence: Kojarena Sandstone.

Family CUCULLAEIDAE Stewart, 1930

Genus CUCULLAEA Lamarck, 1801

Type species: *Cucullaea auriculifera* Lamarck, 1801, by subsequent designation of Children, 1823

Discussion: The first Cucullaeidae described from the Jurassic strata of Western Australia were *C. inflata, C. semistriata,* and *Cucullaea* sp., described by Moore in 1870 from what is now known as the Newmarracarra Limestone. Moore observed that commonest cucullaeid was *C. oblonga* J. Sowerby, which, however, he neither described nor figured. Forty years later Etheridge (1910) did not deny the presence of *C. oblonga,* but found the most abundant species to be *C. semistriata,* which he redescribed. He also described a new species, *C. tibraddenensis,* a more elongate form than *C. semistriata,* which in his opinion was probably identical with the *Cucullaea* sp. of Moore. In addition Etheridge figured *Cucullaea* sp., which resembled Moore's *inflata* but which he thought was insufficiently inflated to be referred to that species.

During the present revision of the Newmarracarra Limestone fauna a large number of specimens of Cucullaeidae became available for study; the results may be summarized as follows:

1. Where visible, the dentition of all the examined Cucullaeidae is basically the same and the small differences in the tooth structure observed in some specimens are of a type which one would expect to find within representatives of a single species.

2. Details of musculature could be observed in too few specimens to allow a general statement. Where visible, however, the muscle pattern seemed to be similar.

3. The degree of inflation varies considerably, and no forms intermediate between *C. semistriata* and *C. tibraddenensis* on the one hand, and *C. inflata* on the other, have been encountered. I have thought it advisable, therefore, to retain *C. inflata* as a separate species, although it may be an aberrant form.

4. The ligament areas are of more than one kind. A few specimens with flat crescentic areas lined with numerous linear grooves were separated as *Cucullaea geraldtoni* sp. nov. (see below). Specimens provisionally referred to *C. inflata* also have a flat ligament area, but the number and nature of grooves which they carry is not visible on the specimen illustrated originally by Moore see Pl. 2, figs 7, 8). All the remaining specimens have broadly triangular, flat to rather tightly inclined areas striated with 12 to 15 grooves, each about 1 mm wide.

5. Exterior concentric lineations consist of growth-lines and growth-rugae, and are present on virtually all specimens, regularly spaced on many of them. In many specimens, however, the lineations are absent from the central portion of the shell or from most of the shell, which in part may be due to mechanical attrition before burial. Low radial riblets are present in *C. geraldtoni,* and cover most of the surface in *Cucullaea?* sp. indet., but are largely absent from most mature specimens, the majority of which are either completely devoid of radial ribbing, or have it only on the most anterior, posterior, or proximal portion of the shell. The small specimens, which may be juvenile and immature forms of large species, have, however, their surfaces completely covered with radial riblets which criss-cross with concentric costae, resulting in a reticulate ornamentation.

6. The ratio of length-to-height varies considerably, but forms intermediate between the relatively high and short specimens on the one hand, and the low and long specimens on the other, are common (text fig. 3). It is because of this, and also because all their other morphological features are identical, that I have put *C. tibraddenensis* in sinonymy with *C. semistriata.*

CUCULLAEA GERALDTONI sp. nov.
(Pl. 22, figs 1, 4, 5; Text-fig. 3)

Material: A complete specimen of the bivalve with both valves in position (GSWA F5911/7); two bivalves in micaceous siltstone with valves slightly offset (GSWA F393/1, 2).

Holotype: GSWA F5911/7 (Pl. 22, figs 1, 4, 5).

Diagnosis: The shell is small for the genus, strongly inflated, and elongate posteriorly. Fine radial ribbing is present over all except the posterodorsal part of the left valve, and seems to be less prominent on the right valve. The area is striated, with about 25 fine chevron-shaped striae.

Description: The shell is probably slightly inequivalve. It is small for the genus, the larger of the two known specimens being only 4.8 cm long, 2.8 cm high, and 2.8 cm thick. It is strongly inflated, produced slightly to the front, strongly to the rear, slightly in the posteroventral direction. The umbo, situated in the anterior third of the shell, is a little depressed but prominent, somewhat incurved, bordered posteriorly by a post-umbonal carina which is sharp proximally but becomes obtuse and ill-defined on reaching about half its distance to the posteroventral shell margin. The area is rounded-triangular, asymmetrical, about 6 mm wide, with about 25 chevron-shaped striae.

The cardinal margin is straight and 37 mm long. It meets the anteroventral shell margin, which is broadly and evenly convex, with a sharp acute angle, and the straight posterior margin with an obtuse angle. The posteroventral margin is convex.

The outside of each valve is ornamented with about 23 radial, somewhat irregularly spaced riblets, which seem to be more prominent on the left than on the right valve and which are absent from the part of the shell dorsal to the post-umbonal carina.

Occurrence: Newmarracarra Limestone.

'CUCULLAEA INFLATA Moore, 1870'
(Pl. 22, figs 6-8)

1870 *Cucullaea inflata* Moore, *Quart. J. geol. Soc. Lond.*, 26, 250, pl. 14, figs 1, 2

Material: The original specimen illustrated by Moore and at present held by the British Museum (Natural History); an internal cast of a bivalve with the two valves somewhat offset from their original position (WAM 65.1197).

Discussion: I have illustrated in Plate 22, fig. 6 an unusually short and inflated *Cucullaea* — the only specimen in the present collection whose overall shape approximates to that of Moore's *inflata,* and whose length-to-breadth ratio is less than one, less than that allowable for *C. semistriata.*

Moore's original specimen is indeed very short and very inflated, and is either a very rare species different from others described above and below from the Newmarracarra Limestone, or an aberrant form of *C. semistriata* Moore, 1870.
Occurrence: Newmarracarra Limestone; Kojarena Sandstone.

CUCULLAEA SEMISTRIATA Moore, 1870
(Pl. 21, figs 1-7; Pl. 22, figs. 2, 3; Text-fig. 3)

1870 *Cucullaea semistriata* Moore, *Quart. J. geol. Soc. Lond.*, 26, 250, pl. 14, fig. 3
1870 *Cucullaea oblonga* Sowerby; Moore, *Quart. J. geol. Soc. Lond.*, 26, 231, 232, 250
?1870 *Cucullaea* sp. Moore, *Quart. J. geol. Soc. Lond.*, 26, 250
1910 *Cucullaea semistriata* Moore; Etheridge, *Geol. Surv. W. Aust. Bull.* 36, 34, 35, pl. 6, figs. 1, 2; pl. 8, fig. 3
1910 *Cucullaea tibraddenensis* Etheridge, *Geol. Surv. W. Aust. Bull.* 36, 35, pl. 5, figs 3, 4

Material: About seventy specimens bearing the following registration numbers:

GSWA: F64A/1-4, 8, 9; F64B; F64C/1, 2; F64E; F65A/1-3; F65C; F86/1; F393/3, 4; F5033C.

WAM: 62.183; 65.1026, 7; 65.1130, 1; 65.1149(2); 65.1198, 9; 65.1209; 66.333(2); 66.333.1, 2, 4; 66.339; 66.75.

UT: 20241; 20271; 20276; 21507; 21766; 21782, 3, 4, 7, 9; 21790; 21808.

AMS: F6058; F6112, 1, 2; F13675-8; F13690; F13696.

Unlocalized numbers from the University of Western Australia include: 23544, 45300, 45300.4, 47441, 47441,3, 47463. Unlocalized numbers from the Queensland Museum are: F5595,8,9, F5600, F5602. Unlocalized numbers from the University of Tasmania are: 20772, 21779.

Description: The shell is equivalve, produced to the front and more strongly to the rear and also posteroventrally. It is up to 8.3 cm long and 6.7 cm high and well inflated. The length-to-height ratio is variable (see Text-fig. 3) but its median value is about 1.6. The umbo is prosogyrous, somewhat depressed, pointed, situated about the middle of the cardinal margin, well defined proximally, bounded by an obtuse post-umbonal carina. It is somewhat depressed and incurved over the ligament area. The area is broadly triangular, variable in its inclination to the commissure. It contains between 12 and 15 grooves each about 1 mm wide; the width is little affected by the age of a specimen. The grooves are separated from each other by definite linear interspaces.

The exterior of the shell is striated with concentric striae and rugae, which in many specimens are regularly spaced. It is possible that the radial ribbing covers the whole shell of juvenile specimens, criss-crossing the concentric lineations to produce a reticulate pattern. On mature specimens, however, radial ribbing is generally confined to the anteriormost portion of the shell, less often it occurs also on the posteriormost part, and more rarely still it covers its proximal portion. Ribbing is of two orders, with the thicker ribs about twice as wide as the thinner linear riblets. The interspaces are flat. More rarely some radial ribbing can be discerned on the entire umbo, but most mature specimens seem to be devoid of it.

The hinge-plate is thinnest in the middle and considerably wider at both ends. Beneath, and for some distance in front of, the umbo, the teeth are short transverse and quite numerous, of rather irregular shape and not very evenly spaced. They tend to become more oblique, and consequently longer rearwards. There are four robust teeth at each end of the hinge-plate. These are long, subparallel to the cardinal margin, convex in transverse cross-section, and have narrow, V-shaped interspaces. They have a tendency to split up into secondary teeth.

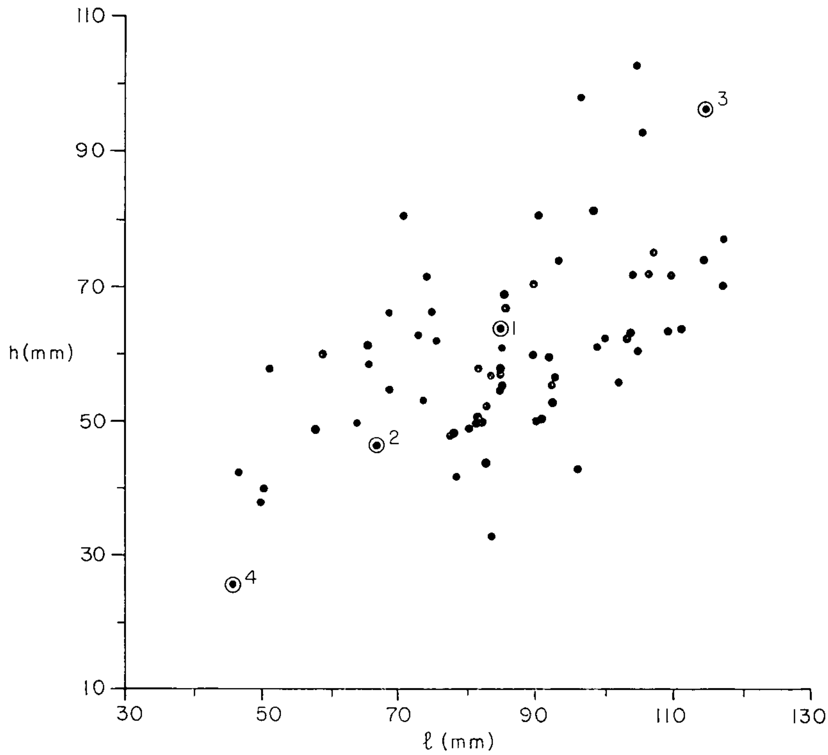


Fig. 3. Distribution of the length-to-height ratios in the Cucullaeidae from the Newmarracarra Limestone. Numbered points are median values of: 1. *C. semistriata* Moore, 2. *tibraddenensis* Etheridge, 3. *Cucullaea* sp., **Moore, 4.** *C. geraldtoni.*

The musculature seems to consist of very shallow and poorly defined anterior and posterior adductor scars and a simple pallial line joining them. The adductor scars are situated beneath the two lateral extremities of the hinge-plate.

Discussion: C. tibraddenensis is placed in synonymy with the earlier established *C. semistriata* because, other aspects of their morphology being similar, the statistical treatment failed to demonstrate any basic difference between their proportions.

Moore (1870) believed that in addition to his *C. semistriata* and *Cucullaea* sp., *C. oblonga* Sowerby was present in Western Australia. Only one of the two specimens originally figured by Sowerby (plate 206, fig. 2) is available for examination. Comparison with the Australian specimens shows only two points of difference between them: first, the British shell seems to have greater tumidity, so that its ventral wall is longer and plunges more steeply into the commissure; and secondly, in Sowerby's specimen the teeth seem to be less elevated than in Australian specimens—particularly at their lateral extremities. Sowerby's specimen is not really, however, representative of the species and its comparison with numerous other specimens referred to *C. oblonga* and held at the British Museum shows that the typical form is more elongate, with post-umbonal carina gently sigmoidally curved and quite well defined even in the distal part of the shell; that the umbones are more attenuated and protruding above the cardinal margin — in a word, that a typical representative of *C. oblonga* is readily distinguishable from *C. semistriata*. It is concluded that *C. oblonga* is absent from Australia.

Occurrence: Newmarracarra Limestone.

Family MYTILIDAE Rafinesque, 1815

Subfamily MODIOLINAE Keen, 1958

Genus MODIOLUS Lamarck, 1799

Type species: *Mytilus modiolus* Linné, 1758, by subsequent designation of Gray, 1847

MODIOLUS (MODIOLUS) MAITLANDI Etheridge, 1910
(Pl. 24, fig. 14)

1910 *Modiola maitlandi* Etheridge, *Bull. geol. Surv. W. Aust.*, 36, 33, 34, pl. 5, figs 1,2

Material: Four bivalves with both valves in position; four single valves; some fragments.

AMS: F6062; F6119; F13695.

GSWA: F62A/13; F75A; F75B/1; F75C.

UWA: 36026.

Original description: 'Shell large, bold, gibbous, oblique, strongly modioliform, and transversely elongate. Cardinal margins straight, about three-quarters the length of the shell; valves convex along the obtuse diagonal ridges, which are at first nearly parallel to the cardinal margins, and then curve outwards and downwards, the valve steep on the fore side, flat on the hind surface. Anterior ends very small, almost undeveloped, the margin bluntly rounded. Ventral margins long, concave in the centre, convex at both ends. Sculpture of fine concentric lines and broad latilaminae of growth.'

Remarks: Little can be added to the original description. The thin hinge-plate of one specimen was cleared, but it showed no discernible structure.

Occurrence: Newmarracarra Limestone.

Genus FALCIMYTILUS Cox, 1937

Type species: *Mytilus (F.) suprajurensis* Cox, 1937, by original designation

FALCIMYTILUS sp.
(Pl. 26, figs 4, 5)

Material: An external and an internal impression of a right valve. Locality SKS9.

Description: The valve is 13 mm high, 13 mm long, and about 3 mm thick, subcrescentic, strongly inequilateral, attenuated in front and broadening posteroventrally.

The umbo is acute, pointed, terminal, and somewhat depressed. The dorsal margin is gently arched except in its rear portion, where convexity increases and the rear margin of the shell is directed ventrally. The anterior margin is sharply curved at the umbo. The anteroventral margin is gently convex dorsally, becoming uniformly concave for its remaining length. At its rear end it turns sharply postero-dorsally to form a fairly gently rounded posterior margin.

The shell is moderately well inflated, with maximum tumidity in the region adjacent to the escutcheon. Thence inflation decreases suddenly down the escutcheon — which is perpendicular to the commissure — and rather gradually in other directions. The outside surface of the shell is smooth except for very faint growth-striae, and rare but prominent growth-rugae.

The musculature consists of a small anterior adductor scar located near the umbo, and a larger but not clearly distinct posterior adductor scar joined to the anterior scar by an entire pallial line, which follows a direction approximately parallel to the shell margin.

The cardinal margin is reinforced on the inside with a thin ledge simulating a hinge-plate, which has no teeth but bears shallow ligament grooves irregular in distribution and direction. The 'hinge-plate' extends in an arc around the anterior portion of the shell, where it is wider than along the cardinal margin, forming a ledge devoid of dentition or lineation.

Occurrence: Kojarena Sandstone.

Family Isognomonidae Woodring, 1925

Genus Isognomon Lightfoot, 1786

Type species: *Ostrea perna* Linné, 1767; M

Isognomon (Isognomon) sp. indet.

(Pl. 25, fig. 2)

The only representative of Isognomonidae in the collection is a fragment of the proximal portion of a right valve of *Isognomon* s. str. from locality WAM 66.311. Its exterior surface is partly abraded and shows no regular lineation of any kind. On the inside there is a ligament plate with nine almost vertical striated ligament grooves, and a greatly thickened and concave anterodorsal margin. Not enough is preserved to allow specific determination, and the specimen is illustrated here merely as part of the Newmarracarra fauna.

Occurrence: Newmarracarra Limestone.

Family Oxytomidae Ichikawa, 1958

Genus Oxytoma Meek, 1864

Type species: *Avicula munsteri* Bronn, 1830; by original designation of Meek

Oxytoma s. str.

Type species: *Oxytoma (O.) inequivalvis* (J. Sowerby)

OXYTOMA (OXYTOMA) DECEMCOSTATA Whitehouse, 1924
(Pl. 24, figs 1-8)

1870 *Avicula munsteri* Goldfuss; Moore (*non* Bronn), *Quart. J. geol. Soc. Lond.*, 26, 231, 232
1878 *Avicula munsteri* Goldfuss; Etheridge, CATALOGUE OF AUSTRALIAN FOSSILS, 107
1910 *Avicula munsteri* Goldfuss; Glauert, *Geol. Surv. W. Aust. Bull.* 36, 100
1924 *Oxytoma decemcostata* Whitehouse, *J. Roy. Soc. W. Aust.*, 11(1), 3, 4, pl. 1, fig. 3
1926 *Oxytoma decemcostata* Whitehouse; Glauert, *Geol. Surv. W. Aust. Bull.* 88, 51

Original description: Left valve very inequilateral, bialate, transversely elongate, produced posteriorly. Main part of the shell ornamented with ten radial costae, the intercostal spaces being almost flat and adorned with about seven fine costulae in each case. Costae produced ventrally as short projecting spines. Growth-lines forming concave curves in intercostal spaces.

The first six costae from the anterior end curving anteriorly; the remaining four with a posterior curvature. Anterior wing ornamented with about five costae; the posterior wing with costulae only. Right valve unknown. Hinge line of the normal *Oxytoma* type.

Material: Twenty specimens and some fragments of the left valve. One almost complete right valve.
WAM: 4978; 65.1108; 65.1117; 65.1144; 65.1175; 65.1176; 65.1187; 66.324a.
UWA: 23651; 36046.
Others: 60.2; Gal; 7088.

Revised description: The largest specimens grow up to 45 mm in height and 40 mm in length, but most are smaller. The shell is strongly inequivalve, with a moderately convex bialate left valve, and a flat right valve. Both valves are produced posteroventrally, and their umbones are narrowly pointed, opisthogyrous, and incurved.

The external surface of the right valve is probably smooth. Its cardinal margin is long and straight. The byssal sinus which parallels it is narrow and deep, and its edges are turned in towards the commissure. The periphery of the rest of the right valve margin is convex except in the posterodorsal part, where it is concavely flexed.

The musculature on the right valve consists of a moderately well incised pallial line, which proceeds ventrally from behind the byssal sinus and just below the cardinal margin to about the middle of the shell, where it swings rearwards to join a muscle scar. The impressions of the muscles are very weak and open to interpretation; there seem to be two scars, one larger than the other and one in front of the other.

The left valve is well inflated, strongly ribbed with three-order radial costae, and with a small anterior and large posterior auricle. The primary ribs number from 9 to 11. They are thin and their width increases but little distally, as opposed to their height, which increases considerably with growth. The interspaces are broad and flat and radially striated with secondary and tertiary ribs. The second-order ribs vary in relief considerably on a given specimen and can be absent on some specimens. There are up to twenty fine tertiary ribs between each pair of primaries.

The anterior auricle is small, with a short, usually straight cardinal margin, and a convex anterior wall which flexes away from the commissure to enable passage of the byssus. The posterior wing is large, well developed, with a long straight cardinal margin. Radial ribbing on the rear ear and probably on the front ear is limited to tertiary ribs. In addition, however, the posterior ear usually carries concave growth-lines, no less prominent, which impart a reticulate pattern absent from other parts of the shell.

The cardinal area on the left valve is up to 2 mm wide, tapering slightly in the front, but of constant width for its remaining length. In some specimens it is somewhat flexed in front of the umbo. It carries two ligamental grooves, a short oblique one directly behind the umbo, and a much longer one farther back. In the anterodorsal corner of the left valve a considerable portion of the shell wall is excavated, the resultant triangular notch corresponding in position and function to the byssal sinus on the right valve.

Remarks: No doubt is felt regarding the identity of the specimens, which are placed into the *Oxytoma* s. str. in keeping with the currently accepted subgeneric subdivision of *Oxytoma.*

Occurrence: Newmarracarra Limestone.

Genus MELEAGRINELLA Whitfield, 1885

Type species: *Avicula curta* Hall, 1852; by subsequent designation of Cox, 1941, p. 134.

MELEAGRINELLA SINUATA (Teichert, 1940)
(Pl. 32, figs 1, 4, 6-9)

1924 *Pseudomonotis echinata* (Sowerby); Whitehouse, *J. Roy. Soc. W. Aust.*, 11(1), 2, pl. 1, figs 2a, b, c

1940 *Echinotis sinuata* Teichert, *J. Roy. Soc. W. Aust.*, 26, 22-24, pl. 1, figs 1-10

1968 *Meleagrinella sinuata* Teichert; Skwarko, *in* Coleman & Skwarko, *Bur. Miner. Resour. Aust. Bull.* 92, 205, pl. 25, figs 2-5

Material: 28 left valves bearing registration numbers:
GSWA: F80B/2; F80C/1; F5025B; F5035A; F5566; F5585; F5911/15.
UWA: 45292.
WAM: 65.1110.
UT: 20025.
and right valves numbered UWA: 45292; 36036.

Remarks: Close examination confirms in the main Teichert's comparatively recent description and comparisons, and little is to be gained by repeating them here. It may be added, however, that there are in fact two sulci on the posterior portion of the left valve, and that the pallial line in both valves is entire.

Occurrence: Newmarracarra Limestone.

Family PECTINIDAE Rafinesque, 1815

AMUSSIUM GROUP

Genus PROPEAMUSSIUM de Gregorio, 1884

Type species: *Pecten (P.) ceciliae* de Gregorio, 1884, by original designation.

?Subgenus PARVAMUSSIUM Sacco, 1897

Type species: *Parvamussium duodecimlamellatum* Bronn, 1831; by original designation of Sacco.

PROPEAMUSSIUM (PARVAMUSSIUM?) GEELVINKI sp. nov.
(Pl. 26, figs 2, 3)

Material: a right valve WAM 66.108 and a left valve WAM 67.495.

Holotype: Right valve, WAM 66.108 (Pl. 26, fig. 2).

Paratype: Left valve(?), (WAM 67.495) (Pl. 26, fig. 3).

Diagnosis: The species is distinguished by a combination of the following factors: small size, smooth outer surface, internal surface ribbed with about a dozen primary ribs, each pair separated by two secondary riblets in the distal portion of the shell, at least on the left valve.

Description: The shell is smooth and small, up to 8 mm high and 7 mm long, moderately inflated, with a straight cardinal margin, auricles smooth but of considerable size relative to the size of the shell.

The proximal portion of the interior of the right valve is striated with up to 12 linear grooves between flat broad riblets, which radiate out from the umbo, rapidly broadening distally. The distal portion of the interior of the right valve is obscured.

The interior of the left valve is proximally striated like the right valve. Distally, the broad flat ribs are striated each with two radial grooves, which split up them into secondary riblets.

Occurrence: Newmarracarra Limestone.

CAMPTONECTES GROUP

Genus CAMPTONECTES Agassiz *in* Meek, 1864

Type species: *Pecten lens* J. Sowerby, 1818; by subsequent designation of Stoliczka, 1871

CAMPTONECTES GREENOUGHI sp. nov.
(Pl. 26, figs ?11, 13-17)

1968 *Camptonectes* sp. nov. aff. *C. lens* (J. Sowerby); Skwarko, *in* Coleman & Skwarko, *Bur. Miner. Resour. Aust. Bull.* 92, 206, 207, pl. 25, figs 11, 12

Material: An incomplete external impression of a right valve and a left valve, and a fragment of an external impression of a valve from the Enanty Hill; a crushed but nearly complete bivalve WAM 67.497; an almost complete right valve from locality WAM 4966.

Holotype: WAM 67.497 (Pl. 26, figs 13, 14), a crushed but nearly complete bivalve.

Paratypes: CPC 11382 (Pl. 26, fig. 11), an impression of the inside of a right valve; UWA 55054 (Pl. 26, fig. 17), an impression of a fragment of the external surface.

Diagnosis: The new species is characterized by the vertically ovate shape combined with shallow, linear, bifurcating ribbing.

Separation from other species: The British *C. lens* seems to be the closest relative of *C. greenoughi.* Sowerby's original figures (Sowerby, 1821, pl. 205, figs 2, 3) appear to be diagrammatic, but comparison with specimens in the British Museum collections shows that while the riblets are narrower and closer set the interspaces are slightly deeper. The British specimens also seem to be more inflated.

Description: The bivalve is thin-shelled and higher than long. The cardinal margin is at least 16 mm long and probably straight in uncrushed specimens.

The anterior ear is slender and not large for the shell. Its anterior margin is convex and ventral margin concave, and the surface is lined with sharp-edged prominent rugae which parallel its anterior and ventral margins. The posterior auricle is striated with shallow linear grooves which make a little less than a right angle with the main body of the shell.

The umbo is angular, well defined, and devoid of sculpture, the latter being limited to the lateral and distal parts of the shell. On the right valve, the anterodorsal shell margin is very gently concave, while the posterodorsal margin is practically straight. The distal periphery is regularly circular. The surface of each valve away from the umbo is covered with shallow linear wavy bifurcating grooves which separate flat-crested costae several times their width. There are also very faint circular lineations, some of which are definitely growth-rugae, while others, present on one specimen only, are probably very faint growth-lines.

On the inside of the right valve the resilium pit is triangular, rather shallow, and situated about 10 mm from the anterior margin of the front auricles. There is a narrow wedge-shaped area of relatively high relief immediately below the dorsal margin of the auricles, which at its greatest width measures 1.5 mm, tapering off regularly in the direction of the resilium pit. Its surface parallels the commissure and is uneven, being lined with transverse linear ridges which have much more closely spaced striations between them. Below this is the triangular auricular depression, bounded above and below by narrow folds; the dorsal fold is directly below the 'wedge'; the ventral one forms the dorsal margin of a triangular elevation which separates the auricular depression from the body cavity.

The byssal notch is moderately deep and has an angular margin; its upper margin is irregularly curved, while its ventral margin is straight before it passes ventrally into an even arc which forms the ventral shell margin. The byssal notch carries four ctenolial barb-like protrusions.

Occurrence: Newmarracarra Limestone.

CAMPTONECTES cf. RIGIDUS (Sowerby, 1821)
(Pl. 26, fig. 10)

Material: single proximally incomplete impression of exterior of right valve (CPC 11381) from locality SKS 7.

Discussion: The ribbing of the single incomplete valve is very similar to that of *Camptonectes lens.* However, the unusually large ratio of the size of the right front ear to the overall size of the right valve is one characteristic of *C. rigidus*, a fact not borne out by its original illustration (Sowerby, 1821, pl. 205, fig. 8). It is possible that *C. rigidus* is indeed present in Australia, but the material is too poor to confirm this.

'CAMPTONECTES' WAGGRAKINENSIS sp. nov.
(Pl. 25, figs 1, 4, 10)

1870 *Pecten cinctus* J. Sowerby; Moore, *Quart. J. geol. Soc. Lond.*, 26, 230-232.
1904 *Pecten cinctus* J. Sowerby; Chapman, *Proc. Roy. Soc. Vic.*, 16(2), 328, 329.
1910 *Pecten(?) cinctus* J. Sowerby; Etheridge, *Geol. Surv. W. Aust. Bull.* 36, 32, pl. 9, fig. 1.
1910 *Pecten cinctus* J. Sowerby; Glauert, *Geol. Surv. W. Aust. Bull.* 36, 101.
1914 *Pecten cinctus* J. Sowerby; Chapman, AUSTRALIAN FOSSILS, 182.
1919 *Pecten cinctus* J. Sowerby; Maitland, *Min. Handbk, Geol. Surv. W. Aust. Mem.* 1, 40.

Material: About thirty specimens of both valves, most fragmentary but some complete or almost complete.

WAM: 63.56; 63.83; 65.956; 65.1014-6; 65.1097-9; 65.1100; 65.1214; 66.297; 170.
GSWA: F66D; F76A/1, 2; F76C/1; F76D/1, 2, 3; F91/1, F95.
AMS: F6124.
UT: 21755.
UWA: 45306 (new no. 65180).

Holotype: UWA 45306 (Pl. 25, fig. 1): right valve.

Paratypes: WAM 66.297 (Pl. 25, fig. 4): proximal part of right valve in interior view; WAM 65.1099 (Pl. 25, fig. 10): left valve.

Diagnosis: The species is distinguished by the combination of large size with lack of any definite ornament, the only sculpture on the exterior surface being the irregular concentric growth-lines and growth-rugae.

Comparison with other species: Of the known species the one most closely related to *C. waggrakinensis* is *Camptonectes cinctus* from the Neocomian of the British Isles.

Description: The shell is large, orbicular, auricular, asymmetrical, inequivalve, acline.

The mature specimens are about 15-16 cm in diameter. The left valve is broadly and evenly convex, while the right valve is flat, slightly concave, or convex. Both valves lack regular ornament and are smooth or striated with irregular concentric growth-lines and growth-rugae. The rugae are numerous and prominent, particularly on the front auricles.

The anterior auricle on the mature right valve is about 40 mm long, with a straight cardinal margin, convex anterior margin, and flexed anteroventral margin. The byssal notch is pointed, narrow, and shallow. The posterior auricle is also about 40 mm long, and also has a straight cardinal margin, but the posterior periphery is almost straight. The periphery of the right valve is fairly evenly convex, except in its anterodorsal part where it is slightly concave, and in its posterodorsal part where it is straight.

No specimens of the left valve have a well preserved proximal region, and the detail of structure in that part of the shell is not known, but the anterior and the posterior auricles seem to be similar in both size and shape.

On the inside of the right valve a weak ridge extends from the dorsal part of the byssal notch to the cardinal margin at the apex of the valve. Below it there is an elongate triangular excavation which is an extension of the sinus.

The bivalve has a lamellar microstructure.

Discussion: The Australian specimens of *C. waggrakinensis* differ markedly from the British specimens of *C. cinctus* from the Neocomian beds from its type locality at Horncastle, with which they were originally identified. They are less symmetrical in the latero-umbonal region, are not as large as the British forms, lack their ornament, and are less inflated. The largest of the British specimens in the collections of the British Museum (Natural History) is about 22 cm across, and many have a diameter of about 20 cm. Both their valves are ornamented with concentric grooves which parallel lines of growth and which are quite conspicuous and regularly spaced — particularly on the left valve and on the proximal region of the right valve. Radial ornament may be found in addition to concentric lineation on one or both valves of the British specimens. On the right valve it may appear in the form of very shallow, closely spaced, subparallel and continuous or interrupted grooves, whereas on the left valve grooving when present may be deeper, more irregular, and more localized.

Apart from these differences there are others, seen in the detail of auricular morphology and internal structure, and, combined, they show convincingly that the large unornamented *Camptonectes* from the Bajocian of Western Australia identified previously with the British *'P cinctus* Sow.' belongs to a different species.

The lack of any discernible radial lineation on the exterior surface questions the validity of its placing in *Camptonectes*.

Remarks on the holotype of C. cinctus: In comparison with other specimens of *C. cinctus* examined at the British Museum, the holotype is not a very satisfactory specimen. It is a right valve 12 cm in diameter, whose surface is largely abraded by boring organisms and which consequently exhibits no concentric grooving. In addition, since its original illustration it has been broken into three fragments of which only two are now present in the collection.

Occurrence: Newmarracarra Limestone.

CHLAMYS GROUP

Genus CHLAMYS Roding, 1798

Type species: *Pecten islandicus* Muller, 1776; S. D. Herrmannsen, 1847.

CHLAMYS ENANTYI sp. nov.
(Pl. 26, figs 1, 6, 12)

1967 *Chlamys?* sp. nov. aff. *C. splendens* (Dollfus); Skwarko, *in* Coleman & Skwarko, *Bur. Miner. Resour. Aust. Bull.* 92, 206, pl. 25, figs 9, 13, 17.

Material: In addition to the material described previously from Enanty Hill (Coleman & Skwarko, 1967) one specimen consisting of a large portion of a valve (WAM 67.482) was found in the Geraldton area.

Holotype: WAM 67.482 (Pl. 26, fig. 6) incomplete valve.

Diagnosis: The detail of ribbing, characterized by absence of secondary growth-lines and by well developed alternation of primary and secondary ribs, separates *C. enantyi* from previously described species.

Separation from other species: The type of ornament, though striking in appearance, is by no means rare among Jurassic species. Among the European forms *splendens* Dollfus, *nattheimensis* and *blyensis* de Loriol, and *fibrosa* Sowerby, to name a few, have this basic kind of ornament. In detail, *splendens* and *nattheimensis* seem to be the closest to that in *enantyi,* though it can be readily distinguished by the absence of diffused growth-lines on ribs and interspaces between the transverse rings; the alternation of primary and secondary ribs also seems to be more consistent in *enantyi.*

Revised description: The shell is at least 47 mm high and 40 mm long. It is vertically ovate, and its body — apart from the auricles, which are not preserved — is fairly symmetrical and evenly inflated. The apical angle is slightly less than 90°. The exterior surface of the shell is lined with about 30 radiating primary and secondary ribs, the primary ribs radiating out from the umbo increasing gradually in breadth to a maximum of 1.5 mm, and the secondaries originating at varying distances from the umbo; they differ from the primaries in smaller thickness only. Both types of ribs are circular in cross-section and bear numerous and conspicuous rings at the junction of the growth-rugae with the radial ribs; the density of rings varies somewhat in different parts of shell as well as from one specimen to another, numbering between 6 and 14 to a centimetre.

Family LIMIDAE Rafinesque, 1815

Genus CTENOSTREON Eichwald, 1862

Type species: *Ostracites pectiniformis* von Schlotheim, 1820, p. 231; M.

CTENOSTREON PECTINIFORMIS (von Schlotheim, 1820)
(Pl. 27, figs 1-6)

1820 *Ostracites pectiniformis* Schlotheim, *Petrefactenkunde,* 1, 231.

1863 *Lima proboscidea* Sowerby; Goldfuss, *Petrafacta Germaniae,* 83, pl. 103, figs 2a, b.

1867 *Lima proboscidea* Clarke, *Quart. J. geol. Soc. Lond.,* 23, 8.

1870 *Lima proboscidea* Sowerby; Moore, *Quart. J. geol. Soc. Lond.,* 26, 231, 232.

1878 *Lima proboscidea* Sowerby; Etheridge, CATALOGUE OF AUSTRALIAN FOSSILS, 109.

1901 *Ctenostreon pectiniformis* (Schlotheim); Etheridge, *Rec. Aust. Mus.,* 4(1), 13-16, pl. 3.

1904 *Ctenostreon pectiniformis* (Schlotheim); Chapman, *Proc. Roy. Soc. Vic.,* 16(2), 329, 330, pl. 30, fig. 1.

1910 *Ctenostreon (Lima) pectiniformis* (Schlotheim); Glauert, *Geol. Surv. W. Aust. Bull.* 36, 100.

1910 *Ctenostreon (Lima) pectiniformis* (Schlotheim); Etheridge, *Geol. Surv. W. Aust. Bull.* 36, 31.

1914 *Ctenostreon pectiniformis* (Schlotheim); Chapman, AUSTRALIAN FOSSILS, 182, 212.

1919 *Lima (Ctenostreon) proboscidea* Sowerby; Maitland, *Min. Handbk, Geol. Surv. W. Aust. Mem.* 1, 1, 41.

Material: 28 specimens in the collection include complete specimens of both valves, fragments, and internal casts.

UT:	20282.
UWA:	37088; 11494.
AMS:	F4547; F6122; F13684.
WAM:	65.1147, 8; 65.1176; 67.496; 70.1379.
GSWA:	F74B, C; F74C/1; F399; F415; F415/1, 2, 3; F5912/1.

Etheridge (1901) described and discussed *C. pectiniformis* from Western Australia in some detail; his description was based on two left valves — the only specimens in his possession at that time. Later (Etheridge, 1910) he had the opportunity of handling another five specimens, but those in his own words were poor, and added little to his earlier description. In both the first paragraph under the 'Observations' (Etheridge, op. cit., p. 14) and in the captions to the plate which accompanied his paper, he erroneously referred to his illustrated shell as being the right valve, although in the description he did, in fact, describe it as a left valve. The relatively large number of specimens now available combined with better preparatory techniques has allowed more thorough examination and a more complete description of this species.

Description: The largest specimen in the collection is 11.5 cm long and almost 13 cm high. An average shell is suborbicular, vertically elongate, inequilateral, possibly equivalve, moderately inflated, and with a short cardinal margin. The anterior auricle is usually small and attached to the proximal part of the umbo. The posterior auricle is triangular in shape, not large but of somewhat variable size; in a few specimens a groove separates it from the main body of the shell. The anterodorsal shell margin is broadly rounded, with greatest convexity in the ventral part of the shell.

There are between 9 and 15 robust round or sharp-crested radial ribs which increase in thickness gradually but conspicuously with increased distance from the umbo. The ribs are rather asymmetrical: those in the front part of the shell lean forward, while those in the rear lean rearwards. The width of the interspaces varies considerably; it may be the same as the ribs which they separate, or up to several times wider. The interspaces are closely or broadly concave in cross-section, and their cross-section is also affected by the asymmetry of the ribs. Both the ribs and the interspaces are offset in a step-like fashion by concentric growth-rugae which are spaced at more or less regular intervals from each other. Where they cross the ribs, the rugae give rise to nodular projections or even tubes up to 2 cm long, depending on the part of the shell: in most though not all specimens the nodular projections increase in size and relief posteriorly, becoming tubular in the rear part of the shell. The tubes either project obliquely away from the shell or hug its surface. The ribs, the interspaces, and the rugae extend on to the posterior ear. Growth-lines were found on one specimen only.

The hinge area is flat, broad, and laminated with numerous and closely spaced shell layers which parallel the hinge-margin. The area is divided by a wide, deeply incised chondrophore which slopes gently to the rear of the shell and extends the lower margin of the area into a short process which marks its ventral termination. Between the process and the body of the shell there is a shallow hepatic fossa.

The anterior adductor muscle scar is moderately large, vertically oval, and impressed on its posterior side. Byssal gape in the anterodorsal portion of the margin is conspicuous when present, but was observed in one specimen only.

Discussion: The relationship between the commonly occurring Western Australian *Ctenostreon* and the European *C. pectiniformis* with which it was originally identified is particularly important as it sheds light on the geographical distribution of the Bajocian bivalves in general. I have examined a number of specimens of *C. pectiniformis* both from the Inferior Oolite (Bajocian) and from the Corallian (Oxfordian) of the United Kingdom, as well as some specimens from the supposedly Bajocian strata of Furstenberg, Germany. The similarity between the European Bajocian specimens and the Australian specimens was such as to leave no doubt as to their specific identity. Even allowing for the considerable intraspecific variation which characterizes both the European and the Australian representatives, the degree of similarity between them is startling. The only British specimen which was obviously dissimilar to the Australian representatives was the smaller of the two specimens illustrated by Sowerby (1820, pl. 264). The illustration, though reversed, is otherwise faithful to the specimen, but I have been told that the fossil itself did not come from Weymouth as stated by Sowerby, but from some other unknown locality (N. Morris, pers. comm.).

For nomenclatorial discussion on *C. pectiniformis* (Schlotheim), *C. proboscideum* (Sowerby), *C. rugosum* (Smith), and *C. rudis* (Sowerby) the reader is referred to Arkell (1932, pp. 145-8). The English palaeontologists refer specimens which closely resemble Australian forms to *C. pectiniformis,* although at least some of those shells deviate considerably from the circular shape of Goldfuss's specimen (Goldfuss, 1863, p. 83, pl. 103, fig. 2). I refer the Australian specimens of *Ctenostreon* also to *pectiniformis,* which name is now well established in Australian literature, rather than change it for another which after the much needed revision of European representatives of *Ctenostreon* may prove to be redundant.

Occurrence: Newmarracarra Limestone.

Genus PLAGIOSTOMA J. Sowerby, 1814

Type species: *Plagiostoma giganteum* J. Sowerby, 1814, by subsequent designation of Stoliczka, 1871.

PLAGOSTOMA CHAMPIONI sp. nov.
(Pl. 24, figs 11-13)

Material: Four specimens including two left valves and two right valves, all crushed to a varied degree.

GSWA: F68B/1.
WAM: 65.1127; 65.1201; 4972.

Holotype: WAM 4972 (Pl. 24, fig. 11), left valve.

Paratype: GSWA F68B/1 (Pl. 24, figs. 12, 13), right valve.

Diagnosis: The diagnostic feature of the new species is the combination of its small size with the shallow and poorly developed ribbing limited to the lateral extremities of each valve, though at times extending in a very indistinct fashion throughout each valve.

Description: The species is about 43 mm high and 41 mm long, moderately well inflated, with greatest tumidity in the proximal third of the shell and along the well defined and extended umbonal ridge.

The anterior auricle is crushed and distorted in all four specimens, but seems to be slightly shorter than the posterior auricle, which in the largest specimen is almost 8 mm long along the cardinal margin. The area seems to be plunging deeply into the commissure; the anterior margin seems to be slightly concave directly below the anterior cardinal margin, and then slightly convex up to the much more closely arched anteroventral part of the shell. In the rear the posterior margin is concave for a short distance below the cardinal margin, then straight for a short distance before flexing in a broad arch, whose convexity is, however, somewhat uneven, being less in the anteroventral part of the shell.

The umbo is depressed proximally, convex in its distal portion, and pointed, its front and rear margins forming an angle a little less than 90°.

The concentric striae cover all or part of the external surface of the shell. They are fine and closely spaced in the front and rear, but tend to form thin rugae in the middle of the shell. The striae are also present on the anterior area, but occur on the auricles in the form of rugae.

The radial sculpture is practically limited to the front and the rear periphery, but is absent from the area and from the auricles. It consists of fine grooves radiating out from the umbo in the rear part of the shell, or fine linear ridges radiating out from near the umbo in the front. The whole surface of each valve carries, however, extremely fine straight but interrupted radial striation.

Occurrence: Newmarracarra Limestone.

Genus PSEUDOLIMEA Arkell *in* Douglass & Arkell, 1932

Type Species: *Plagiostoma duplicata* J. de C. Sowerby, 1827, by original designation.

PSEUDOLIMEA DUPLICATA (J. de C. Sowerby, 1827)
(Pl. 24, figs 9, 10)

1827 *Plagiostoma duplicata* J. de C. Sowerby, MINERAL CONCHOLOGY OF GREAT BRITAIN, 6, 114, pl. 559, fig. 3.

1910 *Radula duplicata* (J. de C. Sowerby); Etheridge, *Geol. Surv. W. Aust. Bull.*, 36, 33, pl. 8, figs 7, 8.

1944 *Pseudolimea duplicata* (J. de C. Sowerby); Cox, *Proc. malac. Soc. Lond.* 26(2, 3), 84 (for synonymy).

1952 *Pseudolimea duplicata* (J. de C. Sowerby); Cox, *Palaeont. indica,* Ser. 9, 3(4), 60, 61, pl. 5, figs 11, 12 (for synonymy).

Material: About 20 left and right valves bearing the following registration numbers:

AMS: F6111.

GSWA: 78C/1-3; F78F; F75C; F81C/1; F410/1, 2; F5912/22; F5916.

WAM: 66.313(?); 66.338; 66.191; 66.309; 66.187; 66.319; 66.183; 2077; 65.1107.

Much of the material is poorly preserved, and no specimen gives insight into the internal structure.

Description: The largest specimen is 20 mm high and about 17 mm long. The bivalve is well inflated, with a pointed and somewhat incurved umbo. Anterodorsally the shell surface plunges fairly steeply towards the commissure, and the posterodorsal surface dips even more steeply. The wings are short, and the cardinal margin is only 4 mm long.

There are about 20 coarse ribs radiating out from the umbo. They are angular in cross-section, with V-shaped interspaces occupied for most of their length from the umbo by thin secondary riblets. Near the anterodorsal and the posterodorsal shell margins the primary ribs decrease in relief.

Remarks: In their smaller size and rib-count the Australian specimens are closer to the Indian specimens from Cutch (Cox, 1952, 60, 61) than to the British and European forms.

Occurrence: Newmarracarra Limestone.

Family OSTREIDAE Lamarck, 1818

Subfamily EXOGYRINAE Vialov, 1936

Genus AMPHIDONTA Fischer & Waldheim, 1829

AMPHIDONTA THOLIFORMIS (Etheridge, 1910)
(Pl. 28, figs 1-3, ?4, 5, ?6, 7-9, 12; ?Pl. 29, figs 1-4)

1910 *Ostrea tholiformis* Etheridge, *Geol. Surv. W. Aust. Bull.* 36, 30, pl. 7, figs 4-7 (non figs 2, 3).

Material: 27 left valves and 12 right valves.

WAM: 65.1017; 65.1019(?); 65.1022(?); 65.1194; 66.326; 68.1214(?); 68.1215, a, b, ?e.

UWA: 16623; 26303 (2 spp.); 23605; 23607; 37088 (2 spp.); 45302 (2 spp.); 47441; 47463.2.

GSWA: F70A/1-3; F70B; F70B/1(?); F70C/1-3; F70D/1; F400/1-3; F411/1-3; F414/1; F5036.

AMS: F13682; F13692; F13697(?).

Lectotype: Etheridge (1910) did not designate a holotype of *A. tholiformis,* and I have chosen the specimen illustrated by him in plate 7, figure 4 (Pl. 28, figs 2, 8 of this paper) as the lectotype.

Description: The shell is about 40 mm across and 20 mm high, of variable and rather irregular shape, although a broadly subcrescentic shape predominates.

The left inflated valve is thick and ridged, but being the valve of attachment is variously deformed, depending on the shape and size of the object of attachment. Outside the area of attachment the surface of the left valve carries prominent growth-rugae.

Inside the left valve the area is asymmetrically triangular, with a similarly-shaped ligament area occupying its middle part. Both the cardinal area and the ligament area are striated with numerous and conspicuous growth-laminae. The adductor scar is circular, and deep and relatively fairly large. A raised welt close to the periphery parallels the shell margin, its function being to prevent the right valve from being forced too deeply into the left valve.

The right valve is thin and basically flat, but has a somewhat undulating surface. It is slightly smaller than the left valve, which overlaps it, and in outline reflects the peripheral shape of the left valve. Its adductor scar is irregularly circular and generally shallow. The area is similar to that in the left valve, but flatter. The outside surface is ridged with irregular concentric growth-rugae.

Remarks: It is unlikely that the right valve figured by Etheridge (1910, pl. 7, figs 2 and 3) (Pl. 28, figs 10, 11 of this paper) is *A. tholiformis,* as it is much thicker and much more rounded, while the muscle scar stands up from the inside surface.

Occurrence: Newmarracarra Limestone.

AMPHIDONTA cf. THOLIFORMIS (Etheridge, 1910)
(Pl. 25, figs 5, 6, 8, 9)

Material: Seven left valves, mostly small, six attached to a single belemnite guard (WAM 68.1213) and one attached to a *Trigonia moorei* (UWA 16146).

Discussion: The small specimens are probably juvenile and immature forms of *Amphidonta tholiformis.* The left, lower valves have large surfaces of attachment and a fairly high wall away from it. Inside the shell the area is similar to that found in *tholiformis,* and there is the interior peripheral welt, and the large adductor scar.

Occurrence: Newmarracarra Limestone.

Subfamily LOPHINAE Vialov, 1936

Genus LOPHA Bolten, 1798

Type species: *Mytilus cristagalli* Linne, 1758

LOPHA MARSHII (J. Sowerby, 1812) AUSTRALIENSIS subsp. nov.
(Pl. 30, figs 1-6)

?1870 *Ostrea marshii* Sowerby; Moore, *Quart. J. geol. Soc. Lond.*, 26, 230, 232.

1910 *Alectryonia marshii* (Sowerby); Etheridge Jnr, *Geol. Surv. W. Aust. Bull.* 36, 31, pl. 6, figs ?5, 6, 7; pl. 8, fig. 4.

?1910 *Alectryonia (Ostrea) marshii* (Sowerby); Glauert, *Geol. Surv. W. Aust. Bull.* 36, 100.

?1919 *Alectryonia (Ostrea) marshii* (Sowerby); Maitland, *Min. Handbk, Geol. Surv. W. Aust. Mem.* 1, 40.

Material: 17 left valves, 3 right valves, and 7 bivalves with both valves joined together.

GSWA: F64A; F66A/1; F66C/1, 2; F412/1, 2; F5594; F5910/1, 3, 4; F5911/1.
WAM: 4954; 66.64; 61.228; 63.118; 65.955; 66.327; 65.1101; 65.1104; 65.1113; 65.1195.
AMS: F13681; F13691; 21274; 21777; 21821.

Description: The bivalve grows to a moderately large size and exhibits considerable variability in most of its morphological features. The largest specimens are up to 8 cm high and 7 cm long, and most are longer than they are high. The umbo is usually pointed and acute, but may be rounded and obtuse. In most immature specimens the anterodorsal and posterodorsal shell margins are more or less straight and slope away steeply from the umbo. The ventral margin is broadly convex. Some degree of symmetry in the overall shape is retained, but some specimens are curved in the plane of commissure: the curving may affect only the proximal part of the shell or alternatively the whole of the shell.

The left valve is generally convex, although the degree of tumidity varies considerably from specimen to specimen, and some left valves are practically flat (Pl. 30, figs. 1, 2). The right valve is flat in most specimens, but rarely it may be pronouncedly concave.

In its proximal portion the outside surface of both valves is uneven and usually devoid of any regular sculpture, but the radial ribbing, once initiated some distance from the umbo, rapidly becomes conspicuous and persistent.

The number of ribs on a valve varies between 9 and 13. They are V-shaped in cross-section but are not excessively sharp-ridged. The interspaces are deep, particularly close to the margin, moderately broad, and also V-shaped in cross-section. In some specimens the ribs radiate out quite evenly from the umbo; more commonly, however, they are unevenly spaced, asymmetrical in cross-section and of variable direction.

The external ornament is rarely reflected on the inside of the valves except at their distal margins, which are serrated and are greatly thickened with successive layers of shell material. On the inflated valve the area is prominent, triangular, either parallel to the commissure or more commonly inclined away from it. It is transversely striated with growth-lines and growth-rugae, which also transgress the ligament area.

The ligament area is centrally situated on the area and vertically elongate. It is moderately deeply incised, and its borders are parallel or slightly inclined to each other, diverging distally. The apex of the right valve may altogether obscure the area of the left valve, or may be located close to its ventral margin.

The adductor scar on both valves is large and circular, its distal edge elevated above the inside surface of the valve.

Discussion: The Australian oysters referred to *A. marshii* by Etheridge (1910, p. 31) appear at first sight to be very similar to the British specimens of *A. marshii.* Their true relationship is, however, uncertain as, firstly, the British representatives show an even greater intraspecific variation than the Australian, and, secondly, while some specimens from the two countries are very similar to each other, some British specimens exhibit morphological trends not paralleled by the Australian shells. These of course may be a result of different environments in two widely separated parts of the world. In order, therefore, on the one hand to stress the obviously close relationship, and on the other to point out the lack of absolute identity, I refer the Australian species to a new subspecies.

Occurrence: Newmarracarra Limestone.

LOPHA MARSHII (J. Sowerby) NEWMARRACARRAENSIS subsp. nov.
(Pl. 31, figs 1-7)

One locality, bearing the registration number UWA 36054, has yielded about a dozen *Lophas,* which, though generally similar to *L. marshii australiensis,* have a more elevated adductor scar, deeper and more closely set ribbing with sharply crested ribs, and micro-reticulate sculpture on the exterior surface. These specimens are here regarded as a distinct subspecies. Since all specimens are from one locality only, and so probably have a very limited lateral distribution, the departure from the usual morphology of *L. marshii* may be due to a distinct local environmental condition.

Description: The largest specimen is 6 cm long and over 9 cm high. The shell is vertically ovate, poorly inflated, with length increasing gradually ventrally. The right valve is a little shorter than the left, but they seem to have similar inflation. Both are strongly ribbed with about nine prominent, fairly regular radiating ribs with sharp ridges and narrow V-shaped interspaces. Faint radial lineation gives rise to micro-reticulate pattern on crossing the growth-lines. The overall shape can be strongly modified by the encrusting oysters of the same or a different species.

On the left valve the area is steeply inclined to the commissure. The ligament area is broad and like the area broadly triangular. The adductor scar is vertically ovate, large and very prominent, with high relief, particularly in its distal portion. It is concentrically striated with growth-lines.

Occurrence: Newmarracarra Limestone.

Subfamily GRYPHAEINAE Vialov, 1936

Genus GRYPHAEA Lamarck, 1801

Type species: *Gryphaea arcuata* Lamarck, 1801.

GRYPHAEA sp. indet.
(Pl. 26, figs 7-9)

Material: A single specimen, UT 21764.

Description: The convex valve is 30 mm high and 26 mm long, strongly inflated, symmetrical except for the beak itself, which is slightly curved to the rear as well as being curved downwards. The exterior surface is free of lineations except for some growth-rugae at the proximal anterior and posterior shell margins.

The concave valve is thin, markedly concave, with its periphery following the periphery of the convex valve. No obvious ornament is visible on the concave valve.

Occurrence: ?Newmarracarra Limestone.

Family Trigoniidae Lamarck, 1819

Genus Trigonia Bruguière, 1789

Type species: *Venus sulcata* Hermann, 1781, pl. 4, fig. 9; ICZN opinion 327 (1955).

Subgenus Trigonia s. str.

Trigonia moorei Lycett, 1870
(Pl. 33, figs 1-7)

1870 *Trigonia moorei* Lycett *in* Moore, *Quart. J. geol. Soc. Lond.*, 26, 254, pl. 14, figs 9, 10.

1910 *Trigonia moorei* Lycett; Etheridge, *Geol. Surv. W. Aust. Bull.* 36, 36-37, pl. 4, figs 1-8.

1963 *Trigonia moorei* Lycett; Skwarko, *Bur. Miner. Resour. Aust. Bull.* 67, 13, 14, pl. 1, fig. 1 (for synonymy).

1967 *Trigonia moorei* Lycett; Skwarko *in* Coleman & Skwarko, *Bur. Miner. Resour. Aust. Bull.* 92, 208, pl. 25, fig. 10.

Material: More than 200 specimens, 90 of which were well enough preserved to be measured. Registration numbers are:

AMS: F1537; F4683, 4; F6065; F6108, 1-5; F13674; F13685, 7-9; F13694.

QM: F5603; F5606,

UWA: 16146; 23564, 1-5; 45300, 1; 47463.1, 3.

GSWA: F62; F62A/1, 5, 7-26, 28; F62B/1-4; F62C/1-42; F62D/1-3; F62G; F64A; F65C/3; F85/1, 2; F401/1-3; F416/3-8; F5029/1, 2; F5032A, D, E, F, H; F5039A, C, D; F5910/2, 5-8; F5911/2, 3, 12.

WAM: 124; 4979; 66.58, 78, 106, 192; 7544; 61.227; 60.424; 65.957, 2, 4, 5, 7; 66.340, 1-5; 65.1028-33, 36, 40; 65.1120, 1; 65.1137, 38, 41, 42, 46, 84; 65.1183, 1-6; 65.1185, 6; 65.1207; 66.303, 1-4, 6.

Discussion: T. moorei is very common in the Newmarracarra Limestone, and consequently has received the attention of the earliest investigators of Western Australian Jurassic fossils. Over the years Moore (1870), Etheridge (1910), Whitehouse (1924), and Skwarko (1963) have ensured that the species is now well known, and consequently the present examination of a very large number of specimens has added but slightly to knowledge of the shell.

T. moorei is a *Trigonia* s. str. My earlier doubt (Skwarko, 1963 pp. 13, 14) regarding the suggestion by Kobayashi & Mori (1954, p. 164), that it is a *Frenguelliella* is confirmed. Although *T. moorei* has a tendency towards concentric ornamentation on the distal portion of the area, and in a few specimens all but the proximal portion of the area is completely devoid of radial ribbing, no specimen with an area completely devoid of radial ribbing was seen among the hundreds examined. While at the British Museum (Natural History) I examined the specimen of *T. moorei* originally illustrated by Moore 1870). Moore's figure — a drawing — shows only concentric ribbing on the area, and is the source of the misunderstanding regarding the generic affinity of *moorei.* Close examination of the actual specimen revealed the presence of radial ribbing on the proximal portion of its area on both valves (cf. Pl. 33, fig. 7).

The ratio of radial to concentric ribbing on the area of *T. moorei* is variable. The ratio of maximum width of the area to the width of the entire shell also varies, as already shown by Whitehouse (1924, p. 5). The length-to-height ratio is, however, fairly constant (fig. 4). Examination of a large number of specimens revealed the presence of intermediate forms between specimens exhibiting differences in measurement ratios, and left little doubt that only one species is in fact represented.

Occurrence: Newmarracarra Limestone; Kojarena Sandstone.

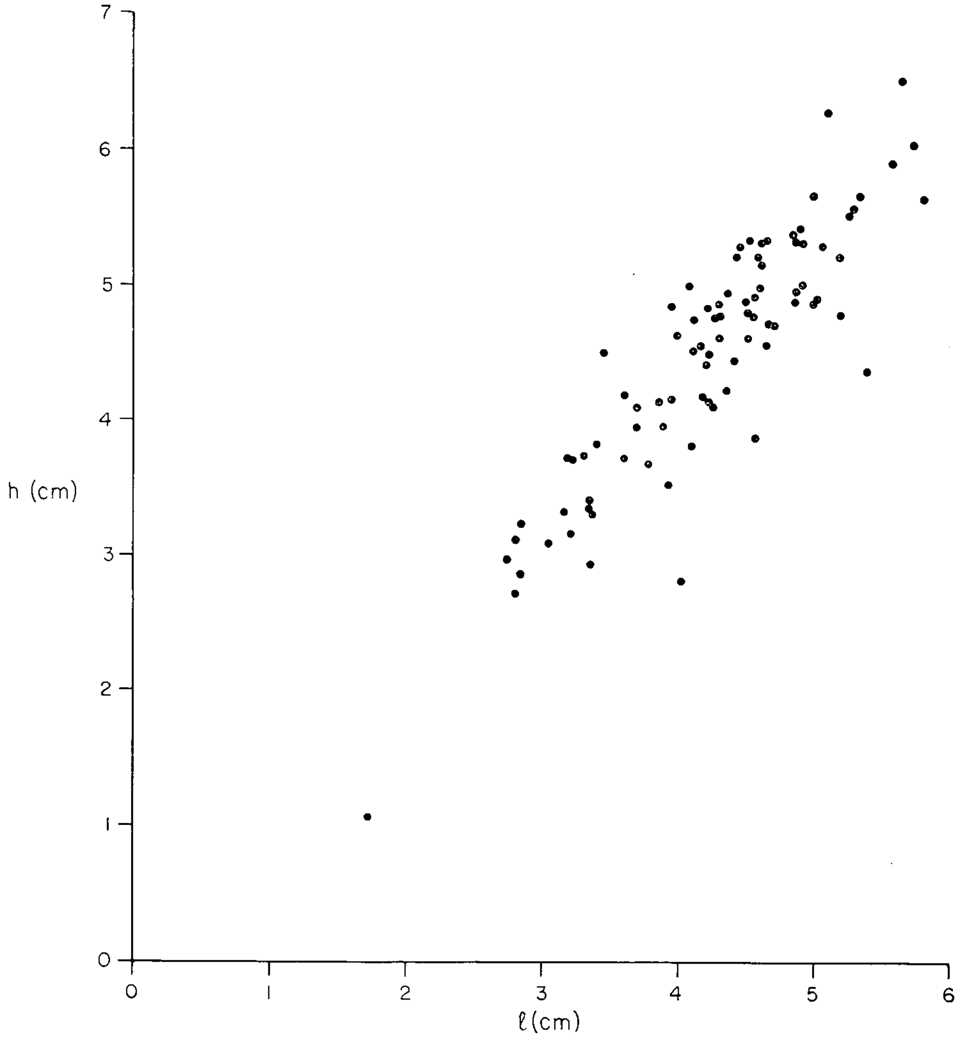


Fig. 4. Distribution of the length-to-height ratio in *T. moorei.*

Family ASTARTIDAE d'Orbigny, 1844

Subfamily ASTARTINAE d'Orbigny, 1844

Genus ASTARTE J. Sowerby, 1816

Type species: *Venus scotica* Maton & Rackett, 1807, by original designation.

ASTARTE s. str.

ASTARTE (ASTARTE) APICALIS Moore, 1870
(Pl. 34, figs 5-9)

1870 *Astarte apicalis* Moore, *Quart. J. geol. Soc. Lond.*, 26, 232, 249, pl. 13, fig. 11.

1968 *?Astarte apicalis* Moore; Skwarko, *in* Coleman & Skwarko, *Bur. Miner. Resour. Aust. Bull.* 92, 208, 209, pl. 25, figs 6, 7.

In 1870 Moore described *Astarte apicalis* from the 'Greenough District', Western Australia, as follows: 'Shell small, trigonal, flattened; ventral margin straight; surface ornamented with distant rised and straight transverse lines of growth.' The illustration which accompanies the description (op. cit., pl. 33, fig. 11) is a drawing of a right valve, which 'enlarged' measures about 20 mm by 20 mm.

Recently I wrote (Skwarko, *in* Coleman & Skwarko, 1967, p. 209) that 'Neither the type species nor any of the original specimens described by Moore (1870) are available for examination, and seem to be irretrievably lost (Glauert, 1910, p. 102)'. Since that time, however, I have been able to locate one small specimen in the collections of the British Museum (Natural History) whose label proclaims it as Moore's figured specimen. Its photograph, magnified about 5 times, when compared with the original figure, gives rise to suspicion regarding its identity; the specimen is, however, unquestionably an *apicalis*. In the Kojarena Sandstone a number of well preserved mature specimens were collected; in this unit *apicalis* appears to be quite common. A revised description of Moore's species is:

The bivalve is up to 9 mm high, 10 mm long, and 4 mm deep. It is subquadrangular to subtrigonal in outline, well inflated, particularly along the post-umbonal ridge, equivalve, and carinate. The umbo is prosogyrous, depressed, and sharply defined, the walls which confine it being inclined to each other at slightly less than a right angle.

The anterodorsal shell margin is straight or slightly concave, but becomes sharply convex where it swings rearwards forming the ventral shell margin. The posterodorsal shell margin is straight or slightly convex at first, arching downwards at about its mid-length to meet the ventral margin in a tight curve.

The external sculpture consists of about 22 robust, narrow, and well defined concentric costae which swing sharply dorsally near the anterior shell margin and along the post-umbonal ridge. They are separated from each other by flat-bottomed interspaces about twice their width.

The escutcheon is narrow and apparently devoid of ornament. The lunule is considerably wider and also devoid of ornament.

The dentition on the right valve consists of a robust triangular 3b, and of a thin and inconspicuous 3a and 5b united to the lunule margin and nymph respectively.

The musculature consists of anterior and posterior adductor scars which are roughly circular and joined together with a simple pallial line which parallels the distal shell margin.

A very small scar after pedal muscle is present close to and above the anterior adductor scar.

The entire distal shell margin is crenulated on the inside of the shell.

Occurrence: Newmarracarra Limestone; Kojarena Sandstone.

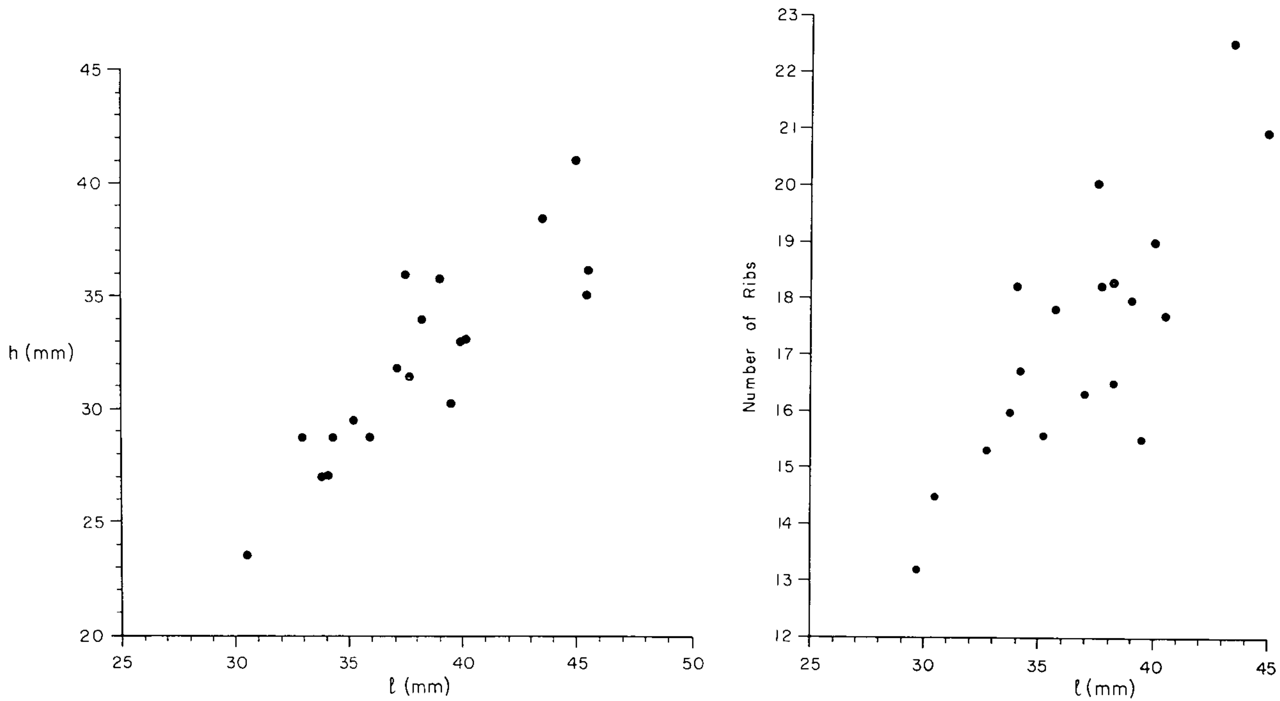


Fig. 5. Distribution of the length-to-height ratio and the number of ribs-to-length ratio in *Astarte Clifioni*

ASTARTE (ASTARTE) CLIFTONI Moore, 1870
(Pl. 34, figs 1-4, 10-13, 15, 16; Text-fig. 5)

1870 *Astarte cliftoni* Moore, *Quart. J. geol. Soc. Lond.*, 26, 232, 249, 250, pl. 13, fig. 10.
1910 *Astarte cliftoni* Moore; Etheridge, *Geol. Surv. W. Aust. Bull.* 36, 37, 38, pl. 5, fig. 8 (*non* figs 5-7; *non* pl. 6, fig. 3).

Moore's original specimen, held by the British Museum (Natural History) and here reproduced in Plate 34 (figs 10, 12, 13) is regarded as the lectotype, and consists of a complete bivalve with both valves in position. The dentition cannot be observed. Moore's description is as follows: 'Shell thick, ovately trigonal, flattened, inequilateral; umbones acute, small, anterior; anterior side short; posterior and the longest, very oblique, and produced towards the ventral margin, which is rounded; lunule rather large, oval; concentric striae very numerous and regular.'

Etheridge (1910) illustrated three specimens (pl. 5, figs 5-7; pl. 5, fig. 8; and pl.6, fig. 3), only one of which (pl. 5, fig. 8) — the only specimen so far to show the dentition — belongs to Moore's species. As Etheridge's revised description of the species dwells almost entirely on the outside structure of the shell, it is largely disregarded here.

More than twenty specimens previously referred to *Astarte cliftoni* have been scrutinized. Two closely related species are recognized, Moore's *A. cliftoni* and a new species, *Astarte tibraddeni* sp. nov. A revised description of *A. cliftoni* is as follows:

The shell is thick-walled; it grows to about 23 mm in height, 34 mm in length, and 16 mm in thickness. It is not strongly inflated.

The umbones are sharp, pointed, obtuse, placed anteriorly, with sharp pre-umbonal and post-umbonal carinae which enclose a short narrow lunule and a somewhat longer but also narrow escutcheon. Only growth-striae line these areas. The exterior of each valve is lined with concentric ribs fairly regularly spaced over all of the shell except on the proximal part of the umbo, where the interspaces are distinctly broader.

The hinge-plate is moderately broad, and supports a normal astartid dentition.

The musculature consists of a deeply incised anterior adductor scar joined by an entire pallial line with a shallower posterior adductor scar. There is a small but deep cavity after the pedal muscle close to and above the front end of the anterior adductor scar. The internal rim of the distal shell margin is crenulated.

ASTARTE (ASTARTE) TIBRADDENI sp. nov.
(Pl. 34, figs 14, 17-19)

Holotype: UWA 36033 (Pl. 34, figs 14, 17) Right valve.

Paratype: UWA 36033 (Pl. 34, figs 18, 19) Left valve.

Diagnosis: The combination of largish size, and height of the shell, thick hinge-plate and closeness of spacing of proximal concentric ribs is diagnostic.

Separation from other species: A. tibraddeni sp. nov. can be distinguished from *A. cliftoni* by thicker hinge-plate, denser spaced ribbing on the beak, and greater height of the shell.

Description: The shell is robust, thick-walled, up to 35 mm high, 37 mm long, and 20 mm thick. It is moderately well inflated.

The umbones are pointed, obtuse, sharp, and depressed, with a sharp post-umbonal carina, and a more rounded pre-umbonal carina. The ligament groove is narrow and inconspicuous; the lunule is fairly deep and wide and oval in shape.

Concentric ribbing covers the whole external surface of the shell, but is absent from the ligament groove and the lunule. It consists of regularly alternating narrow ribs and interspaces, both of which are set most closely together in the proximal portion of the shell.

On the left valve 2 is parallel-sided and prominent because of high relief; 4b is a little longer but of smaller relief, and seems to be adpressed to the hinge-plate. The socket for 3b, which is enclosed by the two teeth, is large; PII cannot be distinguished from the rest of the shell; AII has moderately high relief.

Occurrence: Newmarracarra Limestone.

Family TANCREDIIDAE Meek, 1864

Genus TANCREDIA Lycett, 1850

Type species: *Tancredia donaciformis* Lycett, 1850, by subsequent designation of Norris & Lycett, 1855.

TANCREDIA s. str.

TANCREDIA (TANCREDIA) SANDSPRINGI sp. nov.

(Pl. 35, figs 1-6)

Material: Two bivalves with shells crushed and out of position; four right valves and two left valves, some incomplete. They bear the following registration numbers:
GSWA: F626/4.
WAM: 65.959; 65.1134; 65.1145; 66.68; 70.1380; 169.

Holotype: WAM 65.1145 (Pl. 35, figs 2, 4, 6) Right valve.

Paratype: WAM 70.1380 (Pl. 35, figs 1, 3, 5) Left valve.

Diagnosis: The shell is considerably elongated, with the result that many of its structures, particularly the posterior lateral tooth, are correspondingly elongate. These, together with a very wide posterior gape, tend to separate the new species from previously described forms.

Description: The holotype is about 75 mm long, 41 mm high, and 15 mm thick; the paratype is 37 mm high and probably more than 80 mm long. The bivalve is thick, strongly attenuated in the front and produced both to the front and the rear. It is fairly strongly inflated, carinate, with a depressed prosogyrous umbo, and a wide posterior gape.

The posterodorsal shell margin is straight in lateral view and convex outwards in dorsal view. It is shorter than the anterodorsal margin, which is slightly concave with a resultant subrostrate appearance of the front of the shell. The anterior shell margin is sharply arched and the posterior margin more openly rounded. The ventral margin is gently and evenly convex.

The umbo is situated anteriorly. It is incurved, obtuse and very poorly defined except in its proximal portion. There is a sharp-edged post-umbonal carina which connects the umbo with the posterior shell margin, and which encloses a broad, sickle-shaped, and almost flat area between it and the posterodorsal shell margin. The area is striated with growth-striae, and oriented at right angles to the commissure. The remainder of the exterior of the shell is moderately though evenly inflated, and irregularly and weakly striated with concentric growth-lines and weak rugae.

The ligament is external; the nymphs are sharp-edged and moderately prominent. The hinge-plate is strong, with dentition limited to one prominent and robust central tooth and one posterior lateral tooth on each valve. On the right valve the central tooth is robust, triangular, with its apex curved dorsally. The socket which precedes it is deep and broad. The posterior lateral tooth is attenuated and inconspicuous, with a broad and moderately deep socket above and behind it housing a rather thin but high and prominent posterolateral tooth of the left valve, and situated below the anterior extremity of the hinge-plate.

The anterior adductor scar is fairly large and circular, with the pallial line departing from its posteroventral margin. The line runs subparallel to the ventral shell margin but remote from it for its entire observed length.

Occurrence: Newmarracarra Limestone.

Subgenus Isotancredia Charan, 1950

Type specimen: *Tancredia extensa* Lycett, 1850, by original designation.

Tancredia (Isotancredia) kojarena sp. nov.
(Pl. 35, figs 7-10)

Material: One internal impression of a right valve, and two of the left valve. Locality SKS9.

Holotype: CPC 11392 (Pl. 35, fig. 9).

Paratypes: CPC 11390 (Pl. 35, fig. 7); CPC 11391 (Pl. 35, fig. 8); CPC 11393 (Pl. 35, fig. 10).

Diagnosis: The diagnostic feature of the new species is the combination of its small size with its overall shape, delicate tooth structure, and considerable inflation.

Comparison with other species: Tancredia similis Lycett resembles the new species in shape and size but is less inflated.

Description: The bivalve is up to 12 mm high, 20 mm long, and 8 mm thick. It is equivalve, subequilateral, well inflated, attenuated in the front and broadening for a short distance behind the umbo.

The umbo is ill-defined, situated a little to the front of the middle of the shell. The anterodorsal shell margin is almost straight and directed anteroventrally; the posterodorsal margin is directed first slightly posterodorsally and then posteroventrally. The ventral margin is broadly and evenly convex, and its junction with the anterodorsal margins is tightly rounded, while that with the posterodorsal margin is subangular.

The exterior of the shell appears to be smooth, but may be striated with very weak concentric growth-striae.

The tumidity is greatest in the middle of the shell and along the rather indistinct post-umbonal carina, posterodorsally from which the surface of the shell plunges steeply towards the commissure.

The hinge-plate is thin. In front of the umbo it is of uniform breadth and carries a narrow elongated lateral tooth which corresponds to a thin groove on the left valve. This tooth terminates before reaching a well developed triangular socket beneath the umbo, which houses the corresponding tooth from the left valve. An oblique, thin, triangular tooth is present immediately behind the socket. The hinge-plate widens to about twice its anterior width at the site of the median socket, but narrows somewhat behind the umbo, only to widen again at its rear end, where it houses the posterior lateral tooth of the left valve.

There is an oblong and rather deeply incised anterior adductor scar along the anteroventral projection of the front end of the hinge-plate, and a shallower and smaller posterior adductor scar situated near the posterior termination of the hinge-plate. The pallial line starts at the posteroventral margin of the anterior scar, and proceeds rearwards subparallel to the ventral shell margin but remote from it, turning sharply dorsally with a slight inward flexure before joining the posterior scar.

Occurrence: Kojarena Sandstone.

Family PHOLADIDAE Lamarck, 1809

Subfamily MARTESIINAE Grant & Gale, 1931

Genus MARTESIA Sowerby, 1824

Type species: *Pholas clavata* Lamarck, 1818; by original designation.

Subgenus PARTICOMA Bartsch & Rehder, 1945

Type species: *Pholas cuneiformis* Say, 1822; by original designation.

MARTESIA (PARTICOMA) AUSTRALIS (Moore, 1870)
(Pl. 34, fig. 20; Pl. 36, figs 1, ?2)

1870 *Teredo australis* Moore, *Quart. J. geol. Soc. Lond.*, 26, 255, pl. 12, fig. 11.

Original description: 'Shell small, convex, rather quadrate; umbones mesial; surface with curved furrow proceeding from the umbo to the centre of the ventral margin, and with numerous transverse striae, which pass obliquely into the mesial furrow, especially from the anterior side; anterior end with six or seven faint, close longitudinal striae, which, decussating the transverse lines, give it a wavy look; anterior margin reflected and gaping.'

No new specimens have been collected since Moore's description of the species, and little can be added to his description through the restudy of his material. In Plate 36 (fig. 2) I have figured a maze of burrows which might have resulted from the activity of this species.

Family CERATOMYIDAE Arkell, 1934

?Genus GRESSLYA Agassiz, 1843

Type species: *Lutraria gregaria* Zieten, 1833, by subsequent designation of Herrmannsen, 1847, p. 490.

GRESSLYA SANFORDII (Moore, 1870)
(Pl. 32, figs 2-4, 10-12; Text-fig. 6)

1870 *Myacites sanfordii* Moore, *Quart. J. geol. Soc. Lond.*, 26(1), 232, 253, pl. 13, fig. 9.
1878 *Myacites sanfordii* Moore; Etheridge, CATALOGUE OF AUSTRALIAN FOSSILS, 110.
1907 *Myacites sanfordii* Moore; Maitland, *Aust. Assoc. Adv. Sci.*, 11, 152.
1910 *Myacites sanfordii* Moore; Glauert, *Geol. Surv. W. Aust. Bull.* 36, 102.
1919 *Myacites sanfordii* Moore; Maitland, *Min. Handbk, geol. Surv. W. Aust.*, 1, 40.
1968 *Pleuromya? sanfordii* Moore; Skwarko *in* Coleman & Skwarko, *Bur. Miner. Resour. Aust. Bull.* 92, 209, pl. 25, figs 14, 18, 21.

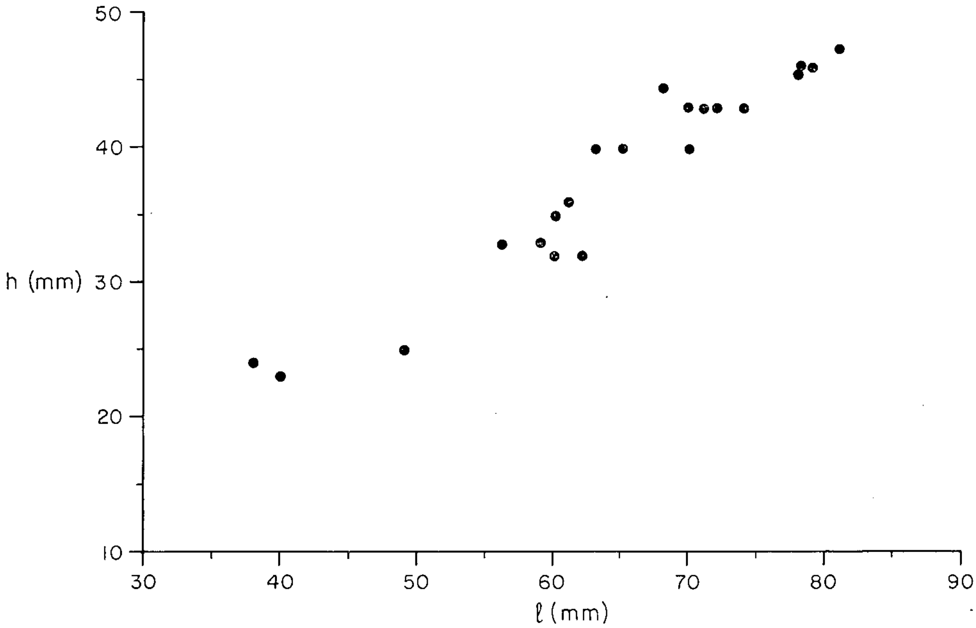


Fig. 6. Distribution of the length-to-height ratio in *Gresslya sanfordii.*

Material: Holotype (Brit. Mus. Nat. Hist. Coll.); 23 more or less complete specimens and some 24 incomplete or badly preserved specimens, bearing the following numbers:

WAM: 156; 168; 63.82; 65.1123; 65.1128.

GSWA: F88/1, 3-5; F89/1; F92/1, 2; F407/2, 3; F408; F5047A, B; F5589; F5590; F5593; F5912/3-6, 8-11, 13-15, 16, 19, 23, 24.

Original description: 'Shell elongate, flattened; umbones rather anterior, close; anterior side slightly produced and rounded, posterior side lengthened and attenuated; front dorsal margin slightly curving, with edges of valves close; both ends slightly gaping.

'This shell approaches very closely *M. calciformis* of the Inferior Oolite.'

Revised description: The shell is equivalve, up to 80 mm long and 48 mm high, with a height-to-length ratio of about 0.59. It is well and medially inflated with incurved, obtuse, and poorly defined umbones.

The umbones are anteriorly placed. The ratio of distance between the umbones and the anterior shell margin to the overall length of the shell varies mainly between 0.45 and 0.48, but is not regarded as a strictly diagnostic feature because of variation.

Behind the umbones the shell tapers somewhat posteriorly, and in front of the umbones it expands somewhat after the initial constriction. The shell gapes slightly at both ends. The exterior is concentrically lined with growth-lines and growth-rugae. The ligament is opisthodetic, subinternal, giving rise to a slit extending back from the beak on internal moulds of some specimens.

Discussion: I have recently placed, though with a qualification, some Western Australian shells previously referred to *Myacites* into *Pleuromya* Agassiz. It is difficult to be certain on the general appearance alone to which genus — indeed, family — these shells devoid of true hinge-teeth belong. I am convinced now, however, that our specimens lack the small protuberances with a small niche on each valve which characterize *Pleuromya* (*Myacites* Schlotheim) and I think that they most probably belong to *Gresslya* Agassiz.

Some specimens of *P. inconstans* Castillo & Augilera from the Oxfordian Caliza Chimeco formation of Mexico appear to be very similar to *G.? sanfordii.* As its name implies, however, the Mexican species varies widely in shape, and most of its specimens are more symmetrical than *sanfordii,* while their postero-ventral margins are curved more upwards, resulting in a more attenuated posterior margin. The preservation of the Mexican specimens is similar to that of the Australian forms; they also may belong to *Gresslya.*

Occurrence: Newmarracarra Limestone.

DERIVATION OF NEW NAMES

australiensis (*Lopha marshii*) — after Australia.
carnarvoni (*Grammatodon* [*Indogrammatodon*]) — after Carnarvon Basin, W.A.
championi (*Plagiostoma*) — after Champion Bay, W.A.
enantyi (*Chlamys*) — after Enantyi Hill, Geraldton district, W.A.
geelvinki (*Propeamussium* [*Parvamussium?*]) — after Geelvink Channel, near Geraldton, W.A.
geraldtoni (*Cucullaea*) — after the township of Geraldton, W.A.
greenoughi (*Camptonectes*) — after Greenough River, W.A.
kojarena (*Isotancredia*) — after Kojarena Sandstone, Geraldton area, W.A.
newmarracarraensis (*Lopha* [*Lopha*]) — after Newmarracarra Limestone.
sandspringi (*Tancredia* [*Tancredia*]) — after Sandspring, Geraldton district, W.A.
tibraddeni (*Astarte* [*Astarte*]) — after Tibradden station, Geraldton district, W.A.
waggrakinensis (*Camptonectes*) — after Waggrakine settlement, Geraldton district, W.A.

LOCALITY INDEX TO FOSSIL REGISTRATION NUMBERS

Western Australian Museum (WAM)

60.424	Sandsprings, 10-15 miles E of Geraldton per W. D. L. Ride, 1960.
61.227, 8	16 miles E of Geraldton. C. Parsons, Aug. 1961.
62.183	Bringo Cutting, Siding and to the S. Geraldton-Mingenew Region. D. L. Cook, Aug. 1960.
63.56	5 miles E of Moonyoonooka, 3-4 miles S of the Mullewa-Geraldton road. Property of Ivan Gould. Collected by O. Drew, 1962.
63.82, 3, 118	Waggrakine Cutting, near Geraldton. P. van Bladel, 1963.
65.955–7, 9	Cave near Waggrakine Cutting on the Geraldton-Nanson road. R. Gerritsen, 1965.
65.995	Cave near Waggrakine Cutting on the Geraldton-Nanson road. R. Gerritsen, 1965.
65.1014–6	Waggrakine, via Geraldton. Cave in ridge near the Geraldton-Nanson road. R. Gerritsen, 1965.
65.1017, 19, 22	Waggrakine, via Geraldton. Cave in ridge near the Geraldton-Nanson road. R. Gerritsen, 1965.
65.1026–33, 36, 40	Waggrakine, via Geraldton. Cave in ridge near the Geraldton-Nanson road. R. Gerritsen, 1965.
65.1097–9	Found without label in collection. Presumed to be from the Geraldton district.
65.1100, 1, 4, 7, 8, 10	Found without label in collection. Presumed to be from the Geraldton district.
65.1113	20 miles E of Geraldton. From railway cutting. Collector and date of collection unknown.
65.1116,7	Geraldton district. Collector and date of collection unknown.
65.1120	Newmarracarra. Collector and date of collection unknown.
65.1121, 3, 7, 8	Moonyoonooka, near Geraldton. Collector and date of collection unknown.
65.1130, 1	Bringo Cutting, Siding and to S. D. L. Cook, Aug. 1960. See comment on 62.183 above.
65.1134	Tibradden station, Victoria district. Collector and date of collection unknown.
65.1137	Newmarracarra. Collector and date of collection unknown.
65.1138	Found in collection without label. Presumed to be from the Geraldton district.
65.1141	Near Tibradden Hill, Champion Bay, Victoria district. Collector and date of collection unknown.
65.1142–4	Locality and collector unknown, presumed from Geraldton district.
65.1145	Waggrakine Cutting, near Geraldton. P. van Bladel, 1963.
65.1146–9	Moonyoonooka near Geraldton, about 600 ft above sea level. Mrs I. Grant, Moonyoonooka, 10.vi.1960.
65.1175, 6	Found in collection without label. Presumed to be from the Geraldton district.
65.1183, 1–6	Waggrakine via Geraldton. From caves near the road to Nanson. R. Gerritsen, M. de Graaf, Oct. 1965.
65.1184	Waggrakine via Geraldton. Caves near the Geraldton-Nanson road. R. Gerritsen, M. de Graaf, Oct. 1965.
65.1185, 7	Waggrakine via Geraldton. From caves near the road to Nanson. R. Gerritsen, M. de Graaf, Oct. 1965.
65.1194–9	Waggrakine via Geraldton. From caves near the road to Nanson. R. Gerritsen, M. de Graaf, Oct. 1965.
65.1201, 7, 9, 14	Waggrakine via Geraldton. From caves near the road to Nanson. R. Gerritsen, M. de Graaf, Oct. 1965.

66.58, 64, 68, 75	Waggrakine via Geraldton. From caves near the road to Nanson. R. Gerritsen, Dec. 1965.
66.108, 83, 87	Waggrakine via Geraldton. From caves near the road to Nanson. R. Gerritsen, Dec. 1965.
66.303, 1–4, 6, 9	Waggrakine via Geraldton. Cliff 1 mile S of cutting on the road to Nanson. M. de Graaf, Dec. 1965. Site reference 4059 (Playford, 1959, pl. 4).
66.313, 4, 9	Waggrakine via Geraldton. Cliff 1 mile S of cutting on the road to Nanson. M. de Graaf, Dec. 1965. Site reference 4059 (Playford, 1959, pl. 4).
66.324, 6, 7, 33	Waggrakine via Geraldton. Cliff 1 mile S of cutting on the road to Nanson. M. de Graaf, Dec. 1965. Site reference 4059 (Playford, 1959, pl. 4).
67.473	Waggrakine via Geraldton. 1 mile S of road to Nanson on W face of hills. From talus slope below outcrop. G. W. Kendrick, 10.vi.1966. Site reference Playford (1959, pl. 4) 588397.
67.482, 92, 95, 96	Waggrakine via Geraldton. 1 mile S of road to Nanson on W side of hills, from outcrop 3 ft below laterite. R. Gerritsen, G. W. Kendrick, 8.iv.1966. Site reference Playford (1959, pl. 4) 588397.
67.497	Approx. 1 mile NW of Mount Fairfax, via Geraldton. W face of hills. R. Gerritsen, 1966.
68.1213.5	Bringo, via Geraldton. Side of railway cutting. G. W. Kendrick, 7.ix.1968.
70.1379	Moonyoonooka near Geraldton, c. 600 ft above sea level. Mrs I. Grant, presented 10.vi.1960.
124	Greenough Flats, W.A.
156	Champion Bay, W.A. H. P. Woodward's 2nd Collection.
168	Moresby Flat Topped Range, Champion Bay, W.A.
169	Champion Bay, Moresby Flat Topped Range, 600 ft above sea level.
170	Moonyoonooka, near Geraldton, W.A. Presented by the Government Geologist, 23.ix.1899.
2077	Greenough River district. Date of accession, 1.iv.1913.
4954	Railway cutting, Grant's, near Geraldton. Collected by L. Glauert, accessed September 1926.
4966	New Fossil Hill. Collected by L. Glauert, accessed Sept. 1926.
4972	New Fossil Hill. Collected by L. Glauert, accessed Sept. 1926.
4978, 9	Round Hill, Newmarracarra. Collected by L. Glauert, accessed Sept. 1926.
5010	NE corner of Horse Hill paddock. Collected by L. Glauert, accessed Sept. 1926.
5011	1 mile SW of Round Hill (Hill No. 8). Collected by L. Glauert, accessed Sept. 1926.
5012 to 5014	Newmarracarra. Collected by L. Glauert, accessed Sept. 1926.
7544	Pipeline on hilltop halfway between Eradu and Northern Gully. Collected by S. Baldwin, accessed 25.v.1934.

Bureau of Mineral Resources

SKS7	Mount Hill, Geraldton area, W.A. Kojarena Sandstone. Collected by S. K. Skwarko, 26.v.1966.
SKS8	Mount Hill, Geraldton area, W.A. Newmarracarra Limestone. Collected by S. K. Skwarko, 26.v.1966.
SKS9	Bringo Cutting, Geraldton area, W.A. Kojarena Sandstone. Collected by S. K. Skwarko, 27.v.1966.

Queensland Museum (QM)

F5595, 8, 9	?Newmarracarra Limestone.
F5600, 2, 3, 6	?Newmarracarra Limestone.

University of Tasmania (UT)

20025	Newmarracarra Limestone. Geraldton, W.A.
20241	Newmarracarra Limestone. Geraldton, W.A.
20271, 6	Newmarracarra Limestone. Geraldton, W.A.
20282	Newmarracarra Limestone. Geraldton, W.A.
21507	Newmarracarra Limestone, Geraldton, W.A.
21755, 66	Newmarracarra Limestone. Geraldton, W.A.
21772, 9	Newmarracarra Limestone. Geraldton, W.A.
21782, 3, 4, 7, 9	Newmarracarra Limestone. Geraldton, W.A.
21790	Newmarracarra Limestone. Geraldton, W.A.
21808, 16	Newmarracarra Limestone. Geraldton, W.A.

Geological Survey of Western Australia (GSWA)

F62	Greenough River district.
F62A/1, 5, 7–26, 28	Tibradden station, Greenough River district. Collected W. D. Campbell.
F62 B/1–4	2 miles east of Moonyoonooka Railway Station, Greenough River district. Collected W. D. Campbell.
F62 C/1–42	Sandspring station, Greenough River district. Collected W. D. Campbell.
F62 D/1–3	Snake Farm, Greenough River district. Collected W. D. Campbell.
F62G	Lycett, ¼ mile NW of Woolanooka, Greenough River.
F64 A/1–4, 8, 9	Tibradden station, Greenough River district. Collected W. D. Campbell.
F64B	2 miles E of Moonyoonooka Railway Station, Greenough River district. Collected W. D. Campbell.
F64 C/1, 2	Sandspring station, Greenough River district. Collected W. D. Campbell.
F64E	½ mile N of Woolanooka, Greenough River district. Collected W. D. Campbell.
F65 A/1–3	Tibradden station, Greenough River district. Collected W. D. Campbell.
F65 C/3	Sandspring station, Greenough River district. Collected W. D. Campbell.
F66 A/1, 2	Tibradden station, Greenough River district. Collected W. D. Campbell.
F66 C/1	Sandspring station, Greenough River district. Collected W. D. Campbell.
F66D	Snake Farm, Greenough River district. Collected W. D. Campbell.
F68 B/1	2 miles E of Moonyoonooka Railway Station, Greenough River district. Collected W. D. Campbell.
F68C	Sandspring station, Greenough River district. Collected W. D. Campbell.
F70 A/1–3	Tibradden station, Greenough River district. Collected W. D. Campbell.
F70 B/1	2 miles E of Moonyoonooka Railway Station, Greenough River district. Collected W. D. Campbell.
F70 C/1–3	Sandspring station, Greenough River district. Collected W. D. Campbell.
F70 D/1	Snake Farm, Greenough River district. Collected W. D. Campbell.
F74 B	2 miles E of Moonyoonooka Railway Station, Greenough River district. Collected W. D. Campbell.
F74 C/1	Sandspring station, Greenough River district. Collected W. D. Campbell.
F75 A	Tibradden station, Greenough River district. Collected W. D. Campbell.
F75 B/1	2 miles E of Moonyoonooka Railway Station, Greenough River district. Collected W. D. Campbell.
F75 C	Sandspring station, Greenough River district. Collected W. D. Campbell.

F76 A/1, 2	Tibradden station, Greenough River district. Collected W. D. Campbell.
F76 D/1, 2, 3	Snake Farm, Greenough River district. Collected W. D. Campbell.
F78 C/1–3	Sandspring station, Greenough River district. Collected W. D. Campbell.
F78 F	
F80 B/2	
F80 C/1	Sandspring station, Greenough River district. Collected W. D. Campbell.
F81 C/1	Tibradden station, Greenough River district. Collected W. D. Campbell.
F85/1, 2	Head of Greenough River, ½ mile S of 15½-mile post, Geraldton-Cue railway line. Collected T. Blotchford.
F86/1	Head of Greenough River, ½ mile S of 15½-mile post, Geraldton-Cue railway line. Collected T. Blotchford.
F88/1, 3–5	Head of Greenough River, ½ mile S of 15½-mile post, Geraldton-Cue railway line. Collected T. Blotchford.
F89/1	Head of Greenough River, ½ mile S of 15½-mile post, Geraldton-Cue railway line. Collected T. Blotchford.
F91/1	Head of Greenough River, ½ mile S of 15½-mile post, Geraldton-Cue railway line. Collected T. Blotchford.
F92/1, 2	Head of Greenough River, ½ mile S of 15½-mile post, Geraldton-Cue railway line. Collected T. Blotchford.
F95	Head of Greenough River, ½ mile S of 15½-mile post, Geraldton-Cue railway line. Collected T. Blotchford.
F393/1–4	Mount Hill, E of Bookara. Collected W. D. Campbell.
F395/1, 2	Mount Hill, E of Bookara. Collected W. D. Campbell.
F399	Greenough, Loc. 1854 near Woolanooka. Collected W. D. Campbell.
F400/1–3	Greenough, Loc. 1854 near Woolanooka. Collected W. D. Campbell.
F401/1–3	Greenough, Loc. 1854 near Woolanooka. Collected W. D. Campbell.
F406	Mount Hill, NW side of summit above main limestone zone near iron-stone lode. Collected W. D. Campbell.
F407/2, 3	Mount Hill, NW side of summit above main limestone zone near iron-stone lode. Collected W. D. Campbell.
F408	Mount Hill, NW side of summit above main limestone zone near iron-stone lode. Collected W. D. Campbell.
F410/1, 2	Mount Hill, limestone zone. Collected W. D. Campbell.
F411/1–3	Mount Hill, limestone zone. Collected W. D. Campbell.
F412/1–2	Mount Hill, limestone zone. Collected W. D. Campbell.
F414/1	Mount Hill, limestone zone. Collected W. D. Campbell.
F415/1, 2, 3	Mount Hill, limestone zone. Collected W. D. Campbell.
F416/3–8	Mount Hill, limestone zone. Collected W. D. Campbell.
F5025B	
F5029/1, 2	Bringo cutting, 15 miles E of Geraldton. Collected A. D. Allen, 1962.
F5032 A, D, E, F, H	Moonyoonooka station, Loc. 2. Collected A. D. Allen, 1962.
F5033 C	Moonyoonooka station, Loc. 2. Collected A. D. Allen, 1962.
F5035 A	Moonyoonooka station, Loc. 2. Collected A. D. Allen, 1962.
F5036	Moonyoonooka station, Loc. 1. Collected A. D. Allen, 1962.
F5039 A, C, D	Moonyoonooka station, Loc. 1. Collected A. D. Allen, 1962.
F5041	Moonyoonooka station, Loc. 1. Collected A. D. Allen, 1962.
F5566	
F5585	
F5594	
F5910/1–8	Round Hill. Collected G. Low, 1965.
F5911/1, 2, 3, 7, 12, 15	Fossil Hill. Collected G. Low, 1965.

F5912/1–24	Mount Hill. Collected G. Low, 1965.
F5916	Champion Bay district. Collected F. C. B. Vasper.

Geology Department, University of Western Australia (UWA)

11494	Geovil district. Collected E. de C. Clarke, 1933.
16146	Geraldton-Cue railway, 19½ miles from Geraldton.
16623	Mount Hill, W.A., SW of Geraldton. Collected E. de C. Clarke, 1936.
23544	Fossil Hill, Newmarracarra. Collected students prior 1938.
23564, 1–5	Geraldton-Cue railway, 19½ miles from Geraldton. Collected students prior 1938.
23603	No. 1 Well, Newmarracarra. Collected students prior 1938.
23605	Fossil Hill, Newmarracarra. Collected students prior 1938.
23607	Sandy facies of Trigonia Beds. Newmarracarra. Collected students prior 1938.
23651	Mount Hill, Newmarracarra. Collected students prior 1938.
36026	Geraldton area 96 chains at 135° from Bringo. Newmarracarra Limestone. Collected P. E. Playford, 1952-3.
36033	96 chains at 135° from Moonyoonooka homestead. Collected P. E. Playford, 1952-3.
36036	Bringo Cutting. Collected P. E. Playford, 1952-3.
36046	75 chains at 161° from Moonyoonooka homestead. Collected P. E. Playford, 1952-3.
36054	Geraldton area. Moonyoonooka station. Collected P. E. Playford, 1952-3.
37088	Bulk fossil sample. Newmarracarra limestone from the "Rabbit Burrow" Loc. 1 mile S of Bringo. Collected B. F. Glenister, 1956.
45292	Bringo Railway Cutting Loc. 1. Collected P. J. Coleman, 7.x.1960.
45300	40 chains SW of Bringo Cutting Loc. 2. Collected P. J. Coleman, 7.x.1960.
45301, 4	Newmarracarra Limestone. Bringo Cutting Loc. 2. Collected P. J. Coleman, 7.x.1960.
45302	Bringo Cutting Loc. 2. Collected P. J. Coleman, 7.x.1960.
45306 (new number 65180)	
47441, 3	Newmarracarra Limestone. Bringo Cutting Creek, flowing north about 300 yards SW of cutting. Collected P. J. Coleman, 3.i.1962.
47463, 1, 2, 3	Bringo Cutting. In gully SW of Bringo Cutting (Excursion Loc.). Collected B. E. Balme, 10.i.1962.
55051	
55053	
55054	Originally numbered 53326. Latex cast of valve anteriorly incomplete. P. 25, fig. 10. S. K. Skwarko and P. J. Coleman, 6.iv.1970.
53326	Mingenew, W.A. SW flank of Enanty Hill, 1 mile NE of Mingenew. Collected P. J. Coleman, 15.ix. 1964.
65180	

Australian Museum, Sydney (AMS)

F1537	Grenough River district, W.A. O.C. 1891.
F4547	"Western Australia".
F4683, 4	Railway Cutting 20 miles W of Geraldton, W.A. Pres. P. G. Black, 1897.
F6058, 62, 65	Moonyoonooka, near Geraldton, W.A. Pres. A. G. Maitland, 1899.
F6108/1–5	Hills S of Geraldton-Cue railway, 15¼ miles NE of Geraldton, W.A. Pres. A. G. Maitland, 1899.
F6111	Hills S of Geraldton-Cue railway, 15¼ miles NE of Geraldton, W.A. Pres. A. G. Maitland, 1899.

F6112, 1, 2	Hills S of Geraldton-Cue railway, 15¼ miles NE of Geraldton, W.A. Pres. A. G. Maitland, 1899.
F6119, 22, 24	Hills S of Geraldton-Cue railway, 15¼ miles NE of Geraldton, W.A. Pres. A. G. Maitland, 1899.
F13674	Tibradden station, Greenough River, W.A.
F13675–8	Tibradden station, Greenough River, W.A. Pres. A. G. Maitland, 1908.
F13681, 82	Tibradden station, Greenough River, W.A. Pres. A. G. Maitland, 1908.
F13684	Fossil Hill, 2 miles E of Moonyoonooka Railway Station, Greenough River, W.A.
F13685, 7–9	Sandspring station, Greenough River, W.A. Pres. A. G. Maitland, 1908.
F13690	Tibradden station, Greenough River, W.A. Pres. A. G. Maitland, 1908.
F13691, 2, 4–7	Sandspring station, Greenough River, W.A. Pres. A. G. Maitland, 1908.
F15266	Railway Cutting at 19¾ miles from Geraldton, Greenough River, W.A.

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PLATE 21

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

Figs 1–7 *Cucullaea semistriata* Moore, 1870.

1, 3. Internal and external views of left valve. WAM 66.339.

2. Anterior view of bivalve with valves in position. GSWA F65A/3. This is specimen of '*P. tibraddenensis* Etheridge Jnr, 1910' illustrated by Etheridge Jnr (1910, pl. 5, figs 3, 4).

4, 5. External and internal views of right valve. GSWA F5033C.

6, 7. Internal and exterior views of plaster copy of Moore's original specimen (Moore, 1870, pl. 14, fig. 3). The specimen itself is housed in the collections of British Museum (Natural History). Locality: "Shark Bay, W.A. Greenough River District", Newmarracarra Limestone.

Plate 21

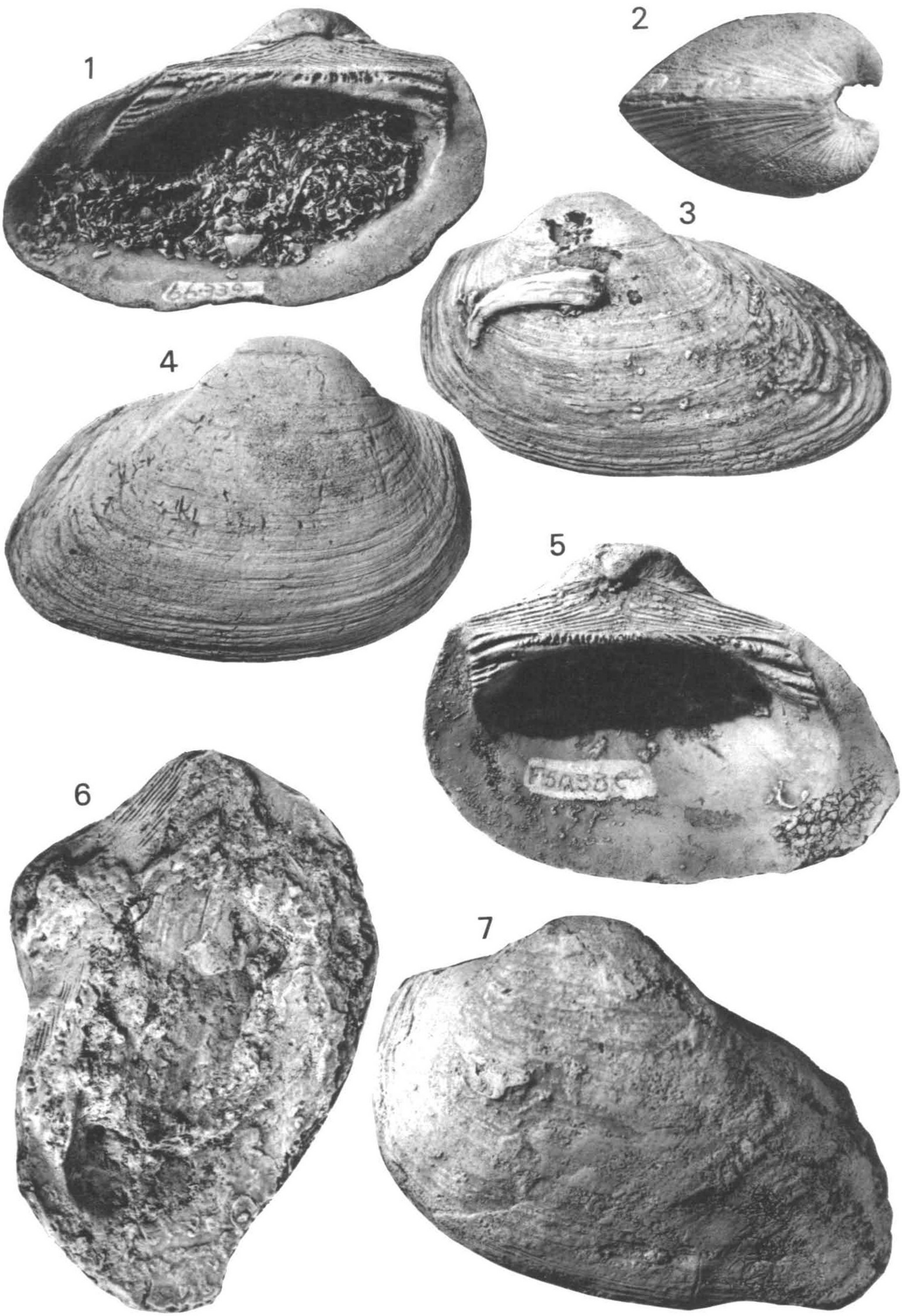

PLATE 22

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

Figs 1, 4, 5 *Cucullaea geraldtoni* sp. nov.
Holotype, GSWA F5911/7 in anterior, lateral, and dorsal view.
Newmarracarra Limestone.

Figs 2, 3 *?Cucullaea semistriata* Moore, 1870.
Immature? specimens in dorsolateral and lateral views. Ga 15 (x 1.7) and CPC 11375 respectively.
Newmarracarra Limestone.

Figs 6–8 '*Cucullaea inflata* Moore, 1870'.
6. Internal cast of bivalve with offset valves, one in oblique and other in end-on view. WAM 65.1197.
7, 8. Plaster copy of Moore's original specimen (Moore, 1870, Pl. 14, figs 1, 2). Original specimen lodged in British Museum (Natural History) collections. Locality "Shark Bay, Greenough River District, W.A."
Newmarracarra Limestone and Kojarena Sandstone.

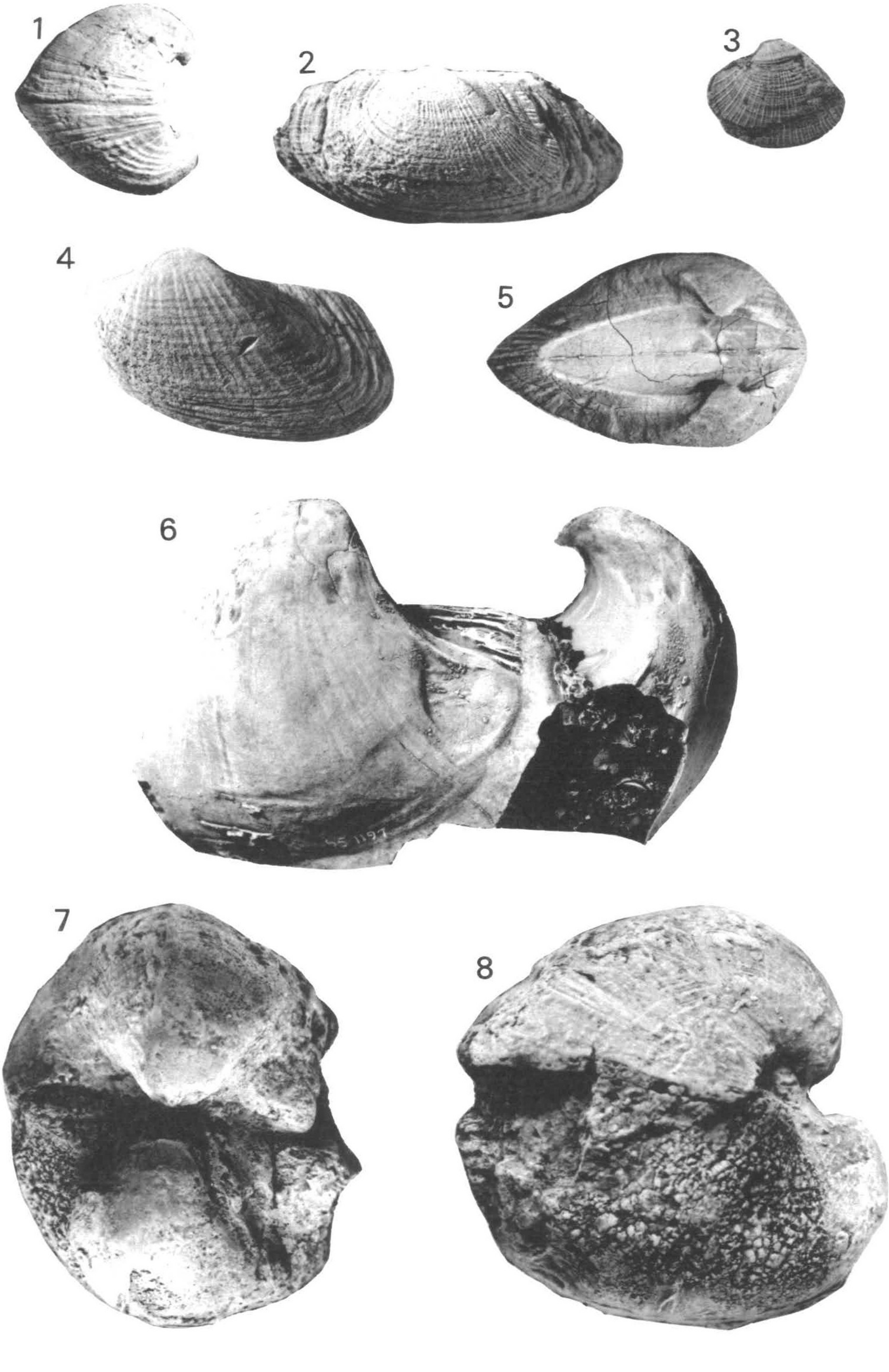
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PLATE 23

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

Figs 1–9 Parallelodontidae spp.
1. Left valve. GSWA F5910/9.
2, 3. Left valve in internal and exterior views. WAM 67.473.
4–6. Mature posteriorly incomplete and abraded specimen in dorsal, internal, and external views. WAM 67.492.
7–9. Anterior portion of mature specimen showing detail of structure. GSWA F5041.
Newmarracarra Limestone.

Figs 10–14 *Grammatodon* (*Indogrammatodon*) *carnarvoni* sp. nov.
10. Paratype, CPC 11376. Latex cast of dentition of almost mature specimen.
11. Paratype, CPC 11377. Latex cast of external impression of immature left valve.
12. Latex cast of incomplete external impression of mature left valve. CPC 11378.
13. Latex cast of anterior portion of impression of juvenile right valve.
CPC 11379.
14. Holotype, Locality SKS 7. GSWA F406. Latex cast of external impression of bivalve with offset valves, one in lateral view, other in dorsal view. Kojarena Sandstone.

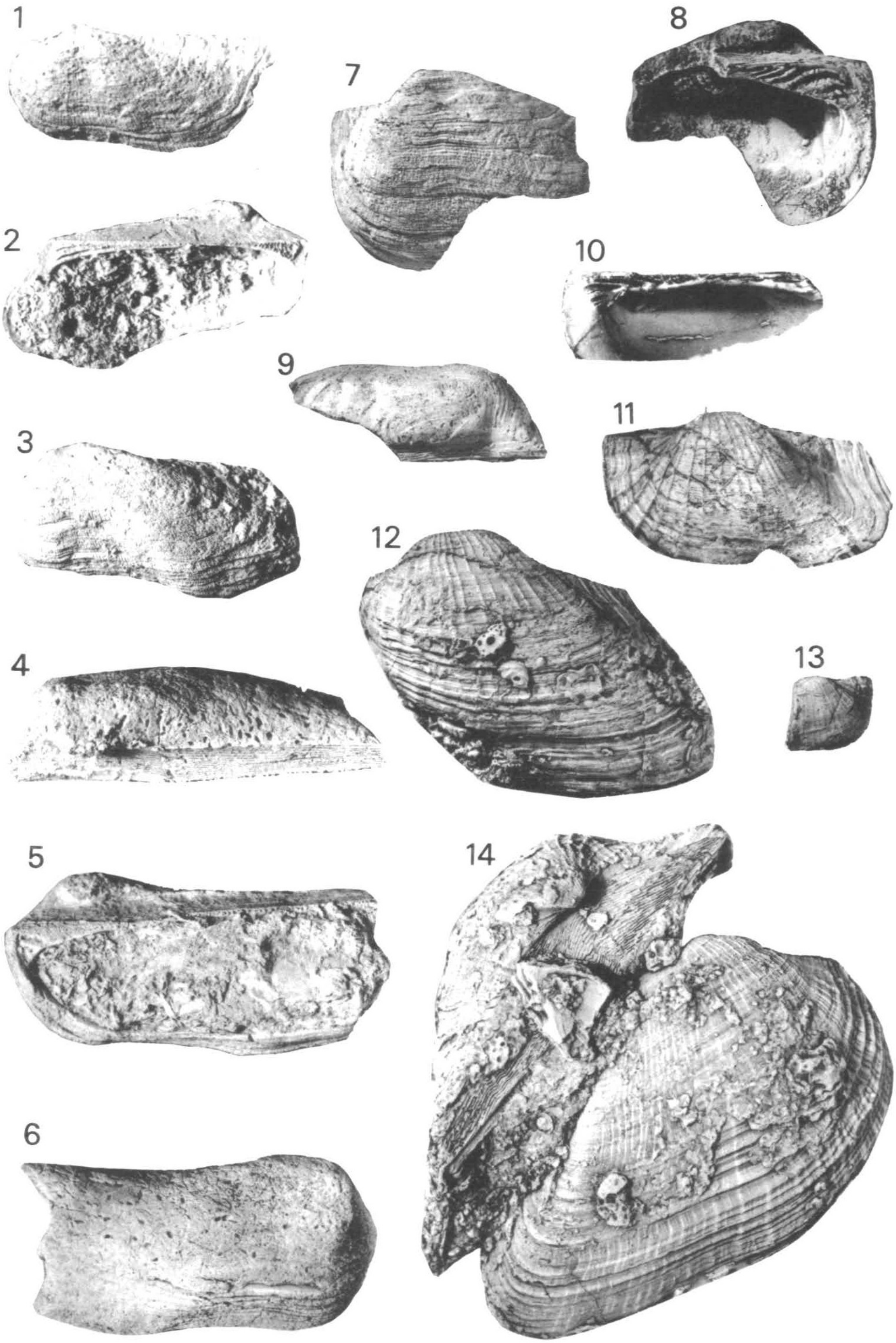
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PLATE 24

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

Figs 1–8	*Oxytoma decemcostata* Whitehouse, 1924. 1, 6. Dorsal, and lateral views of two left valves. Locality not known. CPC 11833. 2. Detail of sculpture on posterior wing of left valve. WAM 66.324a. 3. Anteriorly incomplete left valve. WAM 65.1175. 4. Left valve. WAM 65.1117. 5. Inside of right valve. Locality not known (specimen located on same cobble as specimens in figs 1, 6). CPC 11384. 7, 8. Inside of left valves. UWA 37088 (new number 65 179) and WAM 60.2 respectively, x2. Newmarracarra Limestone.
Figs 9, 10	*Pseudolimea duplicata* (J. de C. Sowerby, 1827). 9. Right valve, x2. WAM 65.1107. 10. Left valve, x2. GSWA F78C/2. Newmarracarra Limestone.
Figs 11–13	*Plagiostoma championi* sp. nov. 11. Holotype, WAM 4972. Left valve. 12, 13. Paratype, GSWA F68B/1. Right valve in anterodorsal and lateral views. Newmarracarra Limestone.
Fig. 14	*Modiolus* (*Modiolus*) *maitlandi* Etheridge Jnr, 1910. Left valve of holotype in lateral view. GSWA F75A. Newmarracarra Limestone.

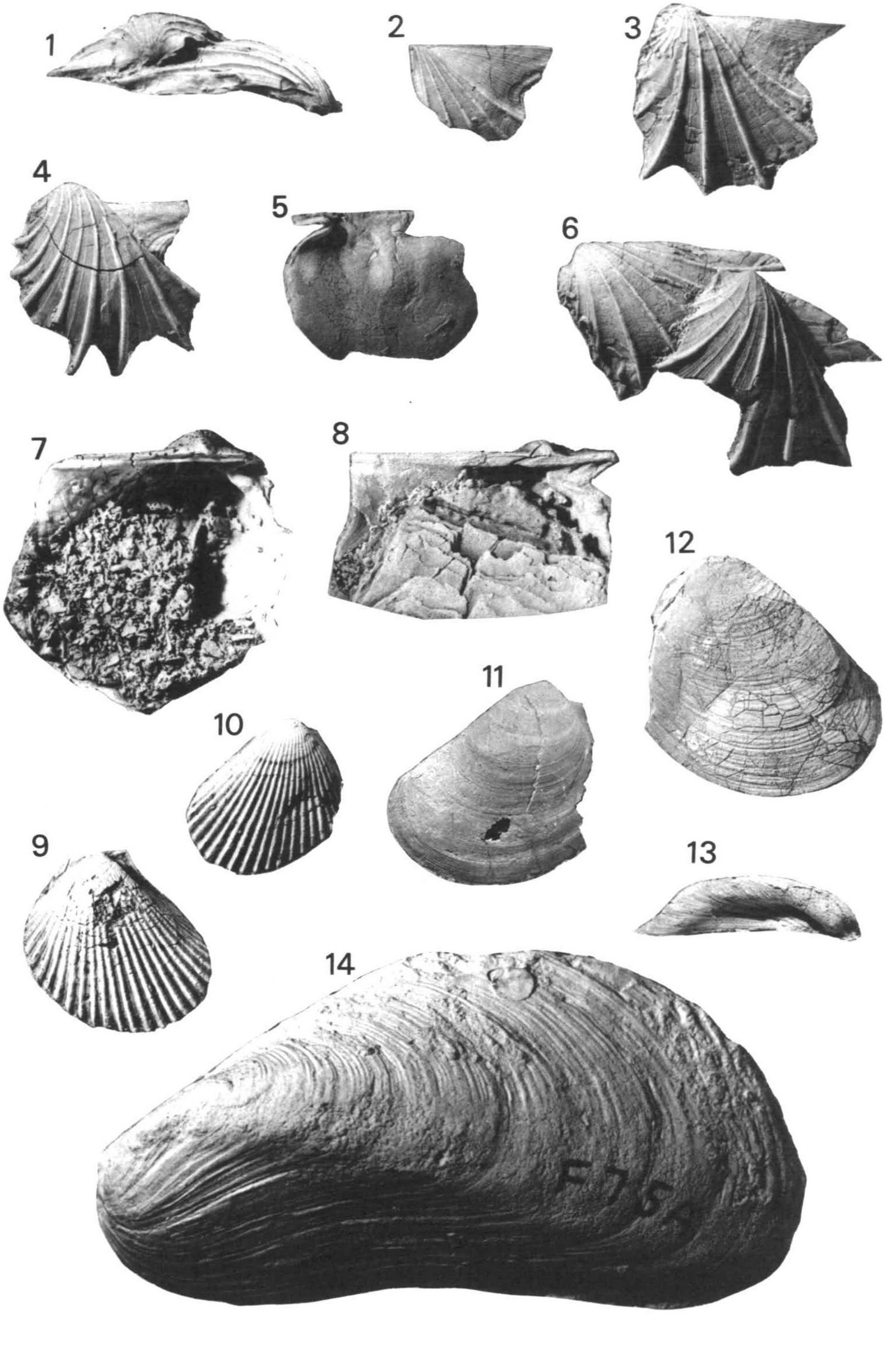
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PLATE 25

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

Figs 1, 4, 10 — *Camptonectes waggrakinensis* sp. nov.
1. Holotype, UWA 45306 (new number 65180). Right valve in lateral view. x$\frac{1}{2}$.
4. Paratype, WAM 66.297. Interior of proximal portion of right valve.
10. Paratype, WAM 65.1099. Left valve in lateral view. x$\frac{1}{3}$.

Fig. 2 — *Isognomon* (*Isognomon*) sp.
Internal view of distally incomplete right valve. WAM 66.311. Newmarracarra Limestone.

Figs 3, 7 — 'Nuculid' indet.
Internal cast and latex cast of part of dentition of right valve. UT 21816. Newmarracarra Limestone.

Figs 5–9 — *Amphidonta* cf. *tholiformis* (Etheridge Jnr, 1910).
5, 6, 8. Various views of several valves of attachment on belemnite guard. WAM 68.1213.
9. More mature specimen attached to *T. moorei*. UWA 16146. Newmarracarra Limestone.

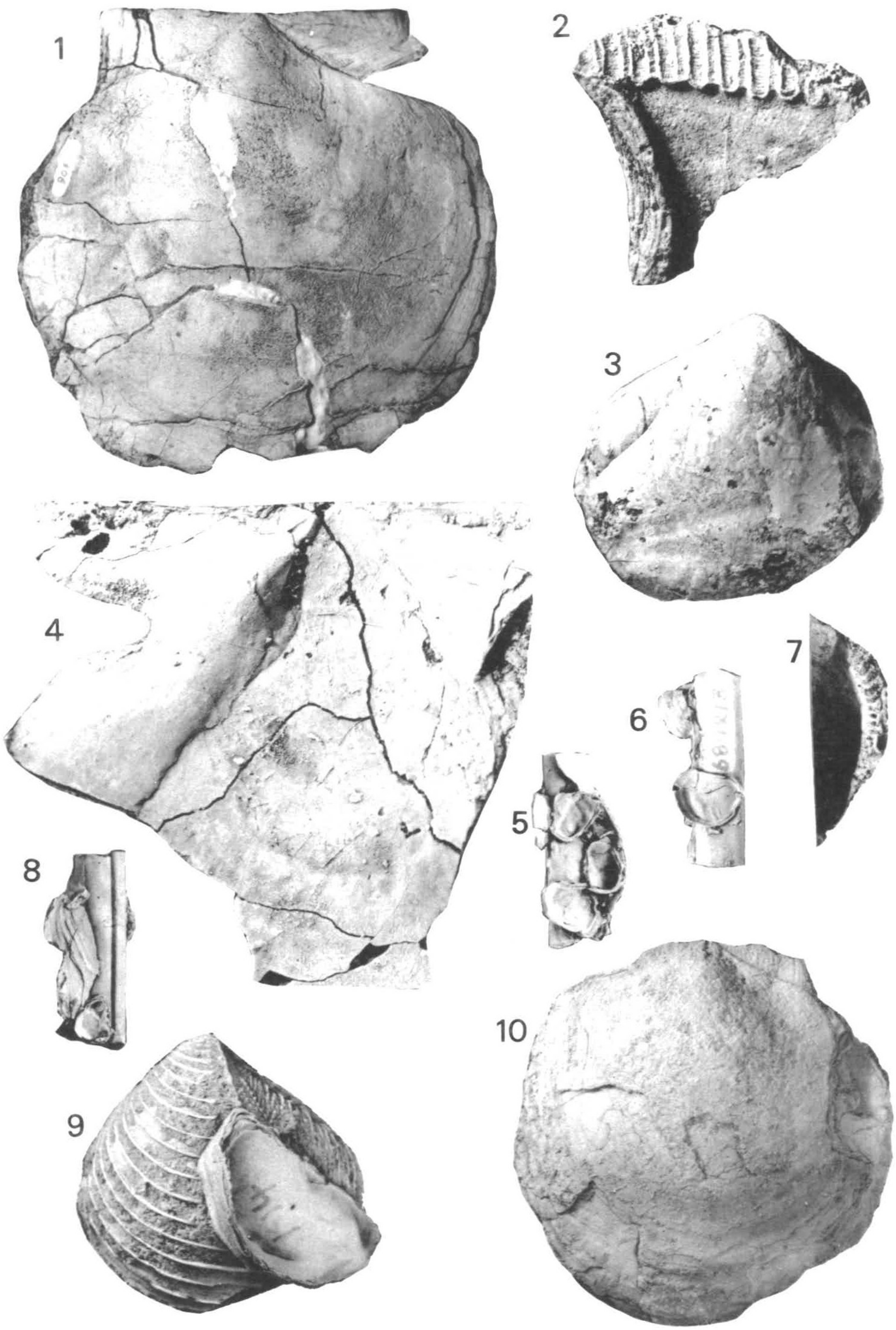
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PLATE 26

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

Figs 1, 6, 12	*Chlamys enantyi* sp. nov. 1. Detail of ornamentation. x3. UWA 55051. 6. Holotype, WAM 67.482. Incomplete valve. 12. Internal cast of ?left valve. UWA 55053. Newmarracarra Limestone.
Figs 2, 3	*Propeamussium (Parcamussium?) geelvinki* sp. nov. Holotype, WAM 66.108. Right valve, x1.7. 3. Paratype, WAM 67.495. Left(?) valve, x1.7. Newmarracarra Limestone.
Figs 4, 5	*Falcimytilus* sp. Internal and external impression of right valve. CPC 11380. Locality SKS9. Kojarena Sandstone.
Figs 7–9	*Gryphaea* sp. indet. Anterior and lateral views of inflated valve; and lateral view of concave valve. UT 21764. Newmaracarra Limestone.
Fig. 10	*Camptonectes* cf. *rigidus* (Sowerby, 1821). Latex cast of external impression of incomplete right valve. CPC 11381. Locality SKS7. Kojarena Sandstone.
Figs 11, 13–17	*Camptonectes greenoughi* sp. nov. ?11. Latex cast of posteroventrally incomplete internal impression of right valve. CPC 11382. Locality SKS7. 13, 14. Left and right valve, somewhat incomplete. WAM 67.497. 15. Distally incomplete right valve WAM 4966. 16. Latex cast showing detail of ornament, x2. UWA 55056. 17. Latex cast of anteriorly incomplete external impression of right valve. UWA 55054. Newmarracarra Limestone.

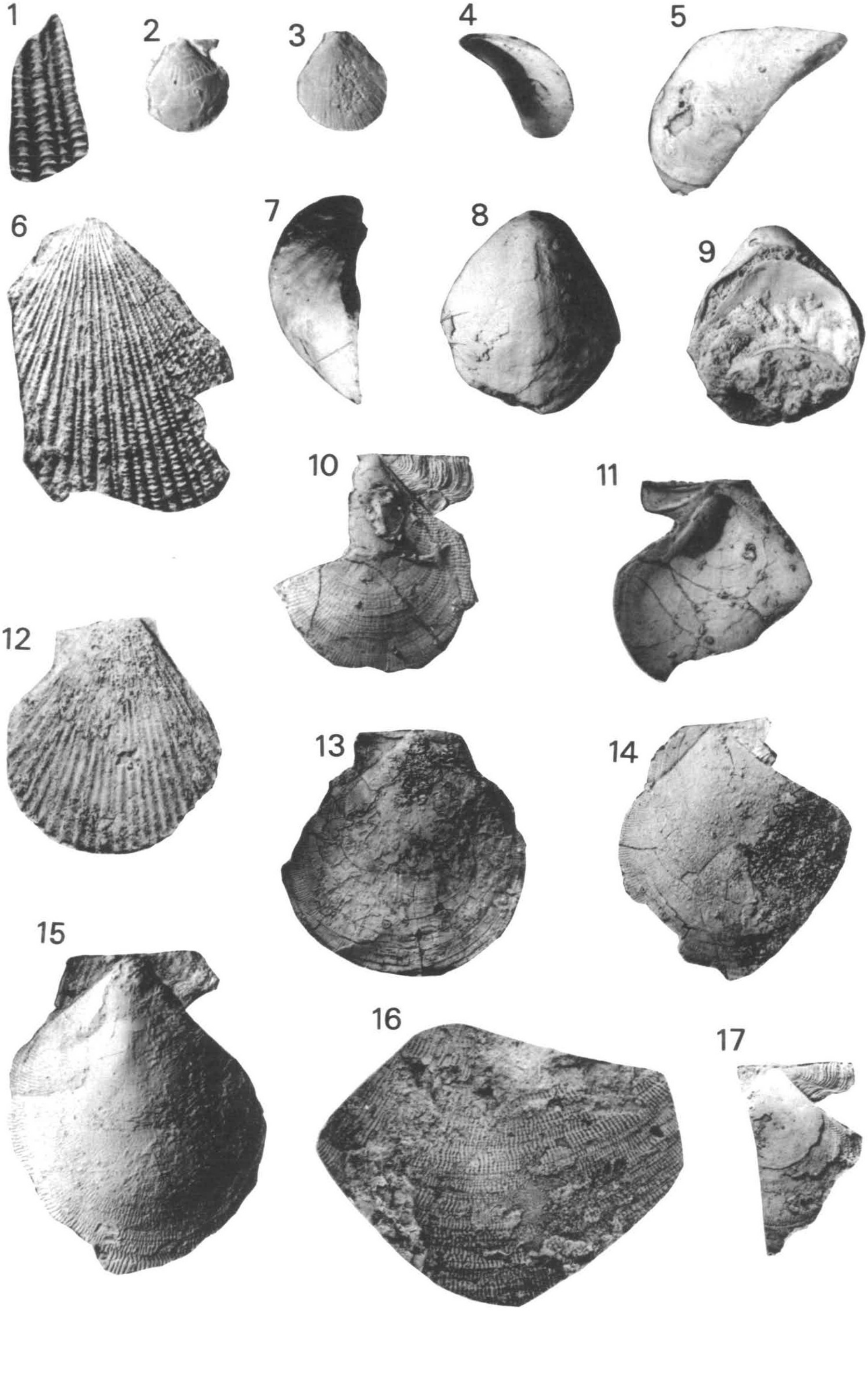
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PLATE 27

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

Figs 1–6 *Ctenostreon pectiniformis* (Schlotheim, 1812).

1, 2. Exterior and internal lateral view of left valve (also illustrated by Etheridge, 1901, pl. 3), x½. AMS F4547.

3, 5, 6. Lateral views of left and right valve (x½), and anterior view of both valves slightly offset (x1). UWA 37088 (new number, 65181).

4. Right? valve in lateral view. WAM 70.1379, x½. Newmarracarra Limestone.

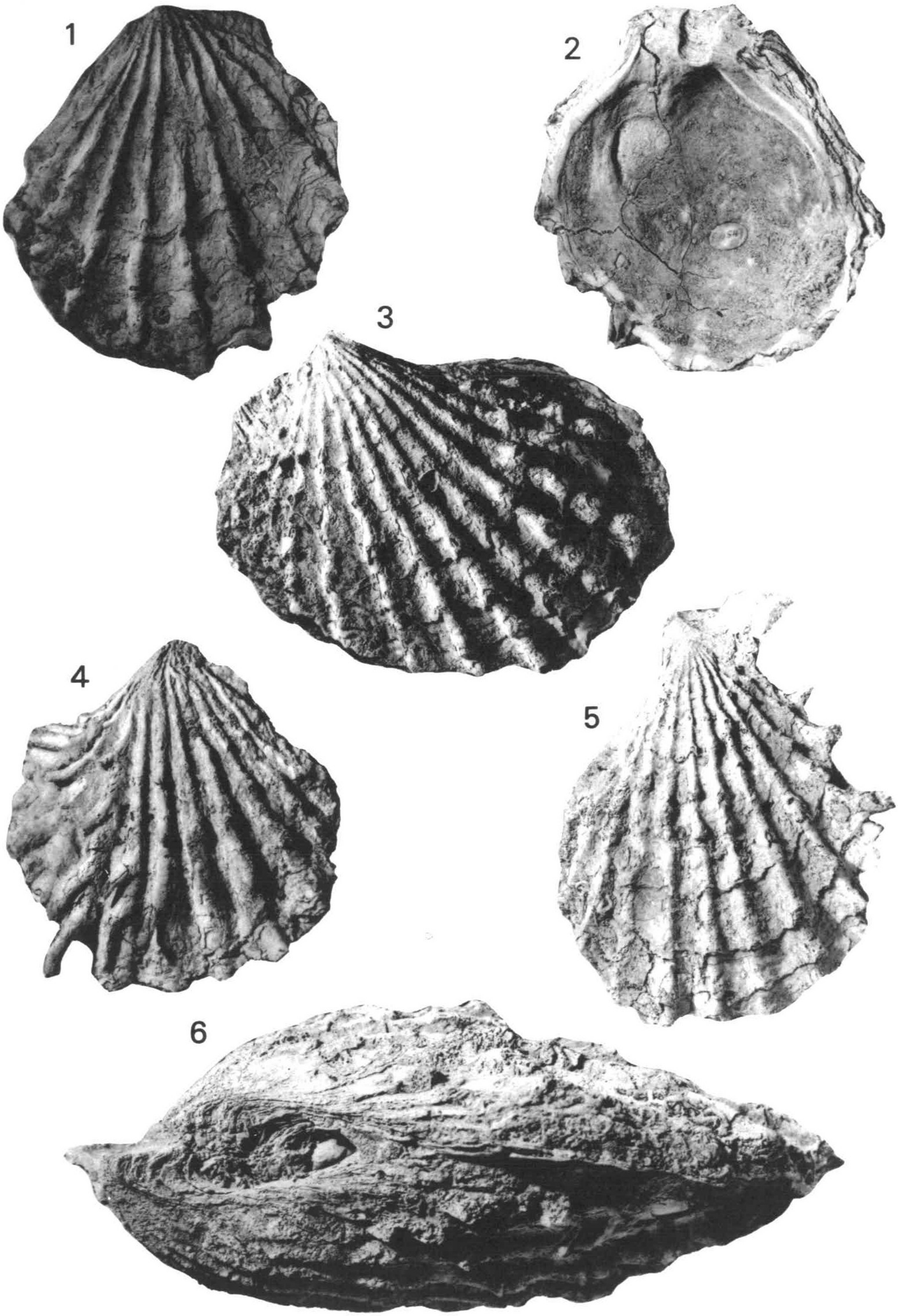

PLATE 28

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

Figs 1–3, ?4, 5, ?6, 7–9, 12 *Amphidonta tholiformis* (Etheridge Jnr, 1910).

1, 7. Left and right valve of same bivalve in external view. UWA 37088 (new number, 65184).
2, 8. Lectotype. Left and right valve of same bivalve in external view. GSWA F70A/1.
3. Left valve. GSWA F70A/1.
?4, ?6. Left valve in external and internal view. UWA 23605 (new number. 65183).
5. Left valve. GSWA F70A/2.
9, 12. Right valve in external and internal view. UWA 23603 (new number 65182). Newmarracarra Limestone.

Figs 10, 11 *Ostrea* sp.
Right valve in external and internal views. GSWA F70A/1. Also illustrated by Etheridge Jnr (1910, pl. 7, figs 2, 3). Newmarracarra Limestone.

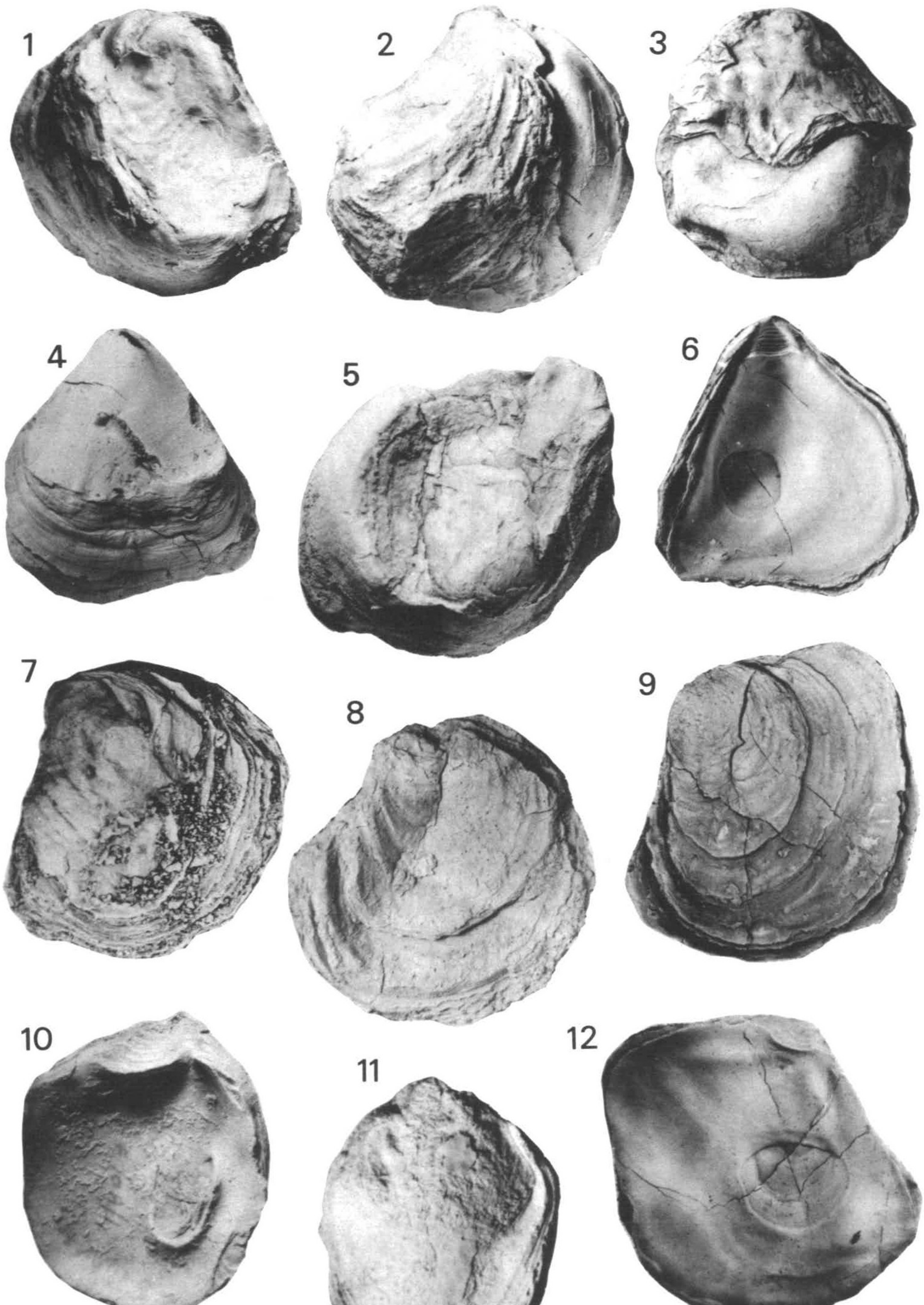
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PLATE 29

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

Figs 1–4 *?Amphidonta tholiformis* (Etheridge Jnr, 1910).
1, 4. Right valve in internal and external views. GSWA F70A.
2, 3. Left valve in external and internal views. GSWA F400/2. Newmarracarra Limestone.

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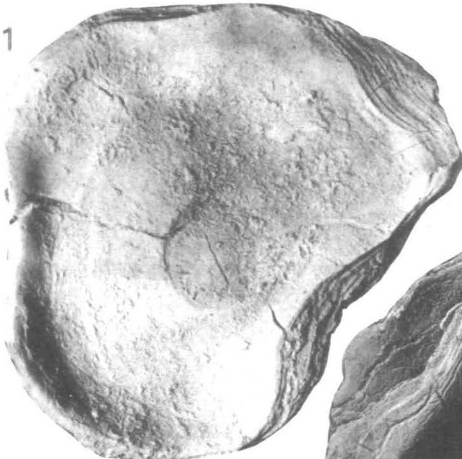

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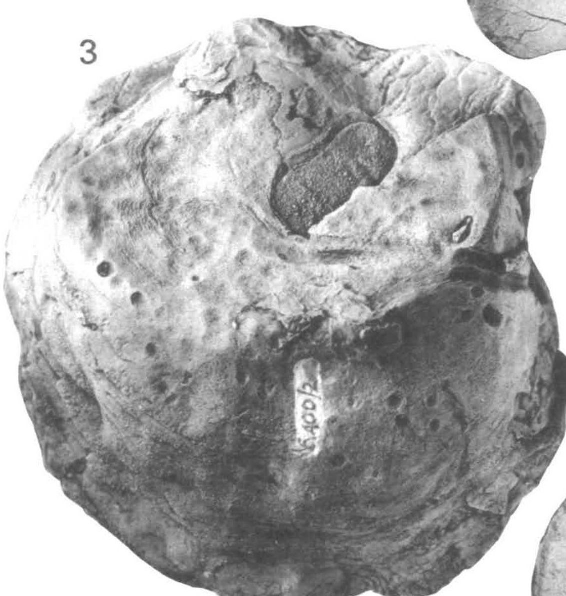

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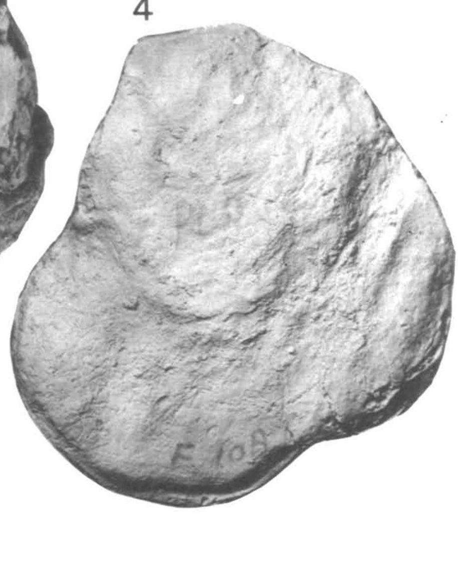

PLATE 30

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

Figs 1–6 *Lopha marshii autsraliensis* subsp. nov.

1, 2. Right and left valve of same bivalve in outside view. WAM 63.118.

3. Interior of left valve. GSWA F66A/1.

4. Interior of mature left valve. UWA 45289 (new number, 65185).

5, 6. Left valves in external view. GSWA F5910/3 and Q.M.? F5594. Newmarracarra Limestone.

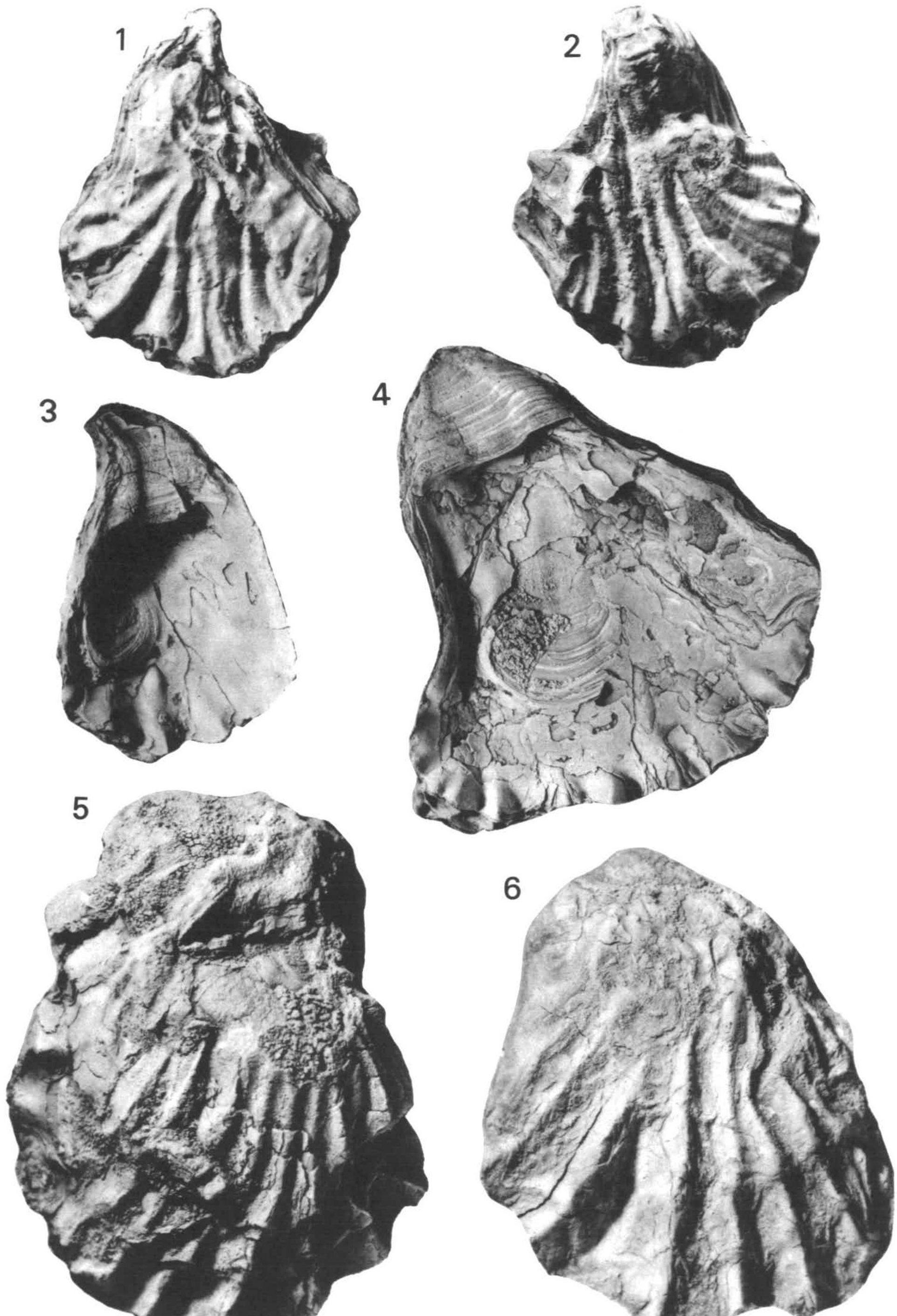
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PLATE 31

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

Figs 1–7 *Lopha marshii nanutarraensis* subsp. nov.

1, 3. External views of both valves of single specimen. New registration number UWA 65186.

2, 4. Internal and external view of young left valve. New registration number UWA 65187.

5. Internal view of immature left valve. New registration number UWA 65188.

6, 7. External and internal view of mature left valve. New registration number UWA 65189.

All specimens bearing registration number UWA 36054. Newmarracarra Limestone.

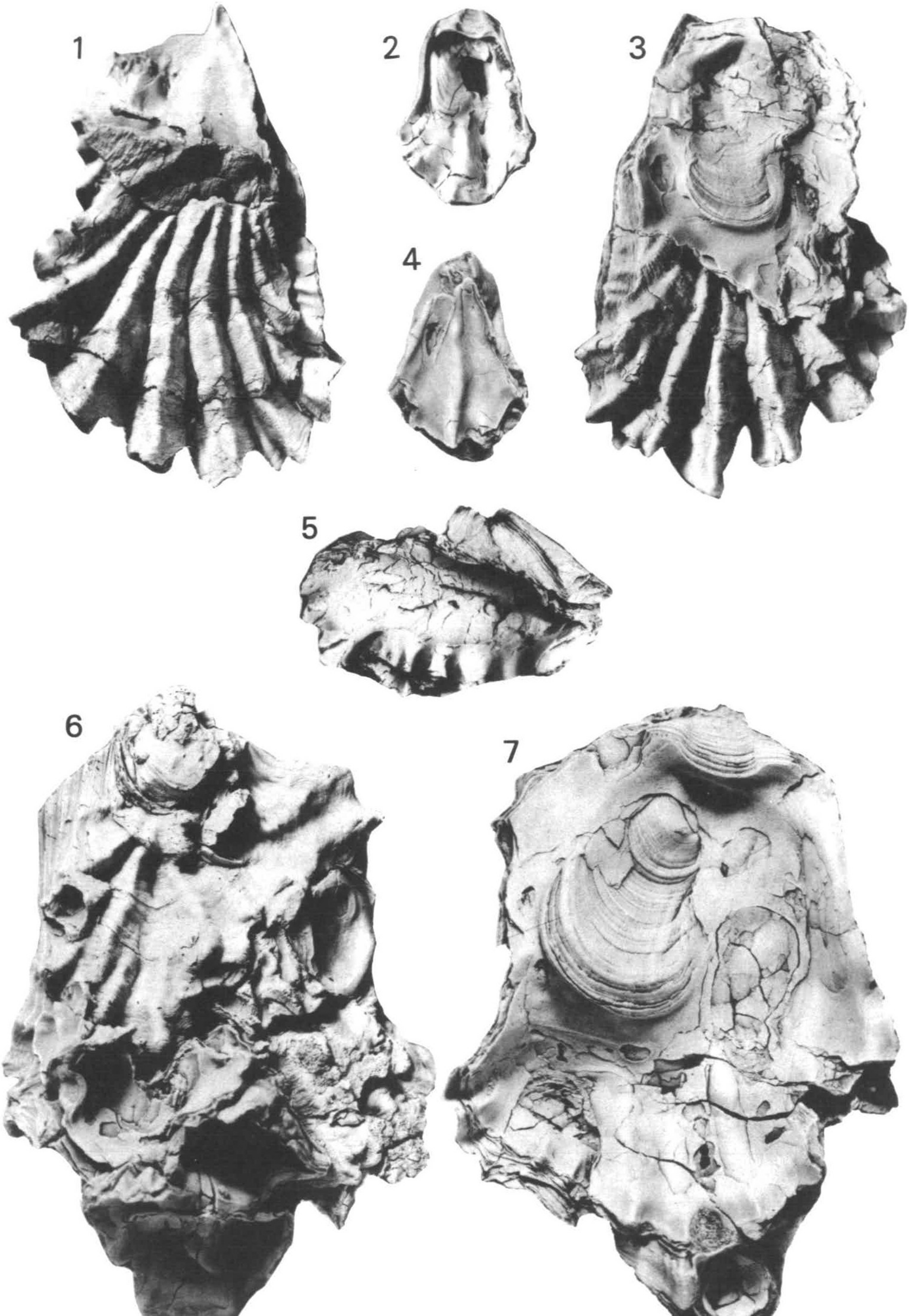
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PLATE 32

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

Figs 1, 4, 6–9 *Meleagrinella sinuata* (Teichert, 1940).
1, 4. External and internal aspect of right valve. UWA 36036 (new registration number, 65190).
6, 9. External and internal views of left valve. UWA 45292 (new registration number, 65191).
7, 8. External and internal views of right valve. WAM 68.1224.
Newmarracarra Limestone.

Figs 2, 3, 5, 10–12 *Gresslya sanfordii* (Moore, 1870).
2, 3, 5. Dorsal, anterior, and lateral view of immature bivalve. Locality unknown.
10–12. Holotype, Brit. Mus. (Nat. Hist.). 'Shark Bay, W.A.' Plaster copy in three views. Newmaracarra Limestone.

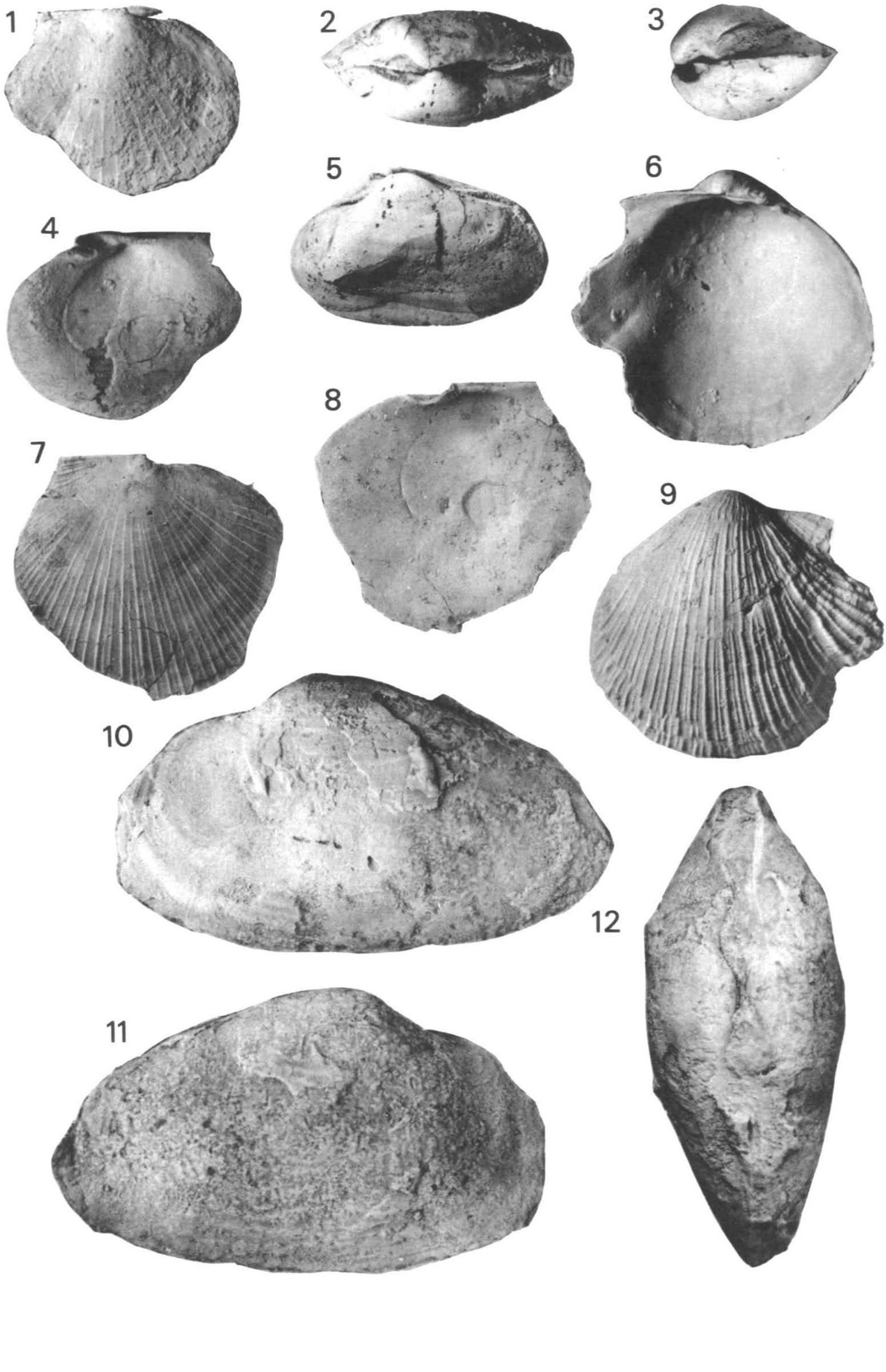
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PLATE 33

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

Figs 1–7 *Trigonia moorei* Lycett, 1870.
1, 2, 4. Right valve in dorsal, lateral, and internal view. WAU 45300.1 (new registration number, 65192).
3. Left valve. GSWA F5032g.
5. View of dentition of both valves. GSWA F621/2.
6, 7. Plaster copy of holotype. Fig. 7 is one of two figures which accompany Lycett's original description of species in Moore (1870, pl. 14, fig. 9). Original lodged in the collection of the British Museum (Nat. Hist.). 'Greenough River District, W.A.' Newmarracarra Limestone. Also occurs in the Kojarena Sandstone.

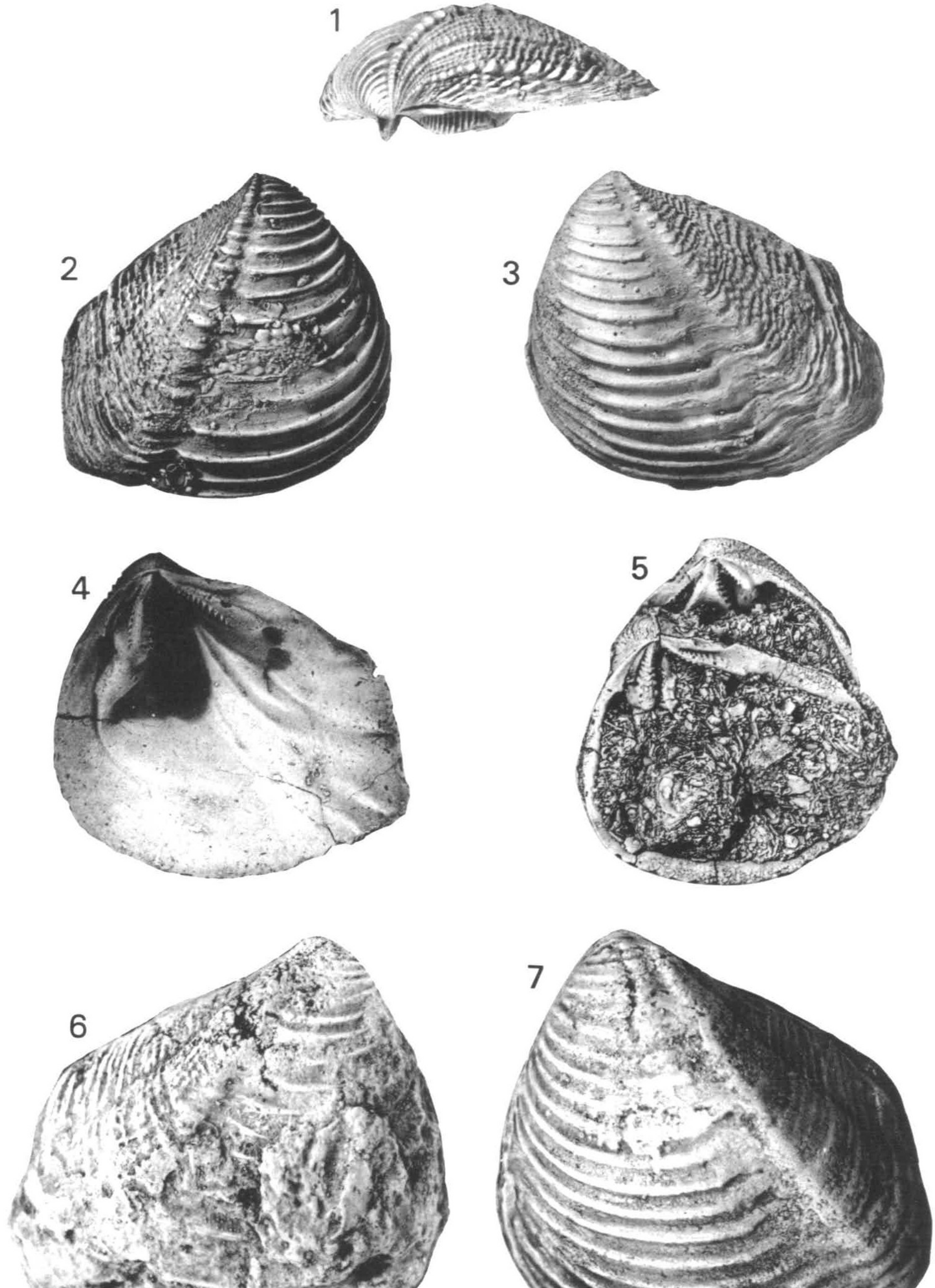
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PLATE 34

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

Figs 1–4, 10–13, 15, 16	*Astarte (Astarte) cliftoni* Moore, 1870. 1–3. Latex cast of proximal portion of left valve in external, dorsal, and internal view. Locality SKS9. x1.7. 4, 11. Internal and external views of left valve. GSWA F417/2. 10, 12, 13. Plaster copy of lectotype in anterodorsal, lateral, and posterodorsal views. (Original at the British Museum [Nat. Hist.]) 15, 16. Left valve in internal and external views. AMS F15266.
Figs 5–9	*Astarte (Astarte) apicalis* Moore, 1870. 5. Latex cast of external impression of right valve. CPC 11386. Locality SKS9. x1.7. 6. Latex cast of internal impression of right valve. CPC 11388. x1.7. 7. Latex cast of external impression of left valve. CPC 11389. x1.7. 8. Holotype?. British Museum (Nat. Hist.). x?5. Newmarracarra Limestone & Kojarena Sandstone.
Figs 14, 17–19	*Astarte (Astarte) tibraddeni* sp. nov. 14, 17. Right valve in internal and external views. UWA 36033 (new registration number, 65193). 18, 19. Left valve in external and internal views. UWA 36033 (new registration number 65194).
Fig. 20	*Martesia (Particoma) australis* (Moore, 1870). Plaster copy of holotype. Original held by British Museum (Nat. Hist.), London.

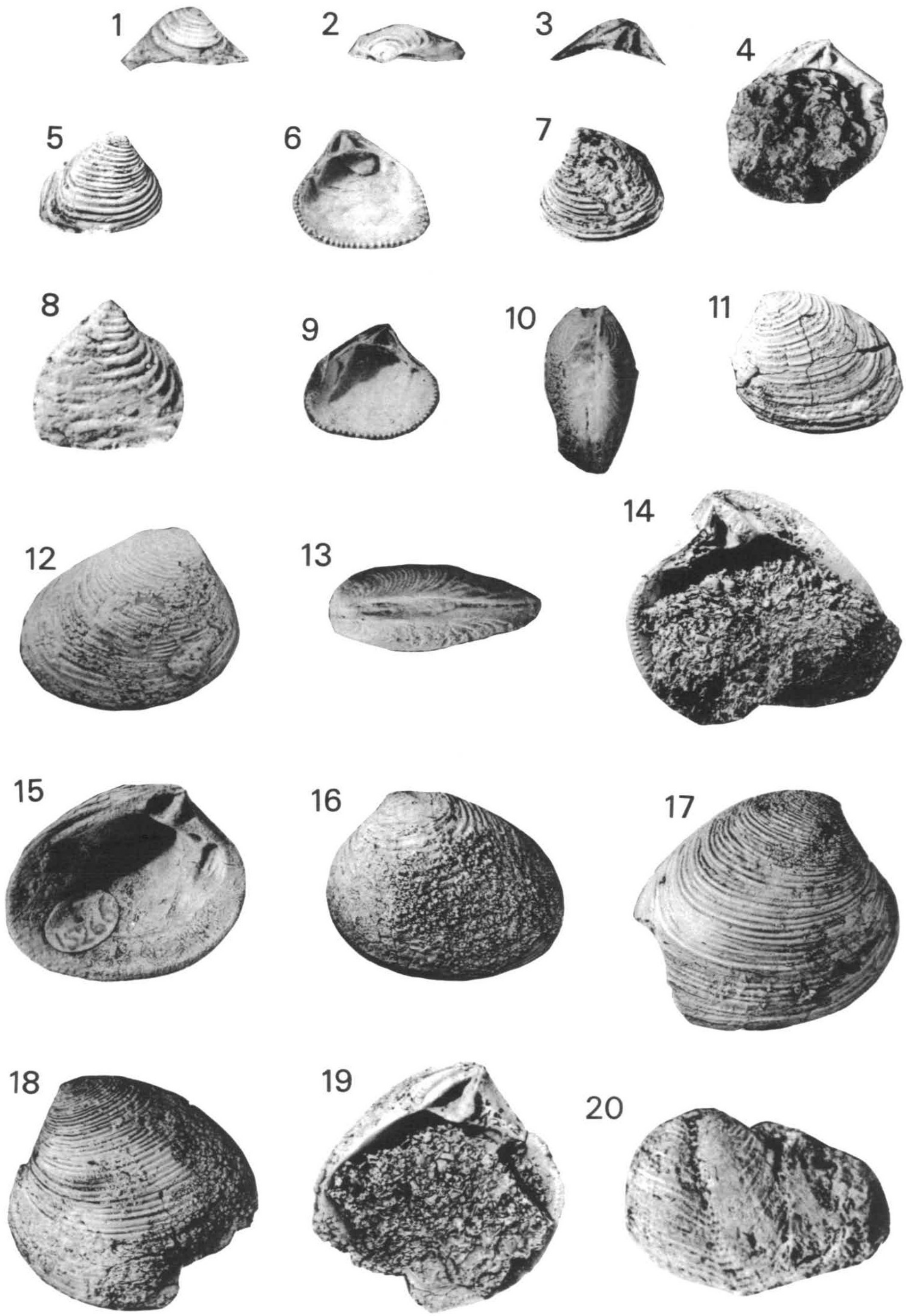
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PLATE 35

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

Figs 1–6 *Tancredia (Tancredia) sandspringi* sp. nov.
1, 3, 5. Paratype, WAM 70.1380. Internal, external, and dorsal views of left valve.
2, 4, 6. Holotype, WAM 65.1145. Internal, external, and dorsal views of right valve. Newmarracarra Limestone.

Figs 7–10 *Isotancredia kojarena* sp. nov.
7. Paratype, CPC 11390. Latex cast of external impression of left valve. Locality SKS9. x1.7.
8. Paratype, CPC 11391. Internal impression of left valve. Locality SKS9. x1.7.
9. Holotype, CPC 11392. Latex cast of internal impression of right valve, x1.7.
10. Paratype, CPC 11393. Latex cast of incomplete internal impression of left valve. Locality SKS9. x1.7. Kojarena Sandstone.

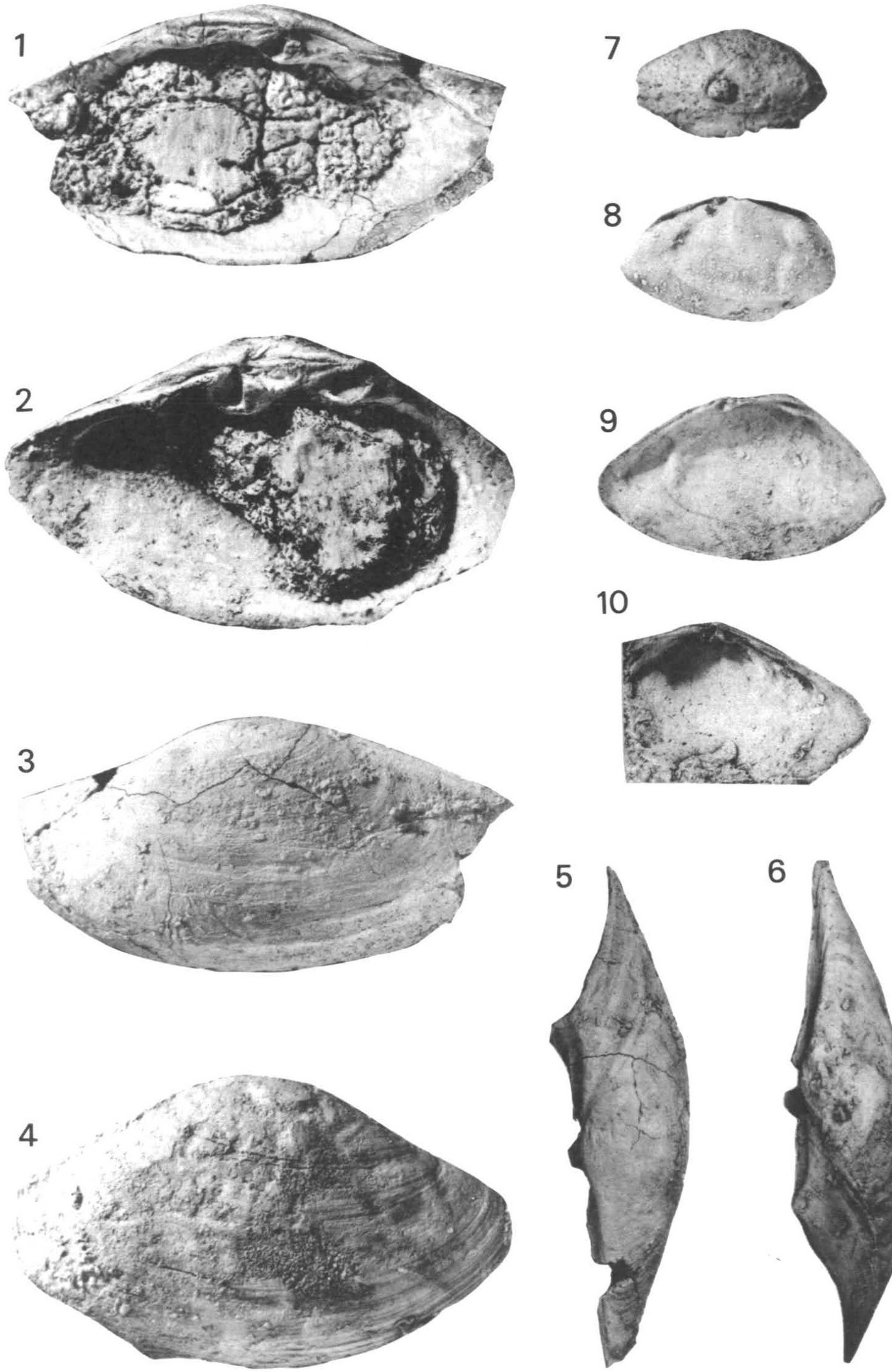
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PLATE 36

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

Fig. 1 *Martesia* (*Particoma*) *australis* (Moore, 1870).
Photograph of much enlarged specimens loaned by British Museum (Nat. Hist.), London (x about 5). Locality described as 'Shark Bay, Western Australia'.

Fig. 2 Worm borings.

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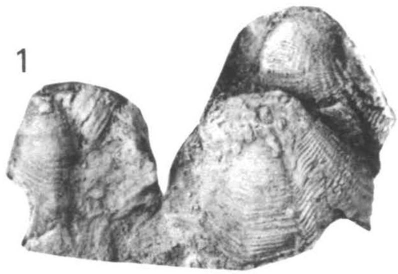

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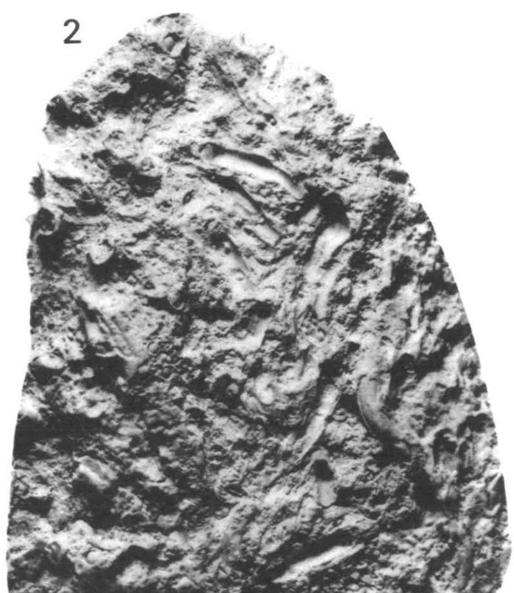

MARINE TRIASSIC MOLLUSCS OF AUSTRALIA AND PAPUA NEW GUINEA

by

S. K. Skwarko and Bernhard Kummel

SUMMARY

Marine Triassic invertebrate faunas of Australia and Papua New Guinea are not numerous and their content is rather meagre. Previous records of fossils of this age from this region are reviewed.

New discoveries reported in this paper are from the Perth Basin Dongara No. 4 borehole, the Sahul Shoal No. 1 borehole on the continental shelf off the northern coast of Western Australia, and outcrops of the Kockatea Shale at Mount Minchin in the Perth Basin.

Core 1 in Dongara No. 4 contains *Proptychites* sp. indet., *?Koninckites* sp. indet., and *?Paranorites* sp. indet. Core 2 contains *Gyronites* cf. *frequens* Waagen, 1895. The specimens of Core 1 indicate corelation with the Ceratite Marls of the Salt Range, West Pakistan; those of Core 2 a correlation with the Lower Ceratite Limestone.

The specimens from the Sahul Shoal No. 1 borehole we tentatively identify as *Nicomedites* of early Anisian age.

The Mount Minchin fauna contains *Arctoceras* sp. indet., *Prionites* sp. indet., *Hemiprionites* sp. indet., and *Anasibirites kingianus* Waagen, 1895 and indicates a mid-Scythian *Owenites* Zone age.

INTRODUCTION

The larger marine fossils of Triassic age are rare in the Australian region, which for the purpose of the present discussion includes, in addition to the continent of Australia, the continental shelf and Papua New Guinea.

Outcroppings of fossiliferous marine Triassic rocks on the continent of Australia are known from Mount Minchin in Western Australia (Edgell, 1964) and the Cordalba-Woondum area north of Brisbane, Queensland (Fig. 1). The Mount Minchin fauna will be discussed in more detail below and some of the specimens described and illustrated. Only bivalves occur at Cordalba (Fleming, 1966), but the Woondum fauna from Queensland described by Runnegar (1969) contains the following cephalopod species:

Latisageceras woondumense Runnegar, 1969
Dieneroceras woondumense Runnegar, 1969
Flemingites sp. indet.
Anaflemingites armstrongi Runnegar, 1969
Paranorites queenslandicus Runnegar, 1969
Paranorites hillae Runnegar, 1969
Pseudohedenstroemia sp.
Arctoceras? sp.

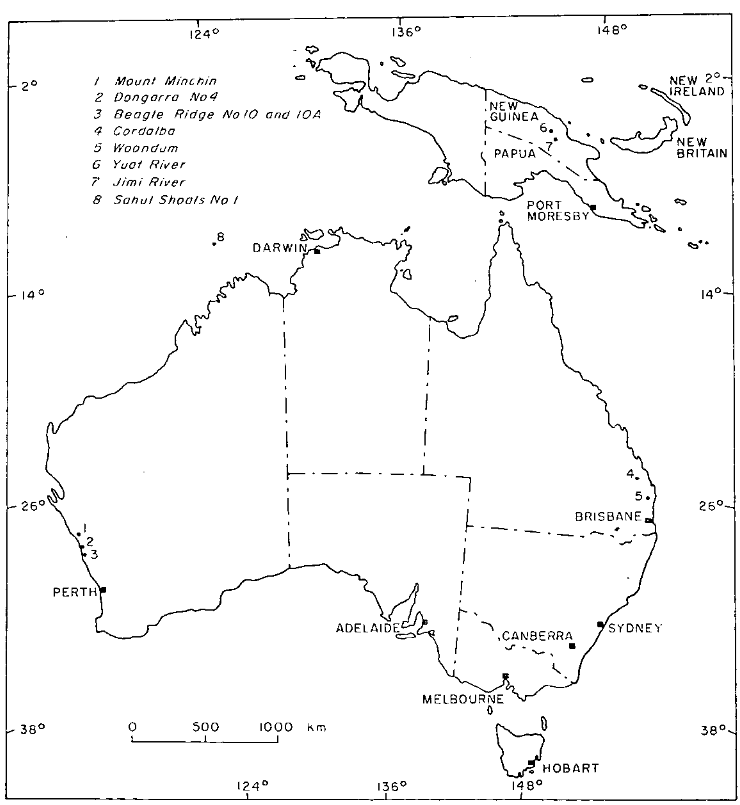

Fig. 1. Distribution of Triassic cephalosod-bearing localities in Australia and Papua New Guinea.

	STAGES	DIVISIONS	ZONES	AUSTRALIAN REGION REPRESENTATIVES
UPPER TRIASSIC	RHAETIAN		*Choristoceras marshi*	
	NORIAN		*Sirenites argonauta* *Pinacoceras metternichi* *Cyrtopleurites bicrenatus* *Cladiscites ruber* *Saganites giebeli* *Discophyllites patens*	Jimi River fauna (Skwarko, 1967) (exact position not known)
	CARNIAN		*Tropites subbullatus* *Carnites floridus* *Trachyceras aonoides* *Trachyceras aon*	
MIDDLE	LADINIAN		*Protrachyceras archelaus* *Protrachyceras reitzi*	Jimi River Halobiidae (Skwarko, 1973b) (exact position not known)
	ANISIAN		*Paraceratites trinodosus* *Paraceratites binodosus* *Nicomedites osmani* *Neopopanoceras haugi*	Yuat River ammonites (Skwarko, 1973a) ? Sahul Shoals No. 1, Core 9 (this paper)
LOWER TRIASSIC	SPATHIAN	PROHUNGARITIAN	*Prohungarites similis*	
		COLUMBITAN	*Columbites parisianus* *Tirolites cassianus*	
	SMITHIAN	OWENITAN	*Anasibirites multiformis* *Meekoceras gracilitatis*	Woondum fauna (Runnegar, 1969); Mount Minchin fauna (Edgell, 1964)
	DIENERIAN	FLEMINGITAN	*Flemingites flemingianus* *Koninckites volutus*	? Cordalba fauna (Fleming, 1966) Core 1 – Dongara No. 4 bore (this paper)
	DIENERIAN / GRIESBACHIAN	GYRONITAN	*Xenodiscoides fallax* *Prionolobus rotundatus* *Proptychites rosenkrantzi* *Vishnuites decipiens*	Core 2 – Dongara No. 4 bore (this paper)
	GRIESBACHIAN	OTOCERATAN	*Ophiceras commune* *Otoceras woodwardi*	? Beagle Ridge fauna (Dickins & McTavish, 1963)

Table 1. The distribution of the marine macrofossil faunas in the rocks of Australia and Papua New Guinea.

This assemblage also includes a gastropod, a bivalve, and an ophiuroid. This fauna is clearly mid-Scythian in age, belonging to the *Owenites* Zone (Table 1).

From the Yuat River gorge in the Western Highlands of New Guinea, the following cephalopod fauna has been described (Skwarko, 1973a):

Beyrichites (*Beyrichites*) *yuati* Skwarko, 1973
Paraceratites cf. *trinodosus* Mojsisovics, 1878
Hungarites (*Israelites*) sp. indet.
Longobardites (*Longobardites*) *maramuniensis* Skwarko, 1973
Parapopanoceras wapii Skwarko, 1973
Ptychites cf. *stachei* Mojsisovics, 1882
Discoptychites aff. *megalodiscus* Beyrich, 1867
Germanonautilus sp. indet.

This assemblage includes associated bivalves, gastropods, and other fossils and has been referred to the upper Anisian Zone of *Paraceratites trinodosus* (Skwarko, 1973a).

The recently described Halobiidae assemblage from the Jimi River area outcrops (Skwarko, 1973b) is Ladinian or Ladino-Carnian in age but contains no ammonities, while the Jimi River fauna itself, which though rich in bivalves contains but one ammonite, *Sirenites* cf. *malayicus* Welter, 1914, has been assigned broadly to the Carnian-Norian (Skwarko, 1967).

Interestingly enough the very first marine macrofossils of Triassic age in the Australian region were recovered by cores from the Beagle Ridge (BMR 10) bore in the Perth Basin, Western Australia. Dickins & McTavish (1963) described and illustrated the following ammonoids from the Beagle Ridge cores:

Ophiceras (*Discophiceras*) cf. *subkyokticum* Spath, 1930
Subinyoites kashmiricus (Diener, 1913)
Glyptophiceras? sp. indet.

Two species of the bivalve genus *Claraia* occur beneath the levels that yielded the ammonoids. Dickins & McTavish (1963) interpreted this ammonoid fauna as of Otoceratan (earliest Scythian) age in the sense of Spath (1934). The nature of the few specimens available to Dickins & McTavish leads Kummel to believe the identifications are suspect.* The fauna is clearly Early Triassic (Scythian) and from the lower half of the stage but not necessarily from the lowest zone.

In recent years cores from two new boreholes have yielded Triassic ammonoids. These are from Dongara No. 4 in the Perth Basin and Sahul Shoal No. 1 on the continental shelf off the northern coast of Western Australia. In addition new collections of the Mount Minchin fauna have become available. The primary purpose of this communication is description and documentation of these new faunas.

Dongara No. 4 borehole

Dongara No. 4 is approximately 65 km north of the Beagle Ridge (BMR No. 10) borehole in the Perth Basin. Two cores from the Kockatea Shale yielded macrofossils. Core 1 (1661-1669 m) has yielded *Proptychites* sp. indet., *?Kon-*

*McTavish & Dickins (1974) now regard the Kockatea Shale in the bore as ranging in age from Otoceratan probably to Owenitan.

inckites sp. indet., and *?Paranorites* sp. indet. Core 2 (1699-1677.3 m) contains *Gyronites* cf. *frequens* Waagen, 1895. The presence of *Gyronites* in Core 2 clearly indicates a correlation with the Lower Ceratite Limestone of the Salt Range, West Pakistan. The only specimen of Core 1 that can be identified generically with confidence is *Proptychites,* which ranges through nearly all the lower half of the Scythian. However, we believe that the identification of the other two specimens is reasonably accurate and suggest correlation with the Ceratite Marl of the Salt Range and the so-called *'Meekoceras'* beds of the Himalayas.

The few specimens from the Beagle Ridge (BMR No. 10) bore described by Dickins & McTavish (1963) could well be correlative with those from Dongara No. 4 bore.

Sahul Shoal No. 1

Early in 1970 the Burmah Oil Australia Ltd drilled through 4000 m of sediments on the Australian continental shelf off the northern coast of Western Australia. A representative portion of the cores was sent to the Bureau of Mineral Resources for examination.

Core 9 yielded a number of ammonite and bivalve fragments, some of them indeterminate, as well as one or two indeterminate brachiopods. The fauna, though not well preserved, is here specially recorded, as it is probably of lower Middle Triassic age, and no marine macrofossils of this age have hitherto been recorded from the Australian region.

Two ammonite genera and species are present. One is represented by two heavily ribbed small specimens from 10734′ 9″ and 10735′ 0″ and their preservation precludes even a generic determination. The other, from 10736′ 3″, 10735′ 9″, 10722′ 0″ and 10720′ 3″ is the more interesting of the two, and at least at this stage the more valuable one, as it is probably *Nicomedites,* a genus hitherto known only from the lower Anisian strata of Asia Minor. No macrofauna of this age has hitherto been known to occur in the Australian region.

The only bivalves that deserve a special mention are the Halobiidae, represented by the large but broken and incomplete specimens from 10739′ 0″ and by small and incomplete specimens from 10739′ 9″. No generic identification is possible, but although the family reached the acme of development in the Ladinian times, it already existed in the Anisian, so that its association with the *Nicomedites?* is not inconsistent with the suggested early Anisian age of Core 9.

Core 10 has yielded but a single fossil, an indeterminate lingulid from 12066′ 0″. No dating is possible, but the lithology of Core 10 is similar to that of Core 9.

The light-coloured limestone from Core 11 yielded Permian brachiopods.

Mount Minchin fauna

Outcrops of Kockatea Shale near Mount Minchin in the Perth Basin have yielded an extremely interesting assemblage of ammonoids generally poorly preserved as moulds. The presence of these fossils was first recorded by Edgell (1964), who correctly concluded they belonged to the mid-Scythian *Owenites* Zone. Recently the area has been mapped by J. Karajas, and he and members of the University of Western Australia have collected a number of new specimens (Fig. 2). P. J. Coleman (in litt.) describes the occurrence of the ammonoids as follows:

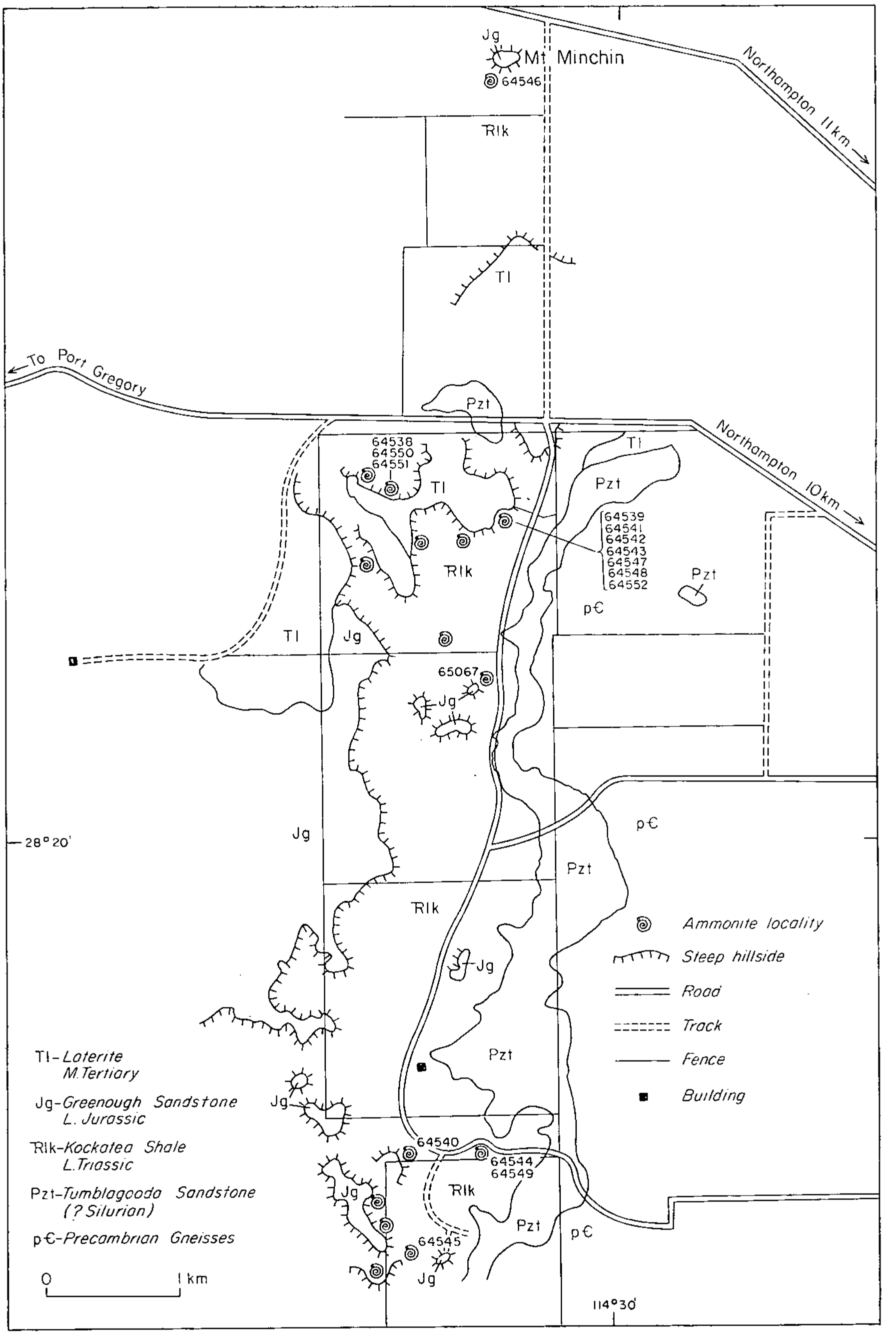

Fig. 2. Collecting localities in the Mount Minchin area (after J. Karajas).

'The Kockatea Shale has a conglomeratic basal layer (difficult to distinguish from the underlying Tumblagooda Sandstone for the cobbles are reworked from it) with which is associated algal mats and mounds. This may be a foot to a few feet thick. Then there comes a finely laminated shale/sand sequence, roughly 2 m thick, but varying from 1 to 15 m, with occasional algal structures and distinguished by extensive sedimentary structures (ripples, cracks, tool-markings, etc.). The ammonite impressions are found in this shale/sand sequence.'

Coleman further writes that:

'Karajas thinks that the Kockatea Shale in this area accumulated in extremely shallow water, in part tidal. The ammonites were washed in, possibly over an offshore bar (this to account for the absence of other fossils).'

The Mount Minchin fauna contains the following species of ammonoids:

Arctoceras sp. indet. A

Arctoceras sp. indet. B

Prionites sp. indet.

Hemiprionites sp. indet.

Anasibirites kingianus (Waagen, 1895)

This assemblage clearly indicates the fauna to be of Owenitan age (Spath, 1934). The precise composition of faunas of this age has been the subject of considerable discussion, because two quite distinct faunas characterize it, one with *Owenites* and the other with *Anasibirites*. In several places in the world it can be shown that faunas with *Anasibirites* overlie those with *Owenites*. On the other hand there are places where the two faunas appear to be mixed. One such fauna is that from Kotal-e-Tera, Afghanistan, described by Kummel & Erben (1968). Kummel & Erben came to the conclusion that the mid-Scythian is best delineated as the *Owenites* Zone, but at the same time recognized two subzones. Finally, it should be noted that faunas of the *Owenites* Zone are known from more localities than those of any other Scythian zone. P. J. Coleman writes that the Mount Minchin fauna was not stratigraphically collected. However, in the light of the interpretation of the depositional environment of the Kockatea Shale in this region the mixed nature of the faunas could readily be explained.

Class CEPHALOPODA Cuvier, 1797

Subclass AMMONOIDEA Zittel, 1884

Family GYRONITIDAE Waagen, 1895

Genus GYRONITES Spath, 1934

Type species: *Gyronites frequens* Waagen, 1895.

GYRONITES cf. FREQUENS Waagen, 1895
(Plate 37, figs 1-6; Text-figs 3a-c)

Material: One complete specimen and two fragments from Core 2, Dongara No. 4, Perth Basin.

Description: The complete specimen has a diameter of 65 mm, adoral whorl height of 26 mm, and width of 13 mm. The flat truncate venter has a width of 4.5 mm. The adoral one-third volution is body chamber. The flanks on the adoral part of the conch are gently convex but on the inner whorls they are nearly flat.

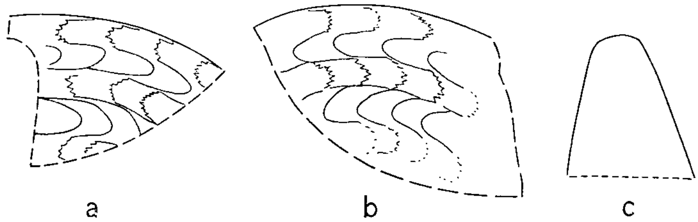

Fig. 3. a-c *Gyronites* cf. *frequens* Waagen, 1895. Fragment of conch in lateral (a, b) and end-on (c) view. CPC 11367 (pl. 1, fig. 4-6). Core 2.

The umbilicus is broad and shallow, with a diameter of 19 mm. The umbilical shoulders are subangular. The suture is ceratitic with two lateral lobes, with a short auxiliary on the umbilical shoulder.

Of the two fragmentary specimens each of approximately one-quarter volution one is all phragmocone and the other has a small portion of the body chamber. The whorl features are essentially the same as those of the complete specimen. In the suture, however, the ventral lobes are more elaborately denticulated. The smallness of the sample makes evaluation of this difference very difficult, but it is thought best to consider all the specimens conspecific.

Discussion: Species of *Gyronites* are the predominant ammonoids in the Lower Ceratite Limestone of the Salt Range, Pakistan. The more or less evolute compressed conch with a truncate venter is very characteristic. Recently Bando (*in* Ishii, Fischer, & Bando, 1971) has described *Gyronites fischeri* from Khoja Ghare Wali, 30 km east of Kabul, Afghanistan. On the basis of Bando's description and illustrations it appears that *G. fischeri* is extremely similar to the specimens we are describing. However, this is difficult to evaluate in a meaningful sense as Bando records only two fairly complete specimens and we have only one. Species of *Gyronites* characterize the lowest Scythian zone present in the Vladivostok region of Siberia. Kiparisova (1961) on the basis of a rather small collection from various localities in the Vladivostok region described *Gyronites separatus* Kiparisova, 1947, *G.* aff. *planissimus* Spath, 1934, and *G.*(?) *subdarmus* Kiparisova, 1961. In the most recent monograph on the Triassic ammonoids from this region Zakharov (1968) described *Gyronites subdarmus* Kiparisova and *G.* aff. *planissimus* Spath, 1934. For the former species he had 89 specimens and documented well the range of variability. This is the only documentation on intra-specific variation for a species of *Gyronites* that we have to date; this makes comparison of the recorded species extremely difficult. It is sufficient to say that the morphological differences in shell form and suture are very slight.

Family PROPTYCHITIDAE Waagen, 1895

Genus PROPTYCHITES Waagen, 1892

Type species: *Ceratites lawrencianus* de Koninck, 1863.

PROPTYCHITES sp. indet.

(Plate 38, figs 4, 5; Text-fig. 4)

Material: One fragment from Core 1, Dongara No. 4, Perth Basin.

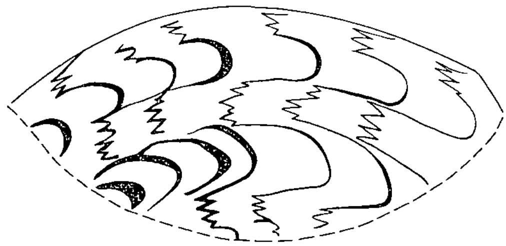

Fig. 4. ***Proptychites*** **sp. indet. Suture pattern in lateral view. Side visible is opposite that in pl. 2, fig. 4. CPC 11372. Core 1.**

Description: The specimen is approximately 10 cm along the venter and is all phragmocone. The venter is broadly arched and the convex flanks bear low broad undulations. The suture is ceratitic and typical for the genus.

Discussion: Proptychites is a fairly common and very widely distributed ammonoid in the lower half of the Scythian stage. The oldest recorded species is *Proptychites scheibleri* Diener, 1897 from the *Otoceras-Ophiceras* beds at Shalshal Cliff, Painkhanda, in the Himalayas. Recently the genus has been recorded from beds with *Otoceras* and *Ophiceras* at Guryul Ravine, near Srinagar, Kashmir (Nakazawa et al., 1970). Species of the genus are very common in the Lower Ceratite Limestone, Ceratite Marl, and Ceratite Sandstone of the Salt Range of Pakistan. They are likewise common in the so-called *'Meekoceras'* beds of the Himalayas. In the circum-Arctic region *Proptychites* has been recorded from Siberia, East Greenland, Arctic Canada, and northern Alaska. Because of the fragmentary nature of our specimen no direct comparison can be made with described species.

Family PARANORITIDAE Spath, 1930

Genus PARANORITES Waagen, 1895

Type species: *Paranorites ambiensis* Waagen

?PARANORITES sp. indet.

(Plate 39, fig. 1; Text-fig. 5)

Material: One fragment from Core 1, Dongara No. 4, Perth Basin.

Description: The specimen consists of one-quarter volution of body chamber with a small portion of phragmocone. The whorls are compressed with narrowly rounded venter. Part of the ventral lobe and two lateral lobes, all denticulated, are preserved. A suggested reconstruction of the shell is shown on Text-figure 5.

Discussion: Owing to the fragmentary nature of the specimen the identification given here is considered the most reasonable in the light of its association with *Proptychites* sp. indet. and *?Koninckites* sp. indet.

Genus KONINCKITES Waagen, 1895

Type species: *Koninckites vetustus* Waagen.

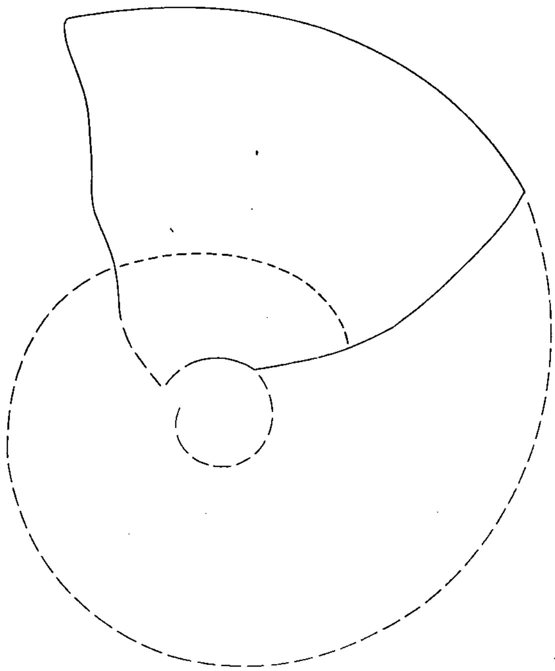

Fig. 5. *?Paranorites* **sp. indet. Reconstruction of specimen CPC 11373 (pl. 3, fig. 1). Core 1.**

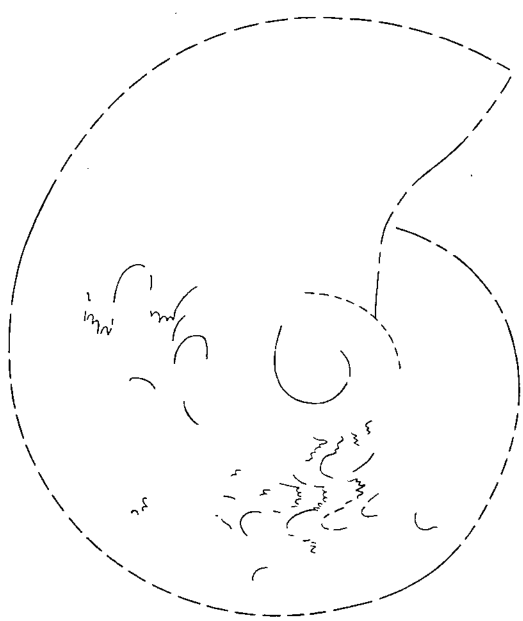

Fig. 6. *?Koninckites* **sp. indet. Reconstruction of specimen CPC 11374 (pl. 3, fig. 2). Core 1.**

?KONINCKITES sp. indet.

(Plate 39, fig. 2; Text-fig. 6)

Material: One crushed specimen from Core 1, Dongara No. 4, Perth Basin.
Description: The specimen is a flattened impression in shale matrix. A reconstruction is shown in Text-figure 6.

Discussion: It is primarily the degree of involution of the conch along with the traces of the suture that suggests this identification, which is supported by the association with *Proptychites* sp. indet. and *?Paranorites* sp. indet.

Family MEEKOCERATIDAE Waagen, 1895

Subfamily ARCTOCERATINAE Hyatt, 1900

Genus ARCTOCERAS Hyatt

Type species: *Ceratites polaris* Mojsisovics, 1886.

ARCTOCERAS sp. indet. A

(Plate 40, fig. 1)

Material: One specimen, UWA 64550, Kockatea Shale, Mount Minchin region.

Description: This is the largest specimen in the collection, with a diameter of 112 mm. Only the outline and impressions of the phragmocone are preserved. The body chamber is moderately well preserved and bears enlarged tubercles on the area of the umbilical shoulder that extend slightly up on to the lateral areas. This is a very characteristic mid-Scythian ammonoid genus, and even though the preservation of the specimen leaves much to be desired the general identification is thought to be justified.

Discussion: The genus *Arctoceras* is very widely distributed and characterizes the mid-Scythian *Owenites* Zone. The type species is from Spitsbergen. Over the years seven species have been assigned to the genus *Arctoceras* from Spitsbergen. However, careful examination of the original collection and new material leads to the conclusion that only one species is represented: *Arctoceras blomstrandi* (Linström) (Kummel, 1961), which is also recorded from the Arctic Islands of Canada and British Columbia (Tozer, 1961). In western United States *Arctoceras mushbachanum* is common. It is also known from Kotal-e-Tera, Afghanistan (Kummel & Erben, 1968), and Popov (pers. comm.) has recognized it in the West Verkhoyan region of Siberia. *Arctoceras blomstrandi* differs from *A. mushbachanum* primarily in having umbilical nodes. *Arctoceras tuberculatum* (Smith) from western United States is quite similar to *Arctoceras blomstrandi,* differing in minor aspects of the early suture. The specimen Welter (1922, p. 126) assigned to *Mekoceras mushbachanum* has low clavi on the umbilical shoulder and thus is more closely allied to *Arctoceras tuberculatum* or possibly to *A. blomstrandi.* Another species from Timor that belongs in *Arctoceras* is *Meekoceras malayicum* Welter, 1922. The genus has also been tentatively recorded from the Traveston Formation of Queensland (Runnegar, 1969).

ARCTOCERAS sp. indet. B
(Plate 42, fig. 8)

Material: One specimen, UWA 65067, Kockatea Shale, Mount Minchin region.
Description: The specimen consists of about a third of a volution of phragmocone and is crushed. One side is completely destroyed, the other vaguely shows the sutures and is reasonably well preserved. The complete specimen probably had a diameter of slightly more than 100 mm. Even though the specimen is crushed there is no reason to believe that the venter was not rounded. The traces of the suture clearly show it included two large lateral lobes and saddles.

Discussion: Arctoceras is a very common and widely distributed genus in the mid-Scythian *Owenites* Zone and in most faunas there are tuberculate and non-tuberculate forms. The specimen we have described above as *Arctoceras* sp. indet. A is a tuberculate form, this specimen is non-tuberculate. The poor preservation and incompleteness of the specimen do not allow any worthwhile comparisons with other species of the genus.

Family PRIONITIDAE Hyatt, 1900

Genus PRIONITES Waagen, 1895

Type species: *Prionites tuberculatus* Waagen, 1895.

PRIONITES sp. indet.
(Plate 40, figs 8-10)

Material: UWA 64552 (5 specimens), Kockatea Shale, Mount Minchin region.

Discussion: Five specimens can be assigned to this genus, but cannot be determined specifically because of poor preservation. The most characteristic features are the subtabulate venter and the prominent tubercles on the whorl sides.

This is another very characteristic mid-Scythian ammonoid, most often associated with *Anasibirites*. It was first recognized from the Upper Ceratite Limestone of the Salt Range, Pakistan. Species of the genus have subsequently been recognized from the Himalayas, Timor, the Vladivostok region of eastern Siberia, British Columbia, and Spitsbergen. It appears to be most abundant in the Tethys.

Genus HEMIPRIONITES sp. indet.

Type species: *Goniodiscus typus* Waagen, 1895

HEMIPRIONITES sp. indet.
(Plate 40, fig. 11)

Material: UWA 64539, Kockatea Shale, Mount Minchin region.

Discussion: The identification is based on a single specimen showing one side of the conch and the venter, but no suture. The compressed, involute conch with a truncate venter and weak slightly sinuous ribs are characteristic of the genus and lend confidence to this identification. No specific identification is possible.

Hemiprionites is another fairly common mid-Scythian ammonoid most often associated with *Anasibirites*. A number of species have been assigned to *Hemiprionites*, but there has been no comprehensive review of the genus. It was first recognized from the Upper Ceratite Limestone of the Salt Range of Pakistan, and species of the genus have subsequently been described from Afghanistan, Timor, Japan, the Vladivostok region of eastern Siberia, several localities in western United States, and Spitsbergen.

Family SIBIRITIDAE Mojsisovics, 1896

Genus ANASIBIRITES Mojsisovics, 1896

Type species: *Sibirites kingianus* Waagen, 1895.

ANASIBIRITES KINGIANUS (Waagen, 1895)
(Plate 40, figs 2-7)

Sibirites kingianus Waagen, 1895, p. 108, pl. 8, figs 1a-c, 2a-c.

Anasibirites kingianus; Kummel & Erben, 1968, p. 135-140, pl. 20, figs 6, 7, 18; pl. 22, figs 12-17; pl. 23, figs 1-18.

Material: Seven plaster casts, UWA 64538, 64546, 64548, 64551, 64552, Kockatea Shale, Mount Minchin region.

Discussion: A. kingianus is one of the easily identifiable of mid-Scythian ammonoids. A very thorough discussion of the species, and a complete synonymy, have been presented by Kummel & Erben (1968). Few Scythian ammonoids present more interesting specific and intraspecific variation than species of *Anasibirites*. Approximately 60 species have been assigned to the genus, all differentiated primarily on differences in strength of ribbing. Welter (1922) in a study of large collections from Timor was the first to recognize that there was enormous variation in rib pattern. He correctly interpreted this as no more than intraspecific variation. Subsequent authors adopted a more narrow approach in definition of species and this led to a great proliferation of species names. Kummel & Erben (1968) based their revision of the genus on the basis of large, well-preserved collections from Afghanistan. Their interpretation was that there is only one species in the genus.

This species is represented by eight specimens and is the most common form in our collection. Some of these specimens are illustrated on Plate 40, primarily to show the great variation in rib strength. Each of these specimens can be compared directly with specimens from the large faunas of Timor or Afghanistan.

Anasibirites is widely distributed in mid-Scythian formations. Within the Tethyan realm it is known from Afghanistan, the Salt Range of Pakistan, the Himalayas, and Timor. In the eastern Pacific realm it is known from Japan and the Vladivostok region of eastern Siberia. In the western Pacific realm it is known from a number of localities in western United States and British Columbia. From the circum-Arctic region it has been recorded from Spitsbergen.

Family BEYRICHIDAE Spath, 1924

?Genus NICOMEDITES Toula, 1896

Type species: *Ceratites* (*Nicomedites*) *osmani* Toula, 1896; S. D. Spath, 1934.

?NICOMEDITES sp. indet.
(Pl. 41, figs 1-5; Pl. 42, figs 3, 4, 6)

Material: Incomplete young specimen, and fragments of mature and near-mature specimens, from 10735′ 9″, 10736′ 3″, 10722′ 0″, and 10720′ 3″, Core 9, Sahul Shoals No. 1.

Description: The shell is discoidal, compressed, involute, and moderately to weakly ribbed, with narrow rounded venter and advanced ceratitic suture with adventitious lobes.

The mature conch reaches a diameter of at least 40 mm. It is compressed, with subparallel straight lateral walls for most of their length. The ribbing is falcate to subfalcate. The young portion of the whorl is fairly strongly sculptured with ribs and furrows which extend over the keel, the mature portion with weak subfalcate riblets which reach maximum relief in the ventral portion of the lateral wall without extending on to the narrowly arched venter.

The suture is known only from the young portion of the conch. There are five saddles entire in the earliest visible part of the shell. The first lateral saddle has eight short rounded elements.

The umbilicus is moderately small in immature specimens.

Subclass NAUTILOIDEA Agassiz, 1847

Family GRYPOCERATIDAE Hyatt in Zittel, 1900

Genus GRYPOCERAS Hyatt, 1883

Type species: *Nautilus mesodiscus* Quenstedt, 1845.

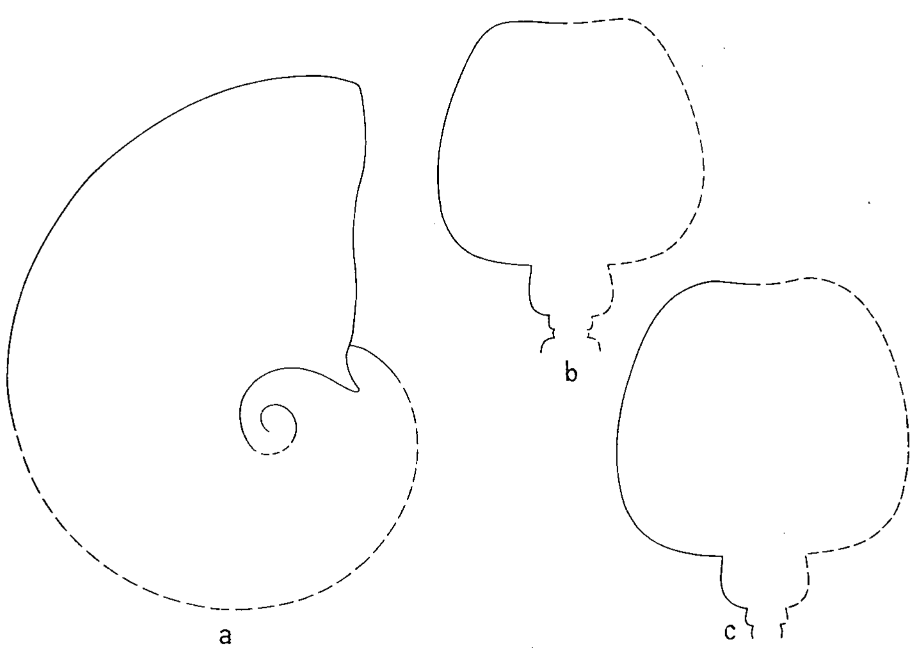

Fig. 7. a-c *?Grypocera* sp. A. Reconstruction of specimen CPC 11369 (pl. 1, fig. 7). a Lateral view. b, c Two Cross-sections through body chambers of ventral view. Core 2.

?GRYPOCERAS sp. A
(Pl. 37, fig. 7; Text-figs 7a-c)

Material: Incomplete and somewhat distorted specimen with most of the proximal portion and the distal portion of the conch preserved, from Core 2, Dongara No. 4, Perth Basin.

Description: The specimen is about 11.5 cm high and 8.4 cm long (both figures obtained by reconstruction). It increases in breadth very rapidly, the body whorl measuring 6.5 cm both in height and breadth. The conch is smooth, with slightly invaginated venter, tightly rounded ventral shoulders, a little less tightly rounded umbilical shoulder, and very steeply dipping umbilical wall. The convexity of the lateral walls decreases markedly with age. The length of the body whorl is about 15 cm. The nature of the suture pattern is not known.

?GRYPOCERAS sp. B
(Pl. 37, fig. 7; Pl. 38, figs 1-3)

In Core 2, apart from *?Grypoceras* sp. A and two very young and incomplete nautiloids, there is a fragment of a probably mature nautiloid which may also be a *Grypoceras,* but a species distinct from *?Grypoceras* sp. A.

It consists of the early portion of the conch and enough is preserved to show its narrow umbilicus bordered by steep walls, the subangular shoulders bordering the venter, and the type of suture pattern. In cross-section the immature whorl is higher and more angular than *?Grypoceras* sp. A.

Class BIVALVIA Linnaeus, 1758
Family NUCULANIDAE Adams & Adams, 1858
Genus NUCULANA Link, 1807

Type species: *Arca rostrata* Chemnitz, 1774.

NUCULANA sp.
(Pl. 42, fig. 1)

A single *Nuculana* from 10733′ 3″ in Sahul Shoal No. 1, originally about 9 mm high and 17 mm long, is characterized by the narrowly arched anteroventral portion of the shell-margin, and the extremely fine concentric sculpture. It is moderately well inflated and has a broad umbo.

Family HALOBIIDAE Kittl, 1912
HALOBIIDAE indet.
(Pl. 42, figs 5, 7)

In Sahul Shoal No. 1, Halobiidae are represented by two crushed and incomplete specimens from 10739′ 0″ and an incomplete specimen from 10739′ 9″. One of them is probably a *Daonella,* and none are specifically determinate; it was, however, found possible to make the following observations on their morphology.

One of the specimens from 10739′ 0″ was originally at least 33 mm high, with rapidly expanding prominent rigid ribs and deep and narrow gradually expanding interspaces. Some of the primaries are divided by a shallow groove which extends longitudinally throughout their observed length; there are also secondary grooves which divide the secondary ribs into tertiary riblets. The other primaries are divided by two narrow linear closely spaced grooves, whose close spacing results in a third, centrally situated, very narrow riblet. This second mode of ribbing is similar to that of *Halobia ocevjana* Kittl, 1912 from the lower Carnian of Bosnia, which, however, has wavy sinuous ribs, and obviously represents a different species.

In the second specimen from 10739′ 0″ the ribs thicken less rapidly distally, and the primaries are split up into secondary and tertiary in the same manner as described for the other specimen from this depth. The proximal region of the specimen was excavated without any evidence of wing being found.

The third specimen, from 10739′ 9″, is immature, and its proximal portion is missing. Its ribs are simple primaries divided by a single longitudinal groove into two secondaries.

PTERIACEA indet.
(Pl. 37, fig. 8)

The only bivalve in either core from Dongara No. 4 is a single proximally incomplete left valve from Core 1.

It is 76 mm long and only 67 mm of its original height remains as the whole of its proximal portion is missing. The main body is ornamented with radial ribs of very low relief, each 2 to 3 mm wide near the distal periphery. They are separated from each other by shallow linear interspaces, which together with ribs gradually radiate in a somewhat irregular fashion from the umbo. The ill-defined posterior wing contains concentric sculpture only. This consists of growth-lines and rugae, but possibly also of concentric ribbing.

The bivalve probably belongs to the Pteriacea, but because of the unsatisfactory preservation, no closer identification is possible.

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PLATE 37

All figures are natural size, and all photographed in lateral view unless otherwise stated.

Figs 1–6	*Gyronites* cf. *frequens* Waagen, 1895. 1. Specimen coated with ammonium chloride. 2, 3. Uncoated in lateral and anterior view. CPC 11366. Core 2. 4. Fragment CPC 11367 in ventral view. 5, 6. Fragment CPC 11368 in end-on and lateral view. Core 2.
Fig. 7	*Grypoceras?* sp. A. Incomplete specimen, CPC 11369 in lateral view. Core 2.
Fig. 8	Pteriacea indet. Incomplete specimen CPC 11370 from Core 1. x½.

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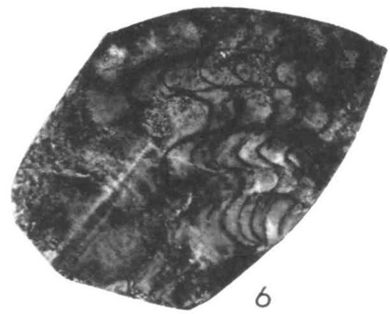

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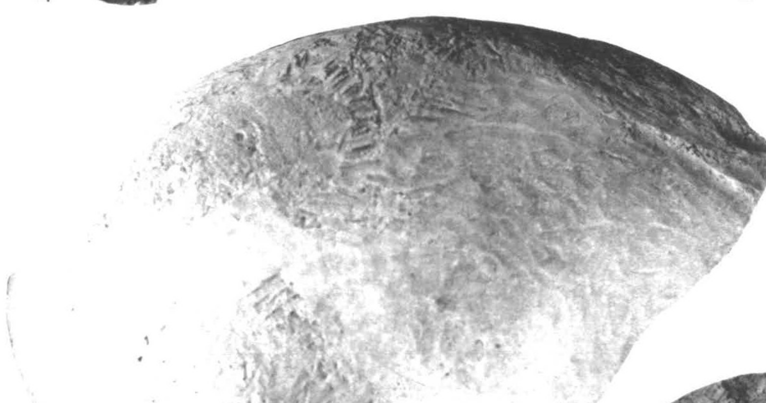

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PLATE 38

All figures are natural size, and all photographed in lateral view unless otherwise stated.

Figs 1–3 — *Grypoceras?* sp. B.
Early portion of conch in lateral and anterior (1, 2, coated with ammonium chloride) and lateral (uncoated) views. CPC 11371. Core 2.

Figs 4, 5 — *Proptychites* sp. indet.
Specimen from Core 1 in lateral and dorsal views. CPC 11372. Core 1.

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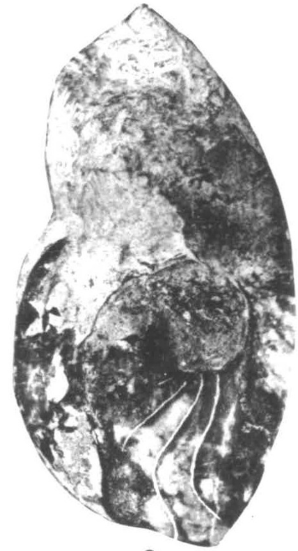

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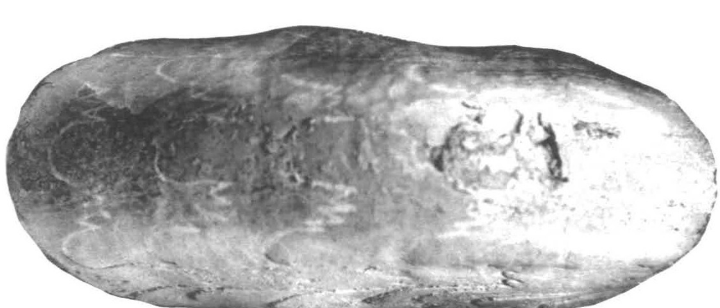

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PLATE 39

All figures are natural size, and all photographed in lateral view unless otherwise stated.

Fig. 1 *?Paranorites* sp. indet.
CPC 11373.

Fig. 2 *?Koninckites* sp. indet.
CPC 11374.

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PLATE 40

All figures are natural size unless otherwise stated.

Fig. 1	*Arctoceras* sp. indet. A. UWA 64550. x0.7.
Figs 2–7	*Anasibirites kingianus* (Waagen, 1895). 2. UWA 64538. 3, 4. UWA 64552. 5. UWA 64551. 6. UWA 64546. 7. UWA 64552.
Figs 8–10	*Prionites* sp. indet. UWA 64552.
Fig. 11	*Hemiprionites* sp. indet. UWA 64539.

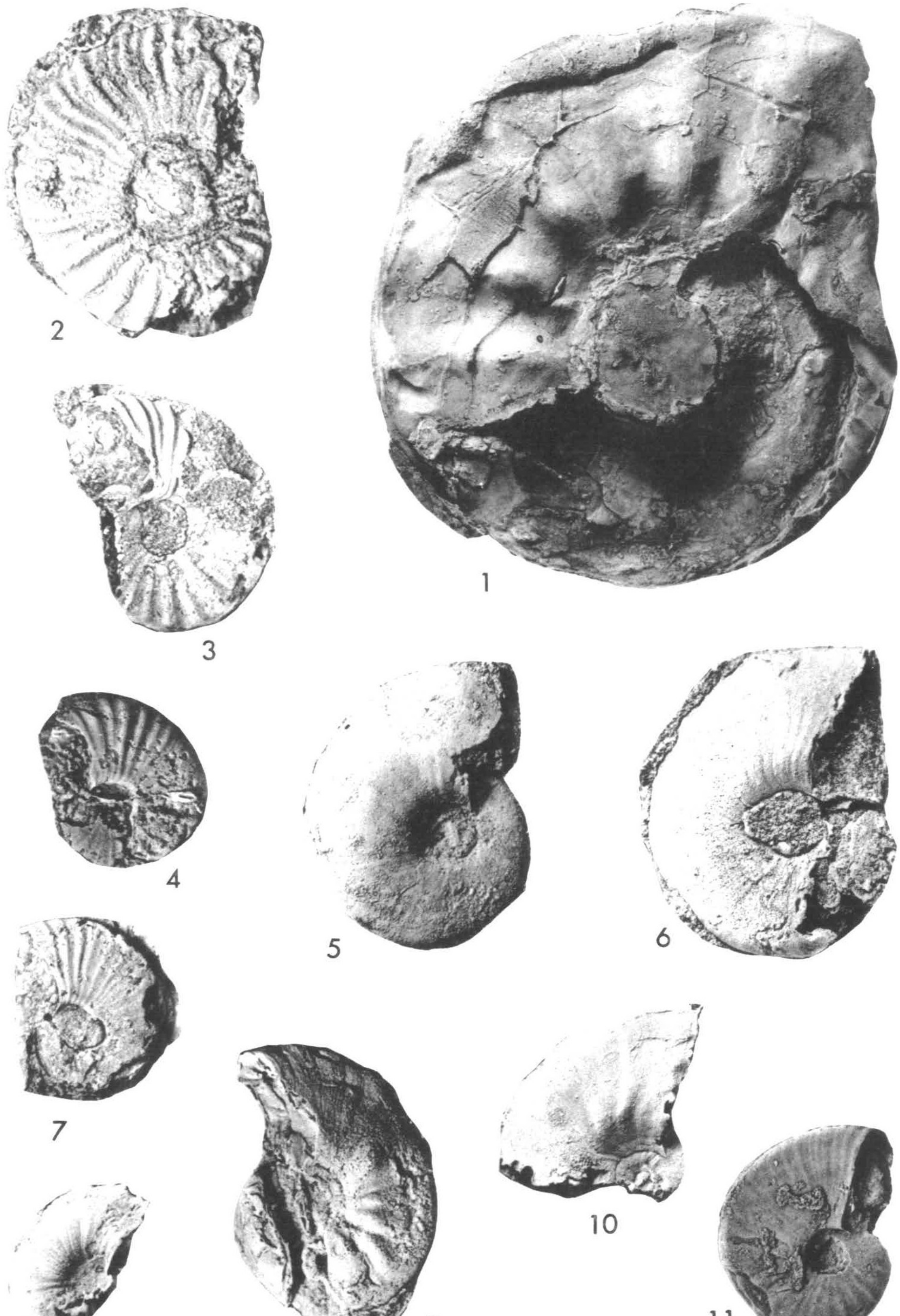
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PLATE 41

Figs 1–5 *Nicomedites?* sp. juv.

1, 5. Dorsal views of venter. x10.

2, 3. Pyritized remains of specimen in lateral view. x2 and x10 respectively.

4. Side impression opposite to that in fig. 2. x1. CPC 11450. Core 9 (10735′ 9″).

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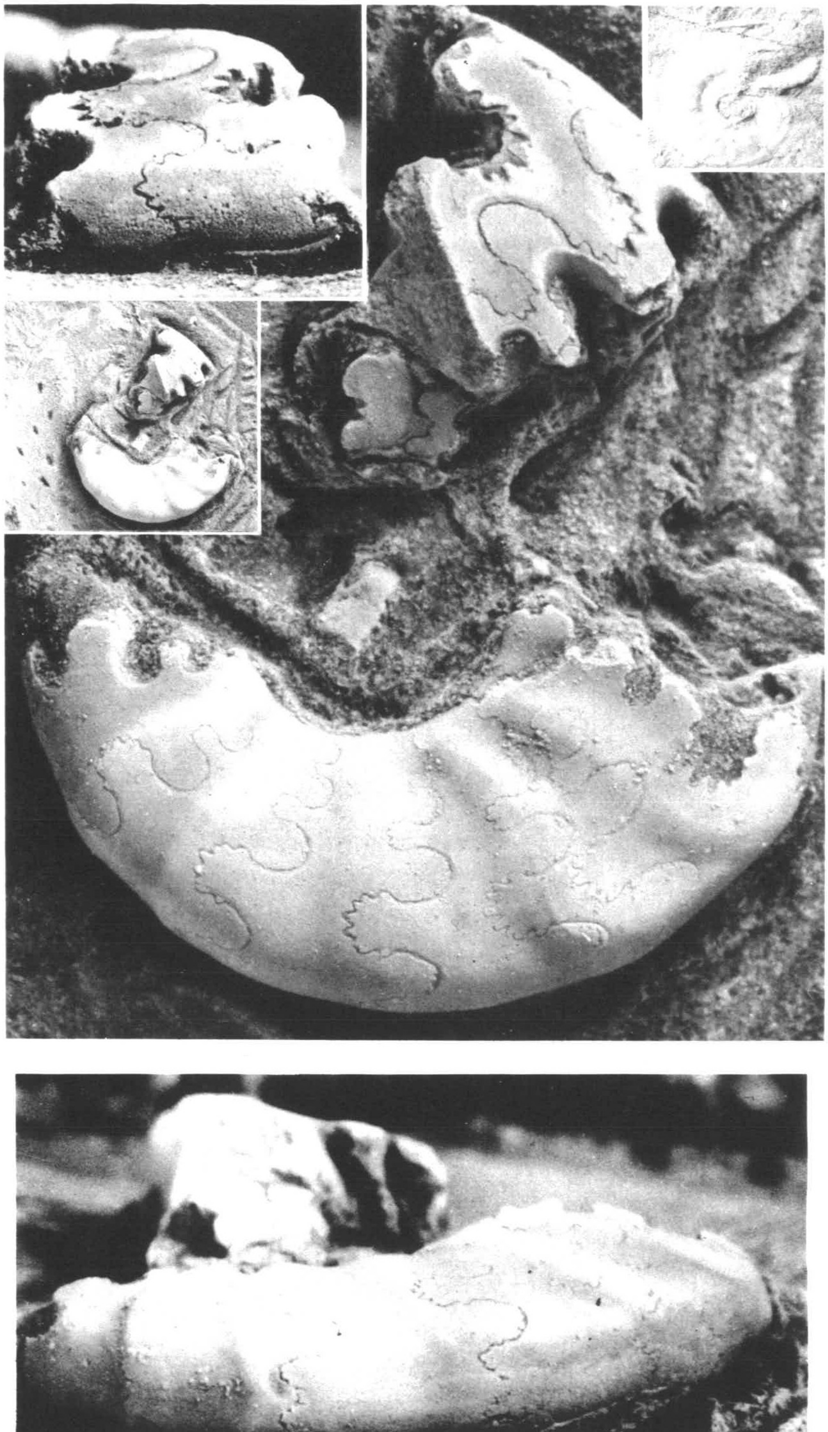

PLATE 42

Fig. 1	*Nuculana* sp. CPC 11451. Core 9 (10733′ 3″). x2.
Fig. 2	Ammonite indet. CPC 11452. Core 9 (10734′ 9″). x2.
Figs 3, 4, 6	*Nicomedites?* sp. Fragments of probably mature specimens, or their impressions. 3. CPC 11453 (Core 9: 10736′ 3″). 4. CPC 11454 (Core 9: 10735′ 9″). 6. CPC 11455 (Core 9: 10722′ 0″). x2.
Figs 5, 7	Halobiidae indet. 5. Proximally incomplete small valve. CPC 11456. Core 9 (10739′ 9″). x2. 7. Three incomplete mature valves. Core 9 (10739′ 0″). CPC 11457.
Fig. 8	*Arctoceras* sp. indet. B. UWA 65067. Crushed fragment of phragmocone. Kockatea Shale, Mount Minchin region, W.A.

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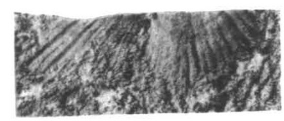

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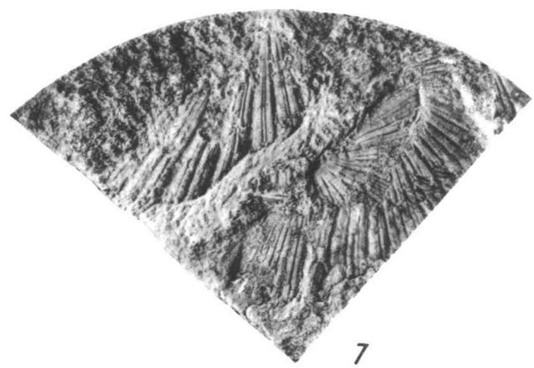

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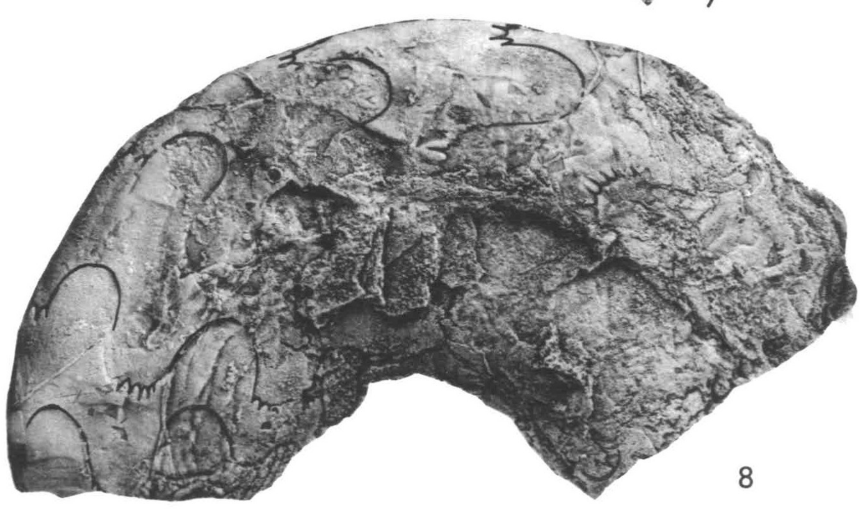

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