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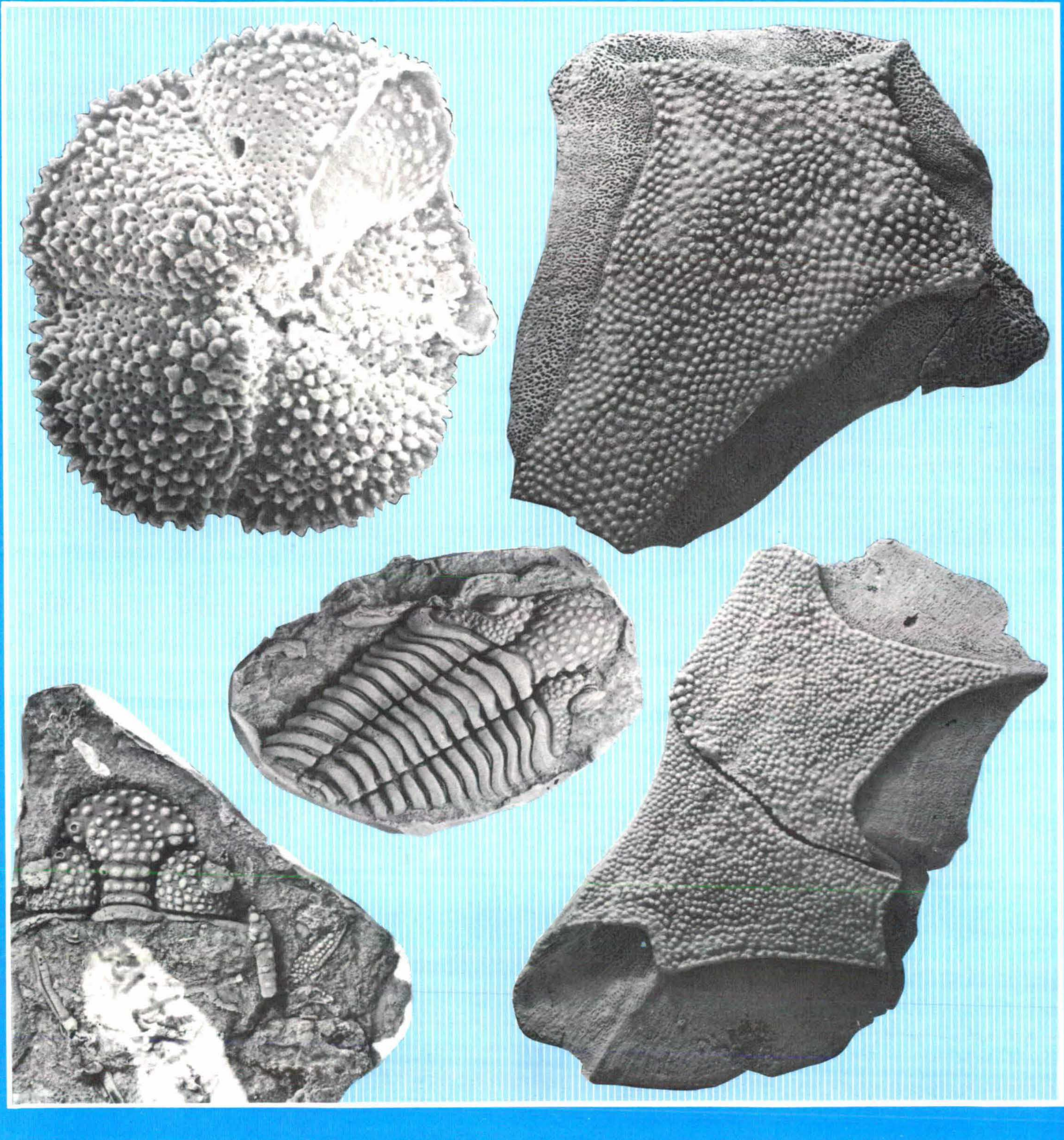

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Note on costellate planktonic foraminifera, and the generic designation of Late Cretaceous forms from Western Australia

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ABSTRACT

Meridionally costellate globigerine genera from the Late Cretaceous are reviewed briefly. Species from Western Australia originally placed in the genus *Rugoglobigerina* are no longer referred to this genus: *R. plana* Belford is placed in *Hedbergella*; and *R. bulbosa* Belford and *R. pilula* Belford are placed in *Whiteinella.*

INTRODUCTION

Three species of costellate planktonic foraminifera from Western Australia that Belford (1960) described as *Rugoglobigerina bulbosa*, *R. pilula*, and *R. plana* have been re-examined in the light of recently available data concerning the morphology and classification of Mesozoic planktonic foraminifera, and are no longer considered to be referable to *Rugoglobigerina.* Both the original material and additional topotypic material have been examined during this study. Figured specimens are deposited in the Commonwealth Palaeontological Collection, Canberra, A.C.T., under numbers 22092 to 22106. The holotype of *Rugoglobigerina plana* is refigured.

These species are part of a distinctive group with well-developed meridional ornamentation (McNulty & Barr, 1979) which appeared in the Santonian and extended into the Campanian. In addition to the Western Australian occurrences, this group has been recorded from several areas in the United States by Takayanagi (1965), Douglas & Sliter (1966), Douglas (1969), McNulty (1976), Frerichs & others (1975, 1977), and Frerichs (1979, 1980) as *Rugoglobigerina*; and by Petters (1977, 1980) as *Whiteinella.*

The Santonian-Campanian taxa from Western Australia under discussion are characterised by meridional ornamentation, globular chambers, an interiomarginal umbilical to slightly extraumbilical aperture, and portici developed to different degrees. As noted by Petters (1977) the original description of the Western Australian specimens given by Belford (1960) was in error in describing the umbilical extensions as tegilla. The possibility that the structures observed result from broken tegilla is considered unlikely because specimens of *Globotruncana* in the same faunas have well-preserved tegilla.

BRIEF REVIEW OF COSTELLATE ORNAMENTATION

McNulty & Barr (1979) distinguished between costellae arranged parallel to the periphery (equatorial) and costellae converging on the distal pole of a chamber (meridional). They discussed meridionally costellate ornamentation of hedbergellid foraminifera, including the taxomonic use of this type of ornamentation, the stratigraphic range of taxa with this feature, and possible causes for its development; they cited papers by Fondecave (1975), Barr (1972), Saint-Marc (1973), and Caron (1978), all of whom figured taxa with costellate ornamentation. As noted by McNulty & Barr, meridionally costellate ornamentation had been regarded as an evolutionary development in the Campanian-Maastrichtian, but evidence that it appeared much earlier came with the description of species such as *Hedbergella libyca* Barr, 1972 (?late Albian-Cenomanian) and *H. costellata* Saint-Marc, 1973 (middle Cenomanian, placed by McNulty & Barr in the synonymy of *H. libyca*).

McNulty & Barr, referring to taxa recognised by Caron (1978), noted that she reported meridional costellation for diverse taxa—including a new species, *Hedbergella angolae*—from the middle to late Albian. However, in remarks on *H. angolae*, Caron noted that the species shows coarse pustulae oriented along lines parallel to the periphery of each chamber (note the term 'pustulae' and not 'costellae', a description borne out by illustration of *H. angolae*). This type of ornamentation is that classed by McNulty & Barr as equatorial. Caron also noted that this distinctive ornamentation is found on other ornamented species occurring at the same level as *H. angolae*—*H. costellata*, *Whiteinella baltica*, and *W. bornholmensis*. The specimen figured by Caron (plate 4, figs. 1–3) as *H. costellata* has a pustulose rather than costellate ornamentation; that figured as *H.* cf. *costellata* (Caron, 1978, plate 4, figs. 8, 9) has a costellate ornamentation, at least on the early chambers of the last whorl, but in an equatorial rather than meridional arrangement. It appears that meridional ornamentation is not developed on any of the taxa figured by Caron. According to the emended definition given by Banner & Blow (1959) the presence of costellae excludes forms from the genus *Hedbergella.*

Saint-Marc (1973) suggested that meridional costellation may have arisen from response to ecological factors—the inner neritic environment. Caron (1978) also suggested that development of the costellae was related not to a definite stage of *Hedbergella* evolution but to external factors resulting from a neritic environment. McNulty & Barr (1979) doubted the neritic environment inferred by Caron for her specimens.

Blow (1979, part 2, section 2, p. 1366) referred to the genetic potential of the genus *Rugoglobigerina* to produce muricate wall surfaces. Both Blow (1979) and McNulty & Barr (1979) noted that costellae arise from the coalescence of pustules ('muricae' of Blow). Olsson (1964) also discussed formation of the rugosities, which he regarded as coarse flattened spines appearing as thin ridges when only the bases of spines are preserved; he noted that the meridional arrangement is the most efficient packing pattern available. Blow (1979) considered that the organisation of the muricae varies in the ontogeny of individual members of a taxon and in a population, both in response to habitat. He considered that meridional ornamentation is characteristic of tropical/equatorial regions, and that the same taxon in extratropical regions shows less distinctly linearly arranged ornamentation, which is more randomly arranged over the surface of the test. He stated that the costellae are poorly developed in juveniles even in fully tropical regions, but this is not borne out by small specimens of *R. pilula* from Western Australia (see Plate 3, figs. 4, 5). The development of the costellae does appear to result from secondary fusing, and they are strongest on early chambers of the test.

The taxonomic significance of meridional ornamentation has received different interpretations. El-Naggar (1971a) regarded it as of no more than subgeneric importance. Olsson (1964) and Kassab (1976) regarded it as only of specific importance. Pessagno (1967) disagreed with this, regarding meridional rugosity as a 'complex morphological feature which is governed by an equally complex genetic code'. As noted above, Blow (1979) regarded the muricae, which fuse to form the costellae, as resulting from genetic factors. The occurrence of many smooth or finely pustulose taxa together with costellate forms—for example, in Western Australia—implies that costellae result from factors other than purely environmental influences. A genetic potential for producing a muricate wall surface would explain the restricted development of this kind of ornamentation. As noted by Blow the costellae may vary in different environments, but I do not believe that environmental factors are the cause of their development. The taxonomic level at which meridional ornamentation is to be applied to classification is a subjective decision, but in my view it should be used, together with other morphological features, at the generic level.

GENERIC DESIGNATION OF THE WESTERN AUSTRALIAN FORMS

Of the three species from Western Australia originally described as *Rugoglobigerina*, two—*R. bulbosa* and *R. pilula*—have an essentially umbilical aperture, tending towards extraumbilical. The third species, *R. plana*, has an extraumbilical aperture. Portici are developed in *R. bulbosa* and *R. pilula*, and narrow apertural lips (?reduced portici) occur in *R. plana*. The genus *Rugoglobigerina* was originally described as having an umbilical aperture; it also has a complex tegillum. Masters (1977) described the aperture as umbilical-extraumbilical; he placed the species *R. bulbosa* and *R. pilula* in the synonymy of *R. rugosa*, and *R. plana* in the synonymy of *R. hexacamerata*. These synonymies are not accepted here. *R. bulbosa* and *R. pilula* differ from *R. rugosa* in the extraumbilical tendency of the aperture, and in lacking a tegillum. *R. plana* has an extraumbilical aperture whereas *R. hexacamerata* has an umbilical aperture; *R. plana* also lacks a well-developed meridional ornamentation, as noted in the original description.

The three Western Australian species under review are no longer considered to be referable to *Rugoglobigerina*: *R. plana* is here placed in *Hedbergella*; the problem is where to place the species *bulbosa* and *pilula*.

The genus *Archaeoglobigerina* as originally defined (Pessagno, 1967) excludes species with meridional ornamentation. Masters (1977) placed *Archaeoglobigerina* (part) in the synonymy of *Globotruncana*, and Petters (1977) noted that at least one species described as *Archaeoglobigerina* is now referred to *Globotruncana*. Petters (1977, plate 3, fig. 16) figured as *Archaeoglobigerina tradinghousensis* (Pessagno) a specimen which in ventral view is very similar to some specimens of *Rugoglobigerina bulbosa* Belford but is not as markedly costellate. Frerichs & others (1977) placed *R. tradinghousensis* Pessagno in the synonymy of *R. pilula*.

Two other genera into which meridionally ornamented forms have been placed are *Whiteinella* Pessagno, 1967 and *Loeblichella* Pessagno, 1967. In his original generic description of *Whiteinella*, Pessagno (1967) made no reference to ornamentation of the test; he did, however, describe the type species—*W. archaeocretacea*—as coarsely rugose, but did not specify the nature of the rugosity. According to Dr S. Petters (University of Ibadan, personal communication, August 1981) the early chambers have a weak meridional alignment. Pessagno (1967) stated that *Whiteinella* often has an imperforate peripheral band, but did not mention this feature in *W. archaeocretacea*; illustrations of the type specimens indicate some compression of the periphery. Petters (1977) stated that *Whiteinella* lacks an imperforate peripheral band, and figured as *Whiteinella* specimens with subglobular chambers and meridionally costellate ornamentation; not all members of the bioseries discussed by Petters have a meridional ornamentation. Douglas (1969) noted that *Whiteinella* includes forms similar to *Hedbergella*, and doubted that separate generic status for *Whiteinella* was warranted. El-Naggar (1971b) placed *Whiteinella* in part in the synonymy of *Archaeoglobigerina* and part in the synonymy of *Hedbergella*; Longoria & Gamper (1975) placed *Whiteinella* in the synonymy of *Helvetoglobotruncana*; and Masters (1977) placed *Whiteinella* (part) in the synonymy of *Globotruncana*.

According to the original generic description, *Loeblichella* Pessagno, 1967 lacks an imperforate peripheral band or carina and has supplementary sutural apertures; Pessagno (1967) made no mention of test ornamentation, but described the type species, *L. hessi* (Pessagno), as coarsely rugose. Dr S. Petters (personal communication, August 1981) stated that types which he has examined have definite test compression, and are lightly pustulose in early chambers and smooth in later chambers. Pessagno (1962) did not note the supplementary apertures in *Praeglobotruncana hessi hessi*, the type species of *Loeblichella*, but indicated (1967) that they are difficult to see except on well-preserved specimens. Masters (1977) stated that an examination of the types of *P. hessi hessi* did not disclose any supplementary apertures; he also noted that the exact status of the species is unclear because the primary types are poorly preserved, probably internal moulds, but placed *Loeblichella* in the synonymy of *Globigerina*. Douglas (1969) reported that he could not detect sutural openings in the type specimens; he further stated that only four of 250 well-preserved specimens that he had examined had some sort of opening on the spiral side. Douglas concluded that these rare sutural openings appear to be a special form of relict aperture, with limited taxonomic value. Longoria (1974) also considered that the sutural apertures are relict apertures, or vestiges of the spiroumbilical primary aperture left uncovered by younger chambers. In this connection it may be noted that Longoria, in emending the definition of *Hedbergella*, stated that relict apertures are often present on the spiral side.

Blow (1979), in a section on the nature and position of apertures in the Globigerinacea, referred to adventitious sutural openings in muricate forms. He described them as developing where the muricae interfere with the areas of adherence of subsequently calcified chambers, and regarded them as of no value in taxonomy. This mechanism gives another possibility for the origin of the supplementary sutural apertures of *Loeblichella*, if they exist.

Douglas (1969) and El-Naggar (1971b) regarded *Loeblichella* as a junior synonym of *Hedbergella*. De Vries (1977) also placed *L. hessi* in *Hedbergella*, and observed only one specimen with supplementary sutural apertures. Kassab (1976) noted meridional rugosities on specimens identified as *Loeblichella hessi* from the late Campanian and Maastrichtian of Iraq, and emended the description of *Loeblichella* to include this feature. However, meridionally arranged rugosities have not been reported from the type specimens. Dr S. Petters (personal communication, August 1981) considered that the specimens that Kassab referred to *Loeblichella* should be placed in *Rugoglobigerina*. Longoria (1974) also emended the description of *Loeblichella*, noting the compression of the test and the smooth to pustulose surface, but did not discuss the arrangement of the ornamentation. Frerichs (1979) and Frerichs & Dring (1981) placed the species *hessi* Pessagno in the genus *Whiteinella*, presumably regarding *Whiteinella* and *Loeblichella* as synonyms.

It is apparent that the generic diagnoses of the Late Cretaceous globigerine taxa are at present unsatisfactory, particularly as regards apertural characters and test ornamentation. These features should be examined with reference to the type material and additional topotypic specimens in the genera *Whiteinella* and *Loeblichella*. It is not intended here to propose any additional generic category to accommodate the Western Australian specimens originally described as *Rugoglobigerina bulbosa* and *R. pilula*, and in spite of any need for revision of existing generic descriptions they are here referred to the genus *Whiteinella*. Dr S. Petters (personal communication, August 1981) is revising the taxonomy of the costellate planktonic foraminifera of the Late Cretaceous, and a new genus may be necessary to accommodate specimens such as those from Western Australia. An objection to the use of the *Whiteinella* is the compression of the type forms, although subsequent workers have placed forms with subglobular chambers in this genus. The genus *Loeblichella* is not used because of the definite test compression of the types, and the uncertainty regarding the supplementary sutural apertures. Correction of the erroneous reference of the Western Australian forms to the genus *Rugoglobigerina* removes one record of a Santonian occurrence of this genus, which has been regarded as a Campanian-Maastrichtian index. Other records of *Rugoglobigerina* in beds of Santonian age should be reviewed in order that the biostratigraphic significance of this genus can be established.

ACKNOWLEDGEMENTS

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SAMPLE LOCALITIES

MR44. Scarp at Toolonga Point, Murchison River area, Western Australia, 2.4 m above base of Toolonga Calcilutite.

MR50. Scarp at Pillarawa Hill, Murchison River area, Western Australia, 4.3 m above base of Toolonga Calcilutite.

71640040. Scarp at Pillarawa Hill, Murchison River area, 4.5 m above base of Toolonga Calcilutite.

71640043. Scarp at Pillarawa Hill, Murchison River area, 7.5 m above base of Toolonga Calcilutite.

71640044. Scarp at Pillarawa Hill, Murchison River area, 8.5 m above base of Toolonga Calcilutite.

REFERENCES

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

Barr, F. T., 1972—Cretaceous biostratigraphy and planktonic foraminifera of Libya. *Micropaleontology*, 18(1), 1-46.

Belford, D. J., 1960—Upper Cretaceous foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 57.

Blow, W. H., 1979—THE CAINOZOIC GLOBIGERINIDA, 3 volumes. *E. J. Brill, Leiden.*

Caron, Michèle, 1978—Cretaceous planktonic foraminifers from DSDP Leg 40, southeastern Atlantic Ocean; *in* Bolli, H. M., Ryan, W. B. F., & others—Initial reports of the Deep Sea Drilling Project, Volume 40. *US Government Printing Office, Washington*, 651-678.

de Vries, H. E., 1977—Late Cenomanian to early Turonian planktonic foraminifera from a section SE of Javernant (Dept. Aube, France). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen*, Series B, 80 (1), 23-38.

Douglas, R., 1969—Upper Cretaceous planktonic foraminifera in northern California. Part 1—systematics. *Micropaleontology*, 15(2), 151-209.

Douglas, R., & Sliter, W. V., 1966—Regional distribution of some Cretaceous Rotaliporidae and Globotruncanidae (Foraminiferida) within North America. *Tulane Studies in Geology*, 4(3), 89-131.

El-Naggar, Z. R., 1971a—The genus *Rugoglobigerina* in the Maastrichtian Sharawna Shale of Egypt; *in* Proceedings of the 2nd Planktonic Conference, Rome, 1970. Part 1. *Edizioni Tecnoscienza, Rome*, 477-537.

El-Naggar, Z. R., 1971b—On the classification, evolution and stratigraphical distribution of the Globigerinacea; *in* Proceedings of the 2nd Planktonic Conference, Rome, 1970, Part 1. *Edizioni Tecnoscienza, Rome*, 421-476.

Fondecave, M. J., 1975—Essai de biozonation par les Foraminifères pelagiques du Sénonien sud-pyreneen. Description d'une nouvelle espèce 'Hedbergella aubertae n. sp.' *Geologie Mediterraneenne,* 2, 5-10.

Frerichs, W. E., 1979—Planktonic foraminifera from the Sage Breaks Shale, Centennial Valley, Wyoming. *Journal of Foraminiferal Research,* 9(2), 159-184.

Frerichs, W. E., 1980—Age of the western interior *Clioscaphites chouteauensis* Zone. *Journal of Paleontology,* 54(2), 336-370.

Frerichs, W. E., Atherton, C. C., & Shive, P. N., 1975—Planktonic foraminifera from the chalky member of the Niobrara Formation. *Journal of Foraminiferal Research,* 5(4), 294-312.

Frerichs, W. E., & Dring, Nancy B., 1981—Planktonic foraminifera from the Smoky Hill Shale of west central Kansas. *Journal of Foraminiferal Research,* 11(1), 47-69.

Frerichs, W. E., Pokras, E. M., & Evetts, M. J., 1977—The genus *Hastigerinoides* and its significance in the biostratigraphy of the western interior. *Journal of Foraminiferal Research,* 7(2), 149-156.

Kassab, I. I. M., 1976—Some Upper Cretaceous planktonic foraminiferal genera from northern Iraq. *Micropaleontology,* 22(2), 215-238.

Longoria, J. F., 1974—Stratigraphic, morphologic and taxonomic studies of Aptian planktonic foraminifera. *Revista Española de Micropaleontologia, Numero Extraordinario,* 1-107.

Longoria, J. F., & Gamper, Martha A., 1975—The classification and evolution of Cretaceous planktonic foraminifera. Part 1: the superfamily Hedbergelloidea. *Revista Española de Micropaleontologia, Numero Especial,* 61-96.

McNulty, C. L. Jr, 1976—*Globotruncana fornicata* Zone of upper Austin Group (Cretaceous), northeast Texas. *Bulletin of the American Association of Petroleum Geologists,* 60, 2058-2062.

McNulty, C. L., & Barr, F. T., 1979—Meridionally costellate hedbergellid foraminifers from the western Atlantic, Deep Sea Drilling Project, Leg 43, Site 386. *Gulf Coast Association of Geological Societies, Transactions of the 29th Annual Meeting,* 302-305.

Masters, B. A., 1977—Mesozoic planktonic foraminifera. *Oceanic Micropalaeontology,* 1, 301-731.

Olsson, R. K., 1964—Late Cretaceous planktonic foraminifera from New Jersey and Delaware. *Micropaleontology,* 10(2), 157-188.

Pessagno, E. A. Jr, 1962—The Upper Cretaceous stratigraphy and micropaleontology of south-central Puerto Rico. *Micropaleontology,* 8(3), 349-368.

Pessagno, E. A. Jr, 1967—Upper Cretaceous planktonic foraminifera from the western Gulf coastal plain. *Palaeontographica Americana,* 5(37), 245-445.

Petters, S. W., 1977—Upper Cretaceous planktonic foraminifera from the subsurface of the Atlantic Coastal Plain of New Jersey. *Journal of Foraminiferal Research,* 7(3), 165-187.

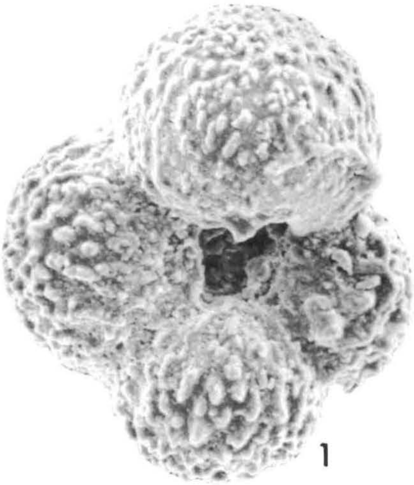
Petters, S. W., 1980—Biostratigraphy of Upper Cretaceous foraminifera of the Benue Trough, Nigeria. *Journal of Foraminiferal Research,* 10(1), 191-204.

Saint-Marc, P., 1973—Presence de *Hedbergella* a 'costellae' dans le Cenomanien moyen du Liban. *Journal of Foraminiferal Research,* 3(1), 7-12.

Takayanagi, Y., 1965—Upper Cretaceous planktonic foraminifera from the Putah Creek subsurface section along the Yolo-Solano County Line, California. *Science Reports of the Tohoku University, 2nd Series (Geology),* 36(2), 161-237.

PLATE 1

Figs.	
1–3	**Whiteinella bulbosa** (Belford) CPC 22092, sample MR50: 1, ventral view, showing remnants of porticus, and extraumbilical tendency of aperture; 2, dorsal view; 3, edge view. All x200.
4–6	**Whiteinella bulbosa** (Belford) CPC 22093, sample 71640044: 4, ventral view; 5, dorsal view; 6, edge view. All x200.
7	**Whiteinella bulbosa** (Belford) CPC 22094, sample 71640043: ventral view showing well-developed portici and markedly umbilicate aperture, x200.
8	**Whiteinella bulbosa** (Belford) CPC 22095, sample MR50: ventral view showing umbilical-extraumbilical aperture, x200.
9	**Whiteinella bulbosa** (Belford) CPC 22096, sample 71640040: ventral view showing porticus on final chamber, x200.
10	**Whiteinella bulbosa** (Belford) CPC 22097, sample 71640044: ventral view of small specimen showing umbilical-extraumbilical aperture, x200.
11	**Whiteinella bulbosa** (Belford) CPC 22098, sample 71640044: ventral view showing umbilical-extraumbilical aperture, x200.
12	**Whiteinella bulbosa** (Belford) Aperture of specimen shown in figure 7, x465.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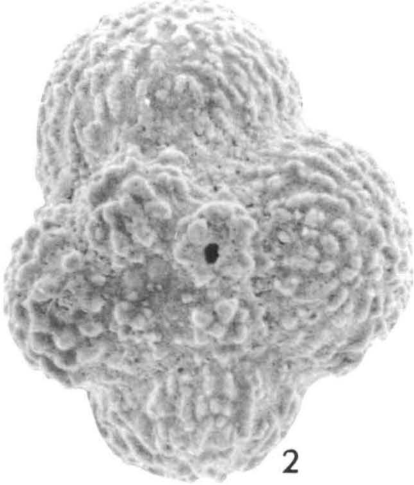
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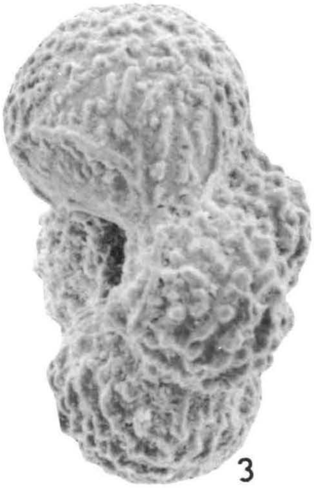
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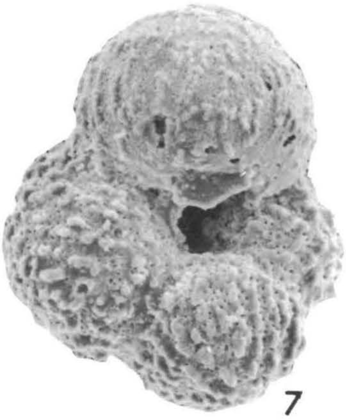
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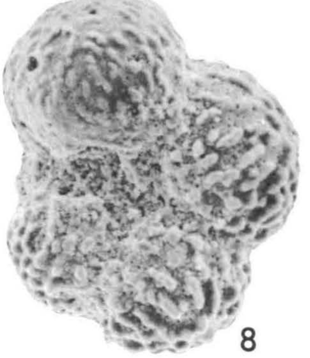
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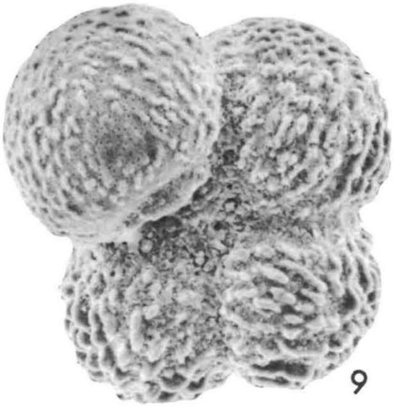
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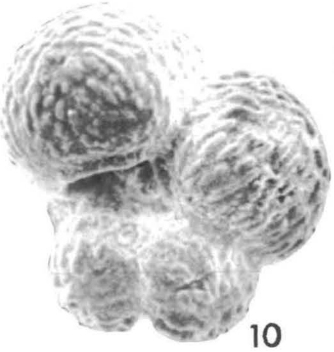
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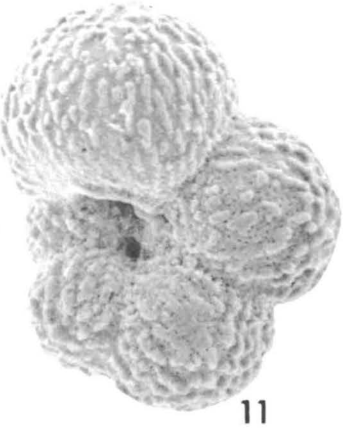
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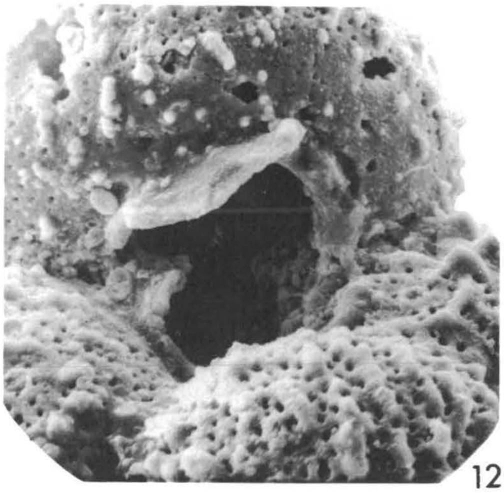
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PLATE 2

Figs.

1	**Whiteinella bulbosa** (Belford) Aperture of specimen shown in Plate 1, figure 9, showing extraumbilical tendency, x465.
2	**Whiteinella bulbosa** (Belford) Aperture of specimen shown in Plate 1, figure 11, showing extraumbilical development, x465.
3–5	**Whiteinella pilula** (Belford) CPC 22099, sample MR50: 3, ventral view showing umbilical-extraumbilical aperture; 4, dorsal view; 5, edge view. All x200.
6, 7	**Whiteinella pilula** (Belford) CPC 22100, sample MR50: 6, ventral view; 7, dorsal view, showing markedly costellate ornamentation on early chambers. Both x200.
8	**Whiteinella pilula** (Belford) Aperture of specimen shown in figures 3–5, showing extraumbilical development, x465.


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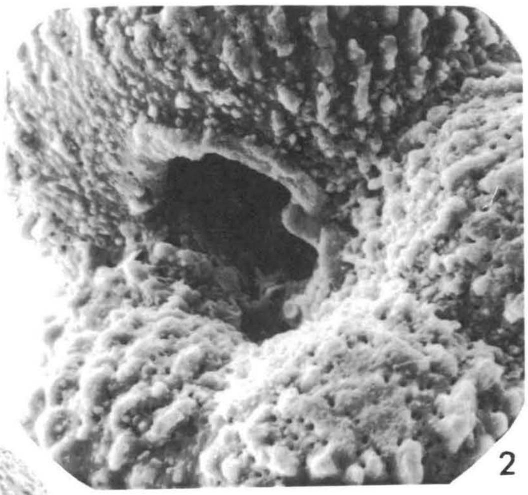
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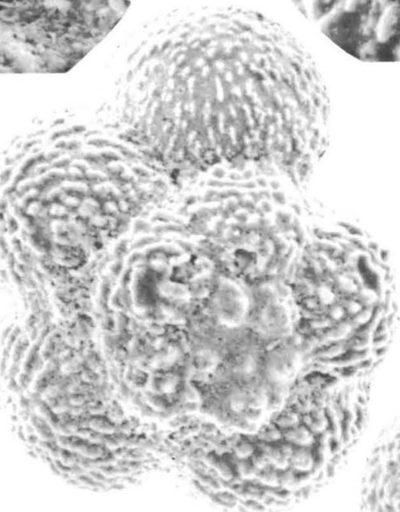
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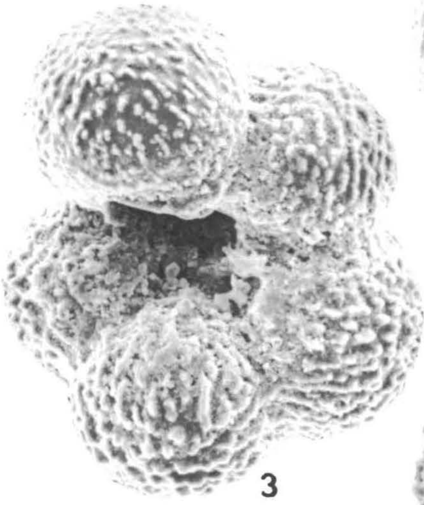
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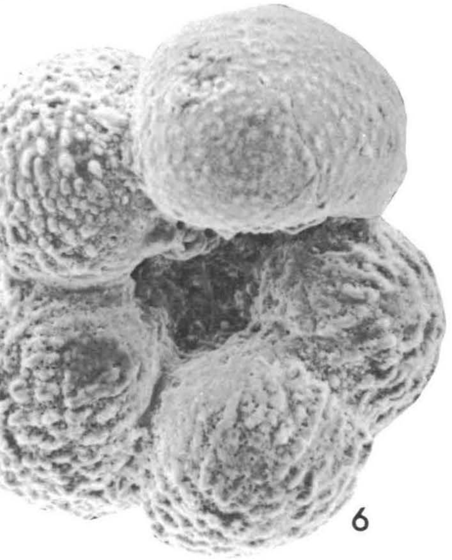
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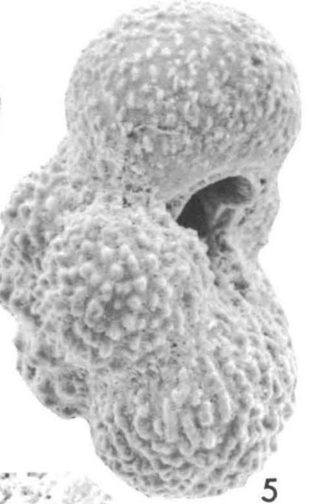
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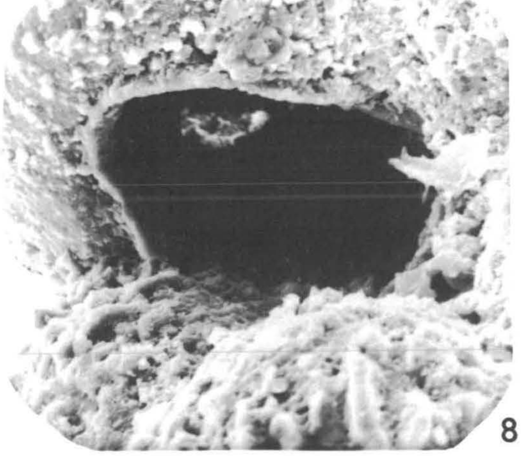
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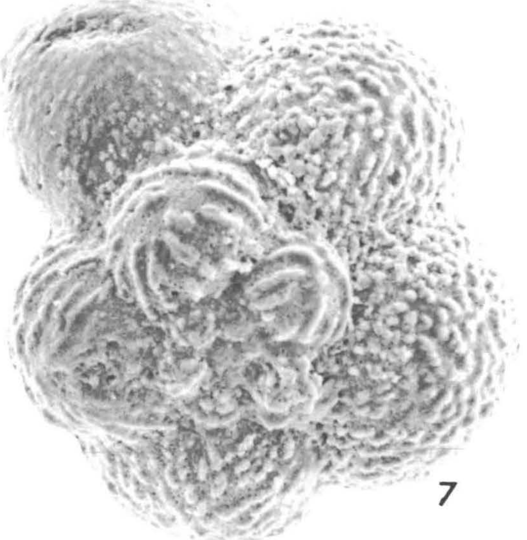
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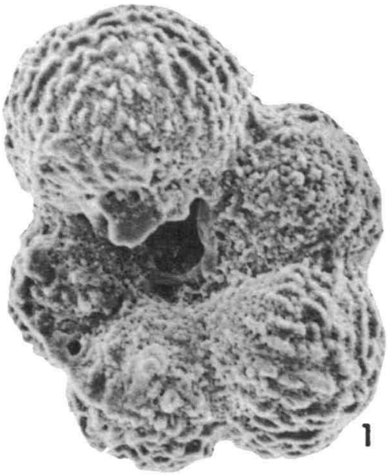
PLATE 3

Figs.

1, 2	**Whiteinella pilula** (Belford) CPC 22101, sample 71640043: 1, ventral view, showing portici; 2, aperture showing extraumbilical development. 1, x200; 2, x465.
3	**Whiteinella pilula** (Belford) CPC 22102, sample 71640043: aperture showing extraumbilical development, x465.
4, 5	**Whiteinella pilula** (Belford) CPC 22103 and 22104, sample 71640044: ventral views of small specimens showing extraumbilical aperture and costellate ornamentation, both x150.
6, 7, 11	**Hedbergella plana** (Belford) Holotype, CPC 3403, sample MR44: 6, ventral view, showing extraumbilical aperture; 7, edge view; 11, aperture. 6, 7, x200; 11, x465.
8	**Hedbergella plana** (Belford) CPC 22105, sample MR50: showing extraumbilical aperture, x200.
9, 10	**Hedbergella plana** (Belford) CPC 22106, sample MR44: 9, ventral view showing extraumbilical aperture; 10, edge view. Both x200.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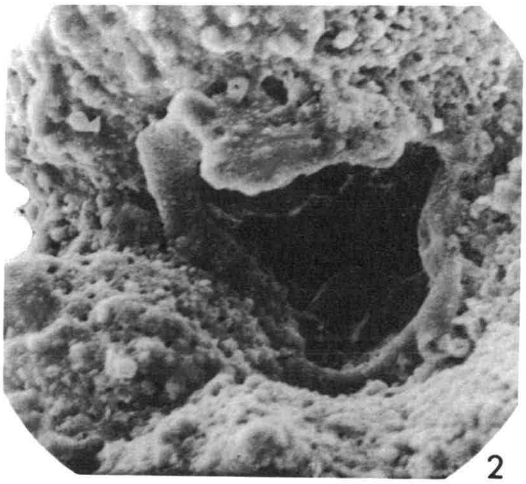
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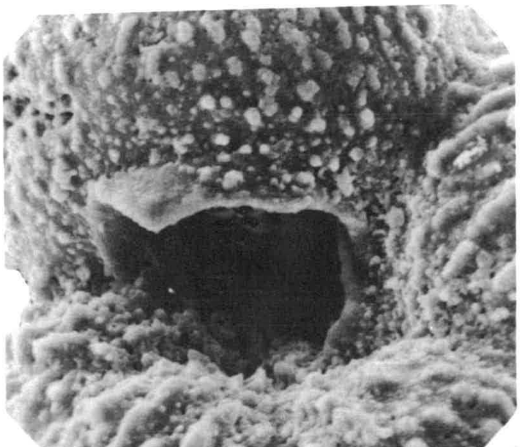
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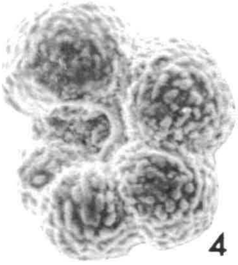
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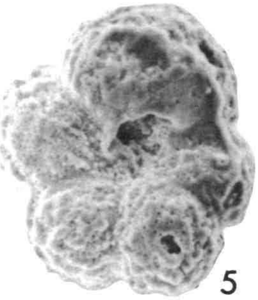
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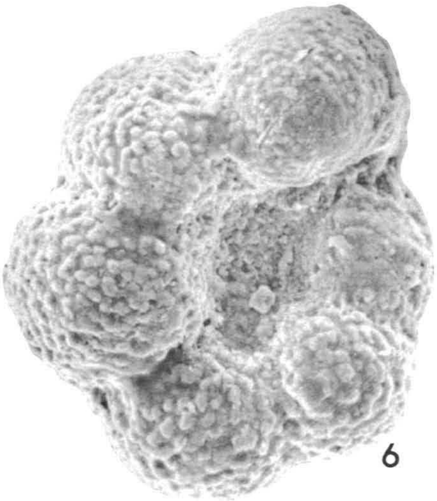
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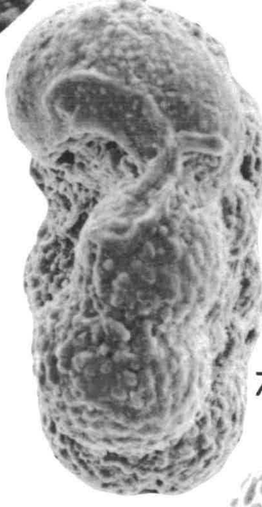
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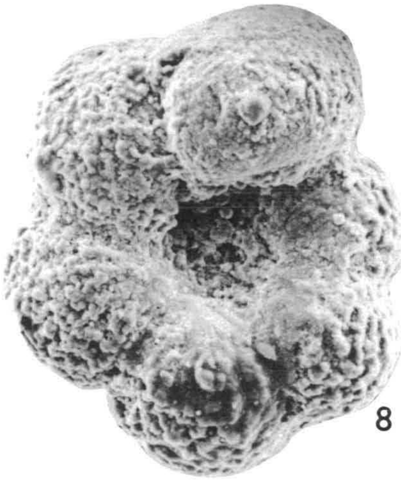
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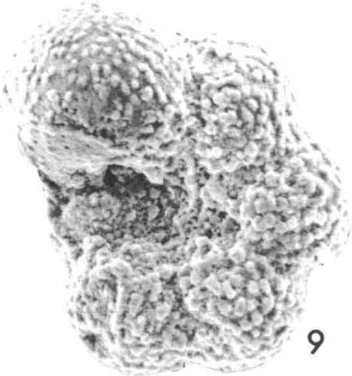
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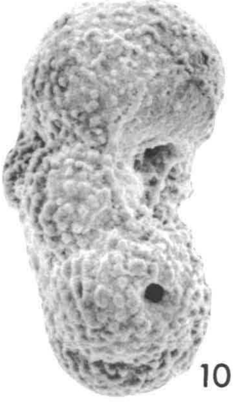
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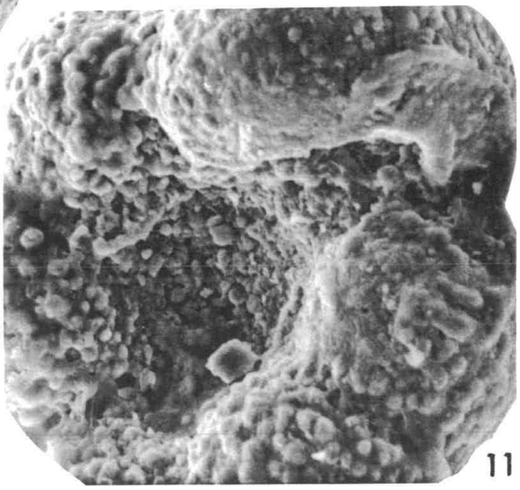
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A probably Coniacian (Late Cretaceous) foraminiferal fauna, Carnarvon Basin, Western Australia

D. J. Belford

BELFORD, D. J., 1983—A probably Coniacian (Late Cretaceous) foraminiferal fauna, Carnarvon Basin, Western Australia; *in* Palaeontological papers 1983. *Bureau of Mineral Resources, Australia, Bulletin* 217, 11-27.

ABSTRACT

The planktonic foraminiferal fauna from a sample collected at a dam site on Cardabia station, south of the type section of the Korojon Calcarenite, is figured and discussed. A Coniacian age is most probable but not definitely established. The occurrence of beds of this age would reduce the inferred duration of the hiatus between the Gearle Siltstone and the beginning of carbonate sedimentation in the Giralia Anticline area.

INTRODUCTION

This paper records the planktonic foraminiferal fauna from a sample collected by G. C. H. Chaproniere at a dam site 9 km east of No. 10 bore, Cardabia station, Western Australia (Fig. 1). This sample provides further evidence for the age of carbonate beds in the area of the Giralia Anticline.

The Korojon Calcarenite, first defined by Condon & others (1956), crops out in the type section in C-Y Creek—at latitude 22°53′S, longitude 114°07′E—to the north of the present locality. Condon (1968) modified the original definition, and noted (p. 33) that the Korojon Calcarenite in the type section rests on 30 m (100 feet) of Toolonga Calcilutite, not on the Gearle Siltstone as originally stated. The Korojon Calcarenite, as originally defined, is, on foraminiferal evidence, Campanian to early Maastrichtian in age (Edgell, 1954, 1957; Belford, 1958), although Condon (1968) continued to give a Santonian to Campanian age on ammonite evidence. Edgell (1962) recorded *Globotruncana concavata carinata* from beds below the Korojon Calcarenite as defined; he considered these beds to be Santonian in age, and recognised the possibility of the Toolonga Calcilutite occurring between the Gearle Siltstone and the Korojon Calcarenite. These are probably the beds that Condon (1968) referred to the Toolonga Calcilutite. Hooper (1977), in describing a new species of *Globotruncana*, regarded the beds (referred to the Toolonga Calcilutite) in which his specimens were found as Santonian-Campanian transition beds. Clark (1979) recognised Santonian beds referred to the Toolonga Calcilutite below the Korojon Calcarenite in C-Y Creek.

The formation represented by the sample from Cardabia station is not known, but it could well be from the Toolonga Calcilutite. The distinction between the Toolonga Calcilutite and the Korojon Calcarenite, and also the relation between them, was discussed by Condon (1968). Van de Graaff & others (1977) showed the location of the excavation from which the sample was obtained as being within the Toolonga Calcilutite.

The fauna of this sample, containing species not recorded previously from the Giralia Anticline, suggests that the age of the carbonate beds could extend down into the Coniacian. The age significance of the fauna is discussed below.

ACKNOWLEDGEMENTS

I wish to thank Dr Viera Scheibnerová for her constructive criticism of the manuscript.

ANNOTATED LIST OF PLANKTONIC FORAMINIFERA

In this list, only the original reference to each species is given, followed by a reference to illustrations in this paper. Figured specimens are deposited in the Commonwealth Palaeontological Collection, Canberra, ACT, under numbers 22107 to 22143.

Genus **Globotruncana** Cushman, 1927

Type species: *Pulvinulina arca* Cushman, 1926.

Globotruncana angusticarinata Gandolfi, 1942: *Globotruncana linnei* d'Orbigny var. *angusticarinata* Gandolfi, 1942, pp. 126, 150, 153, pl. 4, figs. 17, 30; text-fig. 46, 3a–c (Pl. 1, figs. 1–8)

Most specimens here referred to *G. angusticarinata* are of the type that Frerichs (1979) figured with a low biconvex test and with indistinct ventral sutures on the early chambers of the last whorl; the later chambers have arcuate sutures.

Considerable variation is shown in published figures of specimens referred to *G. angusticarinata*, and conflicting views have been expressed concerning the possible synonymy of *G. renzi* and *G. angusticarinata*. Masters (1977) regarded *angusticarinata* as a synonym of *renzi*. Caron (1966) and Caron & Luterbacher (1969), who reported that the holotype of *G. angusticarinata* has been lost, stated that *G. renzi* is single-keeled in the last whorl, but noted that a narrow double keel may persist on the oldest chambers of the last whorl. A double keel is shown on the early chambers of the holotype of *G. renzi*, and also on the specimen figured by Caron (1966). Caron and Caron & Luterbacher described *G. angusticarinata* as having two keels, which vary in the degree of separation along the chamber margin. The specimen of *angusticarinata* figured by Caron (1966) has a more convex dorsal surface than the specimens from the Western Australian sample. Others who have retained the name *angusticarinata* are Frerichs (1979) and Hanzlíková (1972). The specimens figured by Hanzlíková are very compressed, and their keels are narrowly separated; they are unlike the specimens from Western Australia referred to *angusticarinata*.

The total stratigraphic range of *G. angusticarinata*, compiled from several publications, is Turonian to Campanian. The specimen with sharply curved ventral sutures figured by Barr (1972) is from the Coniacian

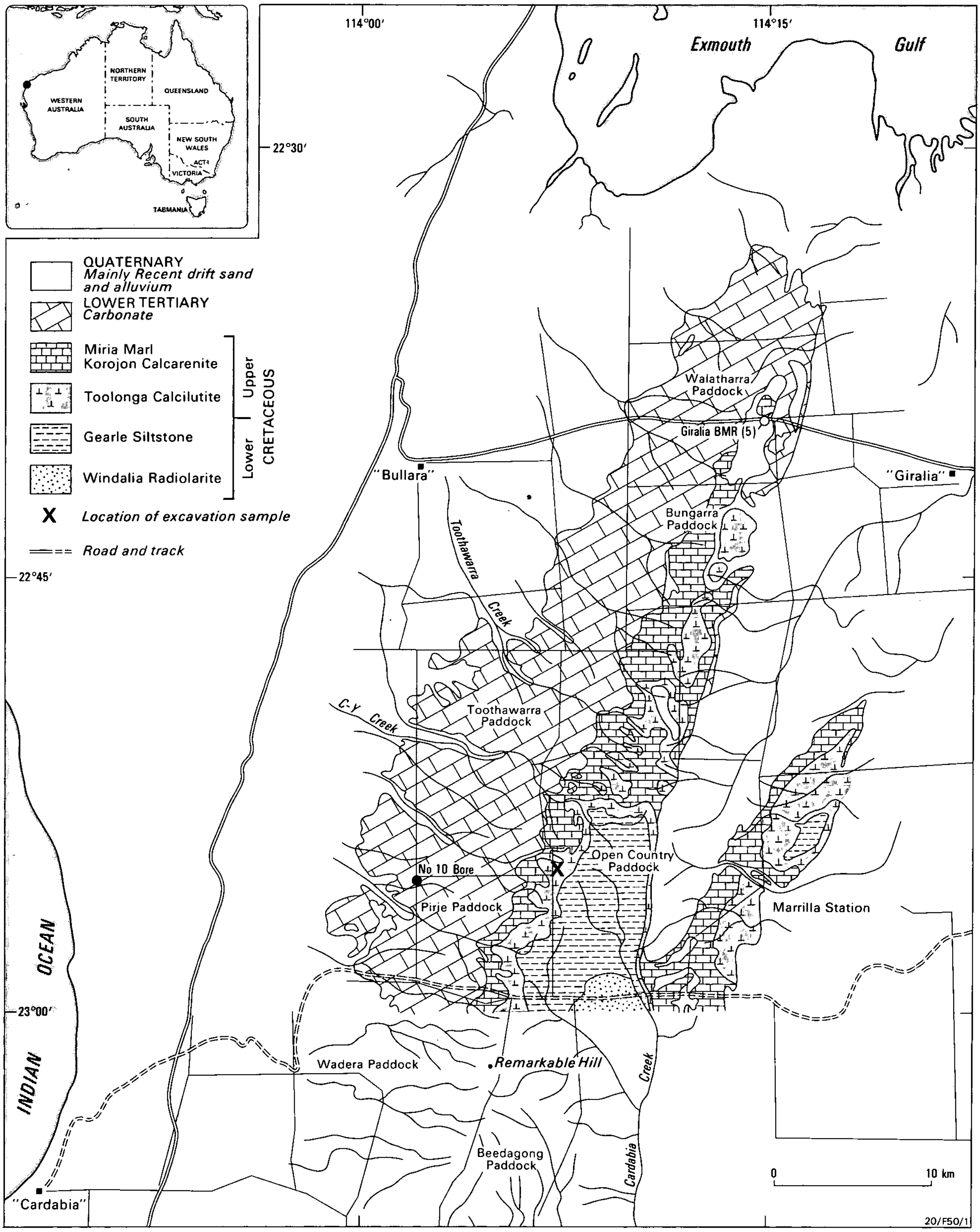

Fig. 1. Location of excavation sample, Giralia Anticline.

of Libya, but the total range in Libya is uppermost Turonian to Santonian. Frerichs (1979) recorded *G. angusticarinata* from the Coniacian interval of the Sage Breaks Shale, Wyoming, but stated that the occurrence was environmentally controlled.

Globotruncana concavata cyrenaica Barr, 1972, p. 19, pl. 8, figs. 1a–d, 2a–c (Pl. 1, figs. 9–12)

Only one specimen referred to this subspecies is evident in the Western Australian sample. It has six chambers in the last whorl and two closely spaced keels which merge into one keel on the later chambers. The dorsal surface is slightly concave, except for a small raised central area, and the surface of the dorsal chambers is depressed below the sutures. The ventral surface is strongly convex. The dorsal sutures are raised and curved, and the ventral sutures radial, smooth, or depressed. The dorsal surface is smooth, and the ventral surface coarsely hispid. The umbilicus is wide and deep, and has remnants of tegilla around the umbilical margin.

G. concavata cyrenaica was described from the earliest Coniacian of Libya.

Globotruncana coronata Bolli, 1945; *Globotruncana lapparenti* Brotzen *coronata* Bolli, 1945; p. 233, pl. 9, figs. 14–15; text-fig. 1, 21–22 (Pl. 1, figs. 13–18)

Abundant large, low trochospiral biconvex specimens from the Western Australian sample are referred to *G. coronata*. The test has two distinct keels, which, in several specimens, are closer together or have merged on the last one or two chambers. The last whorl has seven or eight chambers, and the dorsal chamber surface is inflated. The umbilicus is wide and deep; the aperture is interiomarginal umbilical, and only remnants of the tegilla are preserved. The specimens are similar to those figured by Douglas & Sliter (1966), Douglas (1969), Barr (1972), Hanzlíková (1972), Frerichs (1979), and Peryt (1980).

Douglas (1969) reported that *G. coronata* ranges from Turonian to possibly Campanian but is generally considered an index of the late Turonian-Santonian; he showed it as ranging from Coniacian to earliest Campanian in northern California. Hanzlíková (1972) also noted that *G. coronata* is universally regarded as the Turonian-Santonian index species, and recorded it from the Coniacian-Santonian of Moravia and the west Carpathians. *G. coronata* was recorded from the Coniacian-Santonian interval of the Sage Breaks Shale by Frerichs (1979), and from the latest Turonian-Santonian of Libya by Barr (1972). Pessagno (1967) documented the range of *G. coronata* as Turonian-lower Santonian, and noted that it is abundant in upper Turonian and Coniacian strata.

Globotruncana cretacea (d'Orbigny, 1840): *Globigerina cretacea* d'Orbigny, 1840, p. 34, pl. 3, figs. 12–14 (Pl. 2, figs. 1–8)

Banner & Blow (1960) demonstrated that d'Orbigny's species is to be referred to *Globotruncana*, and designated a lectotype. The specimens from the Western Australian sample agree well with the description and figure published by Banner & Blow. In the last whorl, they have five or six globular chambers with depressed slightly curved dorsal sutures and depressed radial ventral sutures. The surface of the test is pustulose; on most specimens the keels are not as distinct as those on the specimen figured by Banner & Blow, but all specimens have a distinct imperforate peripheral band.

Banner & Blow concluded that *G. cretacea* ranges from Coniacian to Campanian. Masters (1977) listed an extensive synonymy for *G. cretacea* and documented its range as Turonian to Maastrichtian. Douglas & Sliter (1966) reported a range of Coniacian to early Maastrichtian, and Douglas (1969) showed the species as ranging from Santonian to earliest Maastrichtian. Van Hinte (1963) recorded a Santonian to Campanian range in the Krappfeld region of Austria. Tollman (1960) specified a range of Turonian to late Campanian of Europe for *G. globigerinoides*, and noted that it is most abundant in the Coniacian and Santonian; this species is regarded as a synonym of *G. cretacea.*

Globotruncana dentata Hooper, 1977, p. 362, pl. 1, figs. 1a–c, 2a–c, 3a–c, 4a–b (Pl. 2, figs. 9–14)

G. dentata is rare in the sample. Although Hooper noted that *G. dentata* is commonly single-keeled in the last whorl, he stated in his caption to plate 1 that the double keel has merged into a single keel in the final part of the last whorl, a feature shown by the Western Australian specimens. Other features of the specimens are as described by Hooper for *G. dentata.*

Globotruncana marginata (Reuss, 1845): *Rosalina marginata* Reuss, 1845, p. 36, pl. 8, figs. 54, 74; pl. 13, fig. 68 (Pl. 2, figs. 15–20)

G. marginata is rare in the sample. It is distinguished from *G. cretacea* by its less globular chambers and more strongly developed keels. The two specimens figured show the morphological extremes of specimens referred to *marginata.*

G. marginata is a long-ranging species, being recorded from the Turonian to the Maastrichtian.

Globotruncana pseudolinneiana (Pessagno, 1967); *Marginotruncana pseudolinneiana* Pessagno, 1967, p. 310, pl. 65, figs. 24–27; pl. 76, figs. 1–3 (Pl. 3, figs. 1–14)

Included here are double-keeled, flat forms recorded by various authors under the names *G. lapparenti*, *G. linneiana*, and *G. pseudolinneiana.* Douglas (1969) discussed the distinction between these species; however, he noted that *G. pseudolinneiana* has subcrescentic to petaloid chambers on the spiral side, whereas Pessagno (1967) stated that the chambers of *pseudolinneiana* are almost entirely crescent-shaped spirally, and that *linneiana* has more typically petaliform chambers. Both Douglas (1969) and Hanzlíková (1972) placed *G. lapparenti lapparenti* Brotzen of Bolli (1945) in the synonymy of *G. pseudolinneiana*, and *G. lapparenti* Brotzen (part) in the synonymy of *G. linneiana.* Masters (1977) placed *G. pseudolinneiana* in the synonymy of *G. lapparenti* Brotzen, and stated that *G. linneiana* has radial ventral sutures, which are shown on at least the early chambers of the last whorl of the neotype proposed by Brönnimann & Brown (1955). Caron (1966) figured as *G. linneiana* a specimen which is very similar to some from the Western Australian sample (see Pl. 3, figs. 12–14).

In view of the difficulties in distinguishing these species, and their long stratigraphic ranges, no attempt is made here at detailed taxonomic separation.

Globotruncana renzi Gandolfi, 1942, p. 124, pl. 3, fig. 1; pl. 4, fig. 16 (Pl. 3, figs. 15–17)

The taxonomic confusion surrounding this species has been discussed by Caron (1966) and Douglas (1969). The name is used here for specimens of the kind that Gandolfi (1942, pl. 3, fig. 1) figured, and later (1957) designated as the holotype of *G. coldreriensis*, a new name proposed to replace *renzi* Gandolfi; this was thought to be a homonym of *renzi* Thalmann, which was later shown to be invalid. This same specimen was figured by Caron (1966) as the holotype and by Caron & Luterbacher (1969) as the lectotype of *G. renzi* Gandolfi. Pessagno (1967) designated the specimens figured by Gandolfi (1942, pl. 4, fig. 15 and text-fig. 45) as paralectotype and lectotype respectively of *G. renzi*, and, therefore, as noted by Douglas (1969), has a concept of this species which differs from that of other workers. Masters (1977) regarded the designations by Pessagno (1967) and by Caron & Luterbacher (1969) as invalid, and indicated that under the articles of the International Commission for Zoological Nomenclature the designation by Gandolfi in 1957 of a holotype for *G. coldreriensis* also constituted a designation for *G. renzi*.

Only one specimen referred to *G. renzi* is evident in the Western Australian sample. It has six chambers in the last whorl, a strongly convex dorsal surface, and narrowly separated double keels that have fused into a single keel on the last chamber. It is similar to the holotype and to specimens of *G. renzi* figured by Douglas & Sliter (1966), Douglas (1969), and Hanzlíková (1972).

Pessagno (1967) recorded several occurrences of *G. renzi* over the interval Turonian to Santonian. Hanzlíková (1972) stated that it occurs particularly in the Turonian and Coniacian of Europe; she recorded it from the Turonian and Coniacian of the west Carpathians, and the Coniacian of Moravia. Scheibnerová (1969) stated that it does not occur above the Coniacian, even though Bolli (1957) had recorded it from the Coniacian-Santonian of Trinidad. Masters (1977) specified a range of Turonian to Campanian, reflecting the extensive synonymy which he listed for *G. renzi*.

Globotruncana ventricosa White, 1928: *Globotruncana canaliculata* (Reuss) var. *ventricosa* White, 1928, p. 284, pl. 38, figs. 5a–c (Pl. 3, figs. 18–20; Pl. 4, figs. 1–8)

Abundant large specimens referred to *G. ventricosa* occur in the sample. The specimens have two distinct keels, a flat or only slightly convex dorsal surface, and a convex ventral surface. The sutures on the dorsal side are curved, raised, and beaded; on the ventral side, they are raised on the umbilical shoulders of the later chambers in some specimens, but otherwise they are smooth or depressed. The umbilicus is wide and open; the aperture is umbilical, and has only remnants of the tegilla preserved.

The species described by Porthault (1970) as *Marginotruncana paraconcavata*, is, as noted by Masters (1977), similar to *G. ventricosa*. Peryt (1980) figured specimens of *M. paraconcavata* which are similar to some specimens here included in *G. ventricosa*, particularly those with a slightly convex ventral side (see Pl. 4, figs. 1–5). The Western Australian specimens range from forms of this type to others with the flat dorsal and markedly convex ventral surfaces characteristic of *G. ventricosa* (Pl. 3, figs. 18–20).

G. ventricosa has been recorded mainly from the Campanian and the Maastrichtian. Sliter (1968) recorded a late Coniacian to early Maastrichtian range. Herb (1974) recorded *Globotruncana* sp. aff. *ventricosa* from the Coniacian to the Santonian at Deep Sea Drilling Project Site 258; a large specimen that he figured (pl. 7, fig. 1) is similar to one of the figured Western Australian specimens (Pl. 4, figs. 6–8). Douglas (1969) considered that pre-Campanian occurrences are probably confused with *G. concavata*. The Western Australian specimens are not referable to *G. concavata*. Most have the typical development of *G. ventricosa*—a flat dorsal and markedly convex ventral surface—but some specimens resemble forms which have been referred to *Marginotruncana paraconcavata*, a species recorded from the late Turonian to the earliest Campanian of central Poland (Peryt, 1980) and the late Coniacian and early Santonian of southeast France (Porthault, 1970). The possible synonymy of *ventricosa* and *paraconcavata* needs to be investigated, and if confirmed would extend the range of *ventricosa* into the late Turonian.

Globotruncana sp. 1 (Pl. 4, figs. 9–11)

Only one specimen of this kind has been found; it has a flat dorsal surface, slightly convex ventral surface, two widely separated keels, and six chambers in the last whorl. The dorsal sutures are curved and the ventral sutures curved to sigmoid.

This specimen is similar to one figured by Frerichs (1979) as *Marginotruncana canaliculata* (Reuss), but has more chambers in the last whorl; it also lacks the radial ventral sutures of *canaliculata*. Masters (1977) placed *canaliculata* in synonymy with *G. linneiana* (d'Orbigny).

No definite identification of this species can be made.

Globotruncana sp. 2 (Pl. 4, figs. 12–14)

Only one specimen of this form is evident in the sample. It is slightly biconvex and has two distinct keels. The last whorl has five chambers. Radial depressed sutures on the early chambers of the last whorl later become slightly raised and curved. The dorsal sutures are raised and curved, and the central part of the dorsal side is raised above the chambers of the last whorl. The early chambers are pustulose, whereas the later chambers are smooth. The umbilicus is wide and deep; the aperture is interiomarginal umbilical, and only remnants of the tegilla are preserved.

This specimen cannot be referred to any described species. Frerichs (1979) figured as *Marginotruncana* aff. *imbricata* a specimen with radial depressed sutures in the early chambers of the last whorl; the Western Australian specimen is similar in some features, but has narrower ventral chambers and a wider umbilicus.

Globotruncana sp. 3 (Pl. 4, figs. 15–17)

Again, only one specimen of this form is evident in the sample. It has a flat dorsal surface, a convex ventral surface, six chambers in the last whorl, radial depressed ventral sutures on the early chambers of the last whorl, and slightly raised curved sutures on later chambers. It also has similarities to the specimen figured by Frerichs (1979, pl. 6, figs. 7–9) as *Marginotruncana* aff. *imbricata*, but has a flat rather than convex dorsal surface.

This specimen cannot be referred to any described species.

Globotruncana sp. 4 (Pl. 4, figs. 18–20)

One specimen in the sample has a strongly convex dorsal surface and in this respect resembles the type specimen of *G. angusticarinata*, but has a wider peripheral margin. It is similar to a specimen figured by Caron (1966) as *Globotruncana fungicamerata* Martirosjan, but no detailed information on this species is available. It was recorded by Caron from the late Turonian to Santonian.

Globotruncana sp. 5 (Pl. 5, figs. 1–3)

This form, known from only one specimen in the sample, is similar to the specimen figured by Barr (1972) as *Globotruncana angusticarinata* Gandolfi from the Coniacian of northern Cyrenaica, but has less sharply curved ventral sutures.

Genus **Globigerinelloides** Cushman & Ten Dam, 1948

Type species: *Globigerinelloides algeriana* Cushman & Ten Dam, 1948.

Globigerinelloides alvarezi (Eternod Olvera, 1959): *Planomalina alvarezi* Eternod Olvera, 1959, pp. 91, 92, pl. 4, figs. 5–7 (Pl. 5, figs. 4–7)

Rare small specimens from the Western Australian sample are referred to this species. They have seven chambers in the outer whorl, a pustulose test surface, and a low interiomarginal aperture with relict apertures visible at the umbilical margins. Peryt (1980) figured as *G. prairiehillensis* Pessagno specimens which are similar to those from Western Australia. These specimens are compressed, and the chambers increase only gradually in size; they may be referable to *G. alvarezi*.

G. alvarezi was originally described from the Campanian to Maastrichtian; Masters (1977) specified a range of mid-Albian to Campanian.

Genus **Hedbergella** Brönnimann & Brown, 1958

Type species: *Anomalina lorneiana* d'Orbigny var. *trocoidea* Gandolfi, 1942.

Hedbergella simplicissima (Magné & Sigal, 1954): *Hastigerinella simplicissima* Magné & Sigal, 1954, p. 487, pl. 14, figs. 11a–c (Pl. 5, figs. 8–10)

Only one specimen referred to *H. simplicissima* is evident in the sample. Three specific names have been used for forms of this kind—*H. simplicissima*, *H. simplex* (Morrow), and *H. amabilis* Loeblich & Tappan. Caron (1966) placed *H. amabilis* in the synonymy of *H. simplicissima* (referring this species to the genus *Clavihedbergella*), and was followed in this by Herb (1974), Masters (1977), Pflaumann & Krasheninnikov (1977), and Peryt (1980).

Douglas (1969) recognised *H. amabilis* as a distinct species, and placed *simplicissima* in the synonymy of *H. simplex* (Morrow), again using the genus *Clavihedbergella*. Bandy (1967) regarded forms such as *Hedbergella amabilis* as transitional between *H. delrioensis* and *Clavihedbergella subdigitata subdigitata*, and placed these transitional forms in the synonymy of *C. subdigitata*. Pessagno (1967) and Eicher & Worstell (1970) recognised gradational forms between *Hedbergella amabilis* and *Clavihedbergella simplex*, but retained them as separate species. Masters (1977) reached the same conclusion, but, as has been noted, placed *amabilis* in the synonymy of *simplicissima*. Douglas (1969) considered that *amabilis* and *simplex* were closely related, but did not observe a complete gradation between the two species. Pessagno (1967), Masters (1977), and Petters (1977) stated that *amabilis* (= *simplicissima*) gave rise to *Clavihedbergella simplex*.

Magniez-Jannin (1981) figured as *Hedbergella simplex* a specimen similar to that from the Western Australian material. *H. simplex* (originally included in the genus *Hastigerinella*) was described as having a markedly elongate final chamber. The name is generally used for clavate forms; the clavate specimens referred by Loeblich & Tappan (1961) to *Clavihedbergella simplex* (Morrow) were excluded from the synonymy of *simplicissima* by Caron (1966) and Peryt (1980).

The one specimen found in the Western Australian material is not clavate. It is here referred to *H. simplicissima*, and the synonymy of *H. amabilis* with *H. simplicissima* is followed. Specimens of this kind have generally been recorded within the interval Cenomanian to Coniacian, but there are some records from the Santonian.

Hedbergella delrioensis (Carsey, 1926): *Globigerina cretacea* d'Orbigny var. *delrioensis* Carsey, 1926, p. 43 (Pl. 5, figs. 11–16)

Rare small specimens from the sample are referred to *H. delrioensis*. They agree well with published figures of this species, particularly those of Masters (1977), Loeblich & Tappan (1961), and Longoria (1974). The specimens have five chambers in the last whorl, depressed straight radial sutures, a pustulose test surface, and an interiomarginal umbilical-extraumbilical aperture with a narrow lip.

Masters (1977) specified a range of Barremian to Campanian for *H. delrioensis*, but most records—e.g., Loeblich & Tappan (1961), Salaj & Samuel (1966), Sigal (197), Longoria (1974), and Pflamann & Krasheninnikov (1977)—are within the interval early Albian to Turonian.

Hedbergella sp. 1 (Pl. 5, figs. 17–19)

Included here are rare small pustulose specimens with a flat surface, six chambers in the last whorl, depressed radial sutures, and a low interiomarginal umbilical-extraumbilical aperture. They resemble *H. planispira* Tappan, but are more loosely coiled and have more globular chambers.

Genus **Heterohelix** Ehrenberg, 1843

Type species: *Spiroplecta americana* Ehrenberg, 1844.

Heterohelix papula (Belford, 1960): *Guembelina papula* Belford, 1960, p. 57, p. 15, figs. 6–9 (Pl. 5, figs. 20–21)

This form is common in the sample, and was previously recorded from Santonian beds of the Toolonga Calcilutite in the Murchison River area and in the Gingin Chalk.

AGE SIGNIFICANCE OF THE FAUNA

The fauna recorded from this sample differs from, and clearly is older than, faunas previously recorded from this area. A Coniacian age is not firmly established, but on the basis of recorded specific ranges appears to be the most probable. Only one species, *Globotruncana concavata cyrenaica*, is restricted to the Coniacian on published evidence. *Hedbergella simplicissima* (here used to include records of *H. amabilis*) is mostly recorded within the interval Cenomanian-Coniacian, but Santonian records are known. Petters (1977) stated that *H. amabilis* is not known from strata younger than the Coniacian, and that it is replaced in the Santonian by *H. atlantica* and *H. lata*. Further, in remarks concerning the species *H. atlantica* Petters, he referred specimens from the early Santonian of Bornholm Island identified by Douglas & Rankin

(1969) as *Hedbergella* cf. *amabilis* to *H. atlantica.* Pessagno (1967) noted that Santonian occurrences of *H. amabilis* in the Gulf Coast area are in areas where there is a marked disconformity in the sequence, and that in complete sequences *amabilis* appears to be absent from Santonian strata; the implication seems to be that Santonian records are of reworked specimens. Most occurrences of *Globotruncana cretacea* are Coniacian or younger, but Turonian records exist. *Globotruncana coronata* is generally regarded as a Turonian-Santonian index, and in some areas has not been recorded below the Coniacian. Apart from the range given by Masters (1977), *Globotruncana renzi* generally is not recorded above the Santonian, and in Europe is stated not to occur above the Coniacian. Other species recorded are either long-ranging, or, in the case of *Globotruncana dentata*, inadequately dated.

If confirmed, the identification of two species, *Globotruncana ventricosa* and *Hedbergella delrioensis*, would extend their generally recorded stratigraphic ranges. *G. ventricosa* is generally Campanian or younger, although Sliter (1968) recorded it from strata as old as the late Coniacian; the possible synonymy of *G. ventricosa* and *G. paraconcavata* has already been mentioned. *Hedbergella delrioensis*, apart from the long range given by Masters (1977), has been recorded from Turonian or older beds.

Benthic foraminiferal species occurring in the sample include **Pseudospiroplectinata compressiuscula* (Chapman), **Gaudryina pulvina* Belford, *Marssonella oxycona* (Reuss), **Anomalinoides canaliculus* Belford, **A. murchisonensis* Belford, *Reussella* sp., and *Spiroplectammina* sp. Those species marked with an asterisk have been recorded previously only from Santonian beds in Western Australia.

Calcareous nannofossils occurring in the sample support a Coniacian age (S. Shafik, BMR, personal communication, January 1982).

GEOLOGICAL SIGNIFICANCE OF THE FAUNA

The main significance of the identification of probable Coniacian beds in the area of the Giralia Anticline is to the depositional history of the Carnarvon Basin. According to Belford (1958), Late Cretaceous sedimentation in the area started with the deposition of late Campanian carbonate beds disconformably over the Albian to Turonian Gearle Siltstone. Edgell (1962), however, identified Santonian carbonate beds above the siltstone. Confirmation of a Coniacian age for the fauna described above would further reduce the inferred duration of the hiatus between the Gearle Siltstone and the start of carbonate sedimentation in the area. Carbonate deposition was possibly in progress in the area of the Giralia Anticline before it began in the Murchison River area, where the basal beds of the Toolonga Calcilutite are Santonian in age.

REFERENCES

BANDY, O. L., 1967—Cretaceous planktonic foraminiferal zonation. *Micropaleontology,* 13(1), 1-31.

BANNER, F. T., & BLOW, W. H., 1960—Some primary types of species belonging to the superfamily Globigerinaceae. *Contributions from the Cushman Foundation for Foraminiferal Research,* 11(1), 1-41.

BARR, F. T., 1972—Cretaceous biostratigraphy and planktonic foraminifera of Libya. *Micropaleontology,* 18(1), 1-46.

BELFORD, D. J., 1958—Stratigraphy and micropalaeontology of the Upper Cretaceous of Western Australia. *Sonderdruck aus der Geologischen Rundschau,* 47(2), 629-647.

BOLLI, H., 1945—Zur Stratigraphie der oberen Kriede in den höheren helvetischen Decken. *Eclogae Geologicae Helvetiae,* 37(2), 217-328.

BOLLI, H. M., 1957—The genera *Praeglobotruncana, Rotalipora, Globotruncana* and *Abathomphalus* in the Upper Cretaceous of Trinidad, B.W.I. *United States National Museum, Bulletin* 215, 51-60.

BRÖNNIMANN, P., & BROWN, N. K., JR, 1955—Taxonomy of the Globotruncanidae. *Eclogae Geologicae Helvetiae,* 48(2), 503-561.

BRÖNNIMANN, P., & BROWN, N. K., JR, 1958—*Hedbergella,* a new name for a Cretaceous planktonic foraminiferal genus. *Journal of the Washington Academy of Science,* 48(1), 15-17.

CARON, MICHÈLE, 1966—Globotruncanidae du Crétacé supèrieur du Synclinal de la Gruyère (Prealpes médianes, Suisse). *Revue de Micropaléontologie,* 9(2), 68-93.

CARON, MICHÈLE, & LUTERBACHER, H. P., 1969—On some type specimens of Cretaceous planktonic foraminifera. *Contributions from the Cushman Foundation for Foraminiferal Research,* 20(1), 23-29.

CARSEY, D. O., 1926—Foraminifera of the Cretaceous of central Texas. *Texas University, Bulletin* 2612, 1-56.

CLARK, F. E., 1979—Upper Cretaceous foraminifera and biostratigraphy of C-Y Creek, Western Australia. *M.Sc. Thesis, Carleton University, Ottawa, Ontario* (unpublished).

CONDON, M. A., 1968—The geology of the Carnarvon Basin, Western Australia. Part 3: Post-Permian stratigraphy; structure; economic geology. *Bureau of Mineral Resources, Bulletin,* 77.

CONDON, M. A., JOHNSTONE, D., PRICHARD, C. E., & JOHNSTONE, M. H., 1956—The Giralia and Marrilla Anticlines, North West Division, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 25.

CUSHMAN, J. A., 1926—Some foraminifera from the Mendez Shale of eastern Mexico. *Contributions from the Cushman Foundation for Foraminiferal Research,* 2 (1), 16-26.

CUSHMAN, J. A., 1927—An outline of a reclassification of the foraminifera. *Contributions from the Cushman Foundation for Foraminiferal Research,* 3(1), 1-105.

CUSHMAN, J. A., & TEN DAM, A., 1948—*Globigerinelloides,* a new genus of the Globigerinidae. *Contributions from the Cushman Foundation for Foraminiferal Research,* 24(2), 42-43.

D'ORBIGNY, A. D., 1840—Mémoire sur les Foraminifères de la Craie Blanche du Bassin de Paris. *Mémoire Société Géologique France* 4(1), 1-51.

DOUGLAS, R. G., 1969—Upper Cretaceous planktonic foraminifera in northern California. Part 1—systematics. *Micropaleontology,* 15(2), 151-209.

DOUGLAS, R. G., & RANKIN, C., 1969—Cretaceous planktonic foraminifera from Bornholm and their zoogeographic significance. *Lethaia,* 2(3), 185-217.

DOUGLAS, R., & SLITER, W. V., 1966—Regional distribution of some Cretaceous Rotaliporidae and Globotruncanidae (Foraminiferida) within North America. *Tulane Studies in Geology,* 4(3), 89-131.

EDGELL, H. S., 1954—The stratigraphical value of *Bolivinoides* in the Upper Cretaceous of northwest Australia. *Contributions from the Cushman Foundation for Foraminiferal Research*, 5(2), 68-76.

EDGELL, H. S., 1957—The genus *Globotruncana* in northwest Australia. *Micropaleontology*, 3(2), 101-126.

EDGELL, H. S., 1962—A record of *Globotruncana concavata* (Brotzen) in northwest Australia. *Revue de Micropaleontologie*, 5(1), 41-50.

EHRENBERG, C. G., 1843—Verbreitung und Einfluss des mikroskopischen Lebens in Sud- und Nord-Amerika. *Königliche preussische Akademie der Wissenschaften, Berlin, Abhandlungen* 1841/1, 291-446.

EHRENBERG, C. G., 1844—Ein Mittheilung über 2 neue Lager von Gebirgsmassen aus Infusorien als Meeres-Absatz in Nord Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europa und Afrika. *Königliche preussische Akademie der Wissenschaften, Berlin, Berichte über die zur Bekanntmachung geeigneten Verhandlungen*, 57-98.

ETERNOD OLVERA, Y., 1959—Foraminiferos del Cretacico Superior de la Cuenca de Tampico-Tuxpan, Mexico. *Boletín Asociación Mexicana de Geologos Petroleros*, 11(3-4), 63-134.

FRERICHS, W. E., 1979—Planktonic foraminifera from the Sage Breaks Shale, Centennial Valley, Wyoming. *Journal of Foraminiferal Research*, 9(2), 159-184.

GANDOLFI, R., 1942—Ricerche micropaleontologiche e stratigrafiche sulla Scaglia e sul Flysch cretacici dei dintorni de Balerna (Canton Ticino). *Rivista Italiana di Paleontologia e Stratigrafia*, 48, *supplement, Memoir* 4, 1-160.

GANDOLFI, R., 1957—Notes on some species of *Globotruncana*. *Contributions from the Cushman Foundation for Foraminiferal Research*, 8(2), 59-65.

HANZLIKOVA, EVA, 1972—Carpathian Upper Cretaceous Foraminiferida of Moravia (Turonian-Maastrichtian). *Rozpravy Ustredniho Ustavu Geologického*, 39, 1-160.

HERB, R., 1974—Cretaceous planktonic foraminifera from the eastern Indian Ocean; *in* DAVIES, T. A., LUYENDYK, B. P., & OTHERS—Initial reports of the Deep Sea Drilling Project, Volume 26. *US Government Printing Office, Washington*, 745-769.

HOOPER, K., 1977—*Globotruncana dentata*, a new species of planktonic foraminifer from the Toolonga Calcilutite of Western Australia. *Micropaleontology*, 23(3), 361-364.

LOEBLICH, A. R. JR, & TAPPAN, HELEN, 1961—Cretaceous planktonic foraminifera: Part 1—Cenomanian. *Micropaleontology*, 7(3), 257-304.

LONGORIA, J. F., 1974—Stratigraphic, morphologic and taxonomic studies of Aptian planktonic foraminifera. *Revista Española de Micropaleontologia, Numero Extraordinario*, 1-107.

MAGNÉ, J., & SIGAL, J., 1954—Description de quelques espèces nouvelles; Foraminifères; *in* CHEYLAN, G., MAGNÉ, J., SIGAL, J., & GREKOFF, N.—Résultats géologiques et micropaléontologiques du sondage d'El Krachem (Hauts Plateaux algérois). *Bulletin de la Société Géologique de France*, 6(3), 1953, Nos. 4-6, 471-492.

MAGNIEZ-JANNIN, FRANCOISE, 1981—Decouverte de *Planomalina buxtorfi* (Gandolfi) et d'autres foraminifères planctoniques inattendus dans l'Albian supérieur d'Abbotscliff (Kent. Angleterre); consequences paléographiques et biostratigraphiques. *Geobios*, 14(1), 91-97.

MASTERS, B. A., 1977—Mesozoic planktonic foraminifera. *Oceanic Micropalaeontology*, 1, 301-731.

PERYT, DANUTA, 1980—Planktic foraminifera zonation of the Upper Cretaceous in the middle Vistula River valley, Poland. *Palaeontologia Polonica*, 41, 3-101.

PESSAGNO, E. A. JR, 1967—Upper Cretaceous planktonic foraminifera from the western Gulf coastal plain. *Palaeontographica Americana*, V(37), 245-445.

PETTERS, S. W., 1977—Upper Cretaceous planktonic foraminifera from the subsurface of the Atlantic Coastal Plain of New Jersey. *Journal of Foraminiferal Research*, 7(3), 165-187.

PFLAUMANN, UWE, & KRASHENINNIKOV, V. A., 1977—Early Cretaceous planktonic foraminifers from eastern north Atlantic, DSDP Leg 41; *in* LANCELOT, Y., SEIBOLD, E., & OTHERS—Initial reports of the Deep Sea Drilling Project, Volume 41. *US Government Printing Office, Washington*, 539-564.

PORTHAULT, B., 1970—*In* DONZE, P., PORTHAULT, B., THOMEL, G., & DE VILLOUTREYS, O.—Le Senonien inférieur de Puget-Théniers (Alpes-Maritimes) et sa microfaune. *Geobios*, 3(2), 1-106

REUSS, A. E., 1845—DIE VERSTEINERUNGEN DER BÖHMISCHEN KREIDEFORMATION, Abt. 1. *E. Schweizerbart, Stuttgart.*

SALAJ, J., & SAMUEL, O., 1966—Foraminifera der Westkarpaten-Kreide. *Geologicky Ustav Dionyza Stura, Bratislava*, 1-291.

SCHEIBNEROVÁ, VIERA, 1969—Middle and upper Cretaceous microbiostratigraphy of the Klippen Belt (West Carpathians). *Acta Geologica et Geographica Universitatis Comenianae, Geologica*, 17, 5-98.

SIGAL, J., 1974—Comments on Leg 25 sites in relation to the Cretaceous and Paleogene stratigraphy in the eastern and southeastern Africa coast and Madagascar regional setting; *in* SIMPSON, E. S. W., SCHLICH, R., & OTHERS—Initial reports of the Deep Sea Drilling Project, Volume 25. *US Government Printing Office, Washington*, 687-723.

SLITER, W. V., 1968—Upper Cretaceous foraminifera from southern California and northwestern Baja California, Mexico. *University of Kansas, Palaeontological Contributions*, 49, Article 7.

TOLLMAN, A., 1960—Die Foraminiferen fauna des Oberconiac aus der Gosau des Ausseer Weissenbachtales in Steirmark. *Jahrbuch Geologischen Bundesanstalt* 103, 133-203.

VAN DE GRAAFF, W. J. E., DENMAN, P. D., HOCKING, R. M., & BAXTER, J. L., 1977—Explanatory notes on the Ningaloo-Yanrey, W.A., 1:250 000 Geological Sheet. *Geological Survey of Western Australia, Record* 1977/9 (unpublished).

VAN HINTE, J. E., 1963—Zur Stratigraphie und Mikropaläontologie der Oberkreide und des Eozäns des Krappfeldes (Kärnten). *Jahrbuch der Geologischen Bundesanstalt*, Sonderband, 8, 1-147.

PLATE 1

All figures × 80

Figs.	
1–8	**Globotruncana angusticarinata** Gandolfi 1–3, CPC 22107: 1, ventral view; 2, dorsal view; 3, edge view. 4–6, CPC 22100: 4, ventral view; 5, dorsal view; 6, edge view. 7–8, CPC 22109: 7, ventral view; 8, edge view.
9–12	**Globotruncana concavata cyrenaica** Barr CPC 22110: 9, ventral view; 10, dorsal view; 11, edge view, front; 12, edge view, rear.
13–18	**Globotruncana coronata** Bolli 13–15, CPC 22111: 13, ventral view; 14, dorsal view; 15, edge view. 16–18, CPC 22112: 16, ventral view; 17, dorsal view; 18, edge view.


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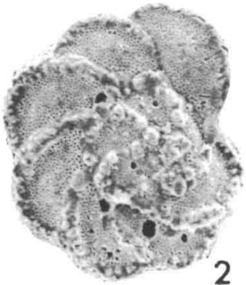
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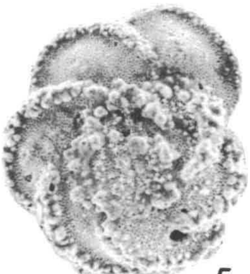
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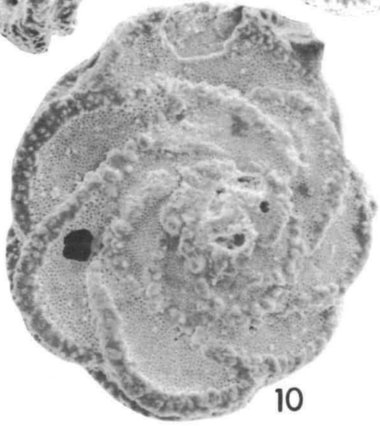
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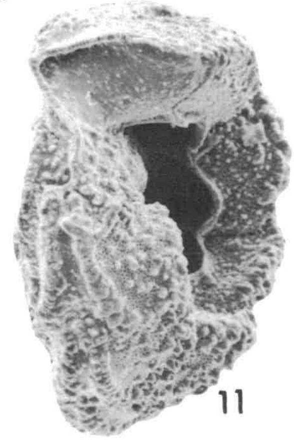
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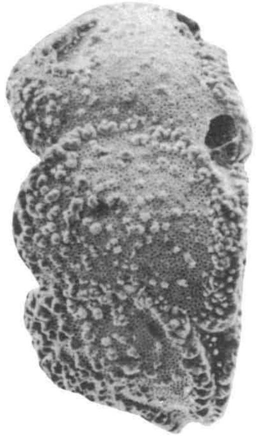
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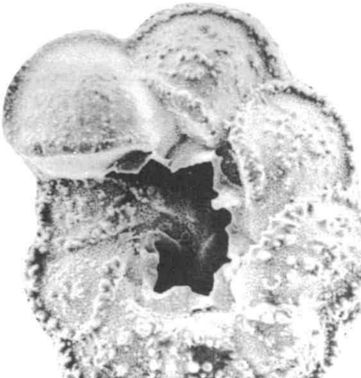
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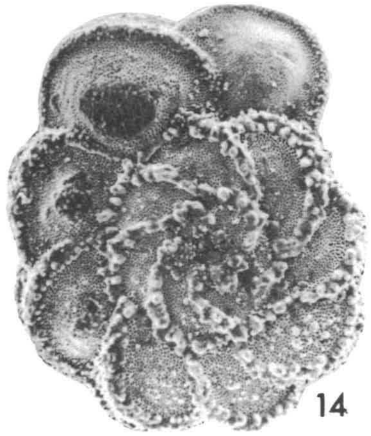
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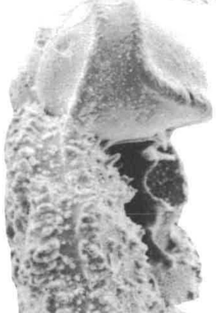
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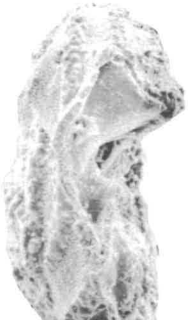
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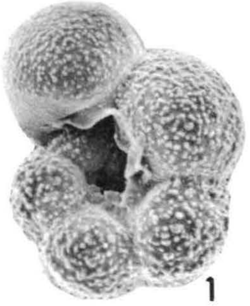
PLATE 2

All figures × 80

Figs.	
1–8	**Globotruncana cretacea** (d'Orbigny) 1–3, CPC 22113: 1, ventral view; 2, dorsal view; 3, edge view. 4–6, CPC 22114: 4, ventral view; 5, dorsal view; 6, edge view. 7–8, CPC 22115: 7, ventral view; 8, edge view.
9–14	**Globotruncana dentata** Hooper 9–11, CPC 22116: 9, ventral view; 10, dorsal view; 11, edge view. 12–14, CPC 22117: 12, ventral view; 13, dorsal view; 14, edge view.
15–20	**Globotruncana marginata** (Reuss) 15–17, CPC 22118: 15, ventral view; 16, dorsal view; 17, edge view. 18–20, CPC 22119: 18, ventral view; 19, dorsal view; 20, edge view.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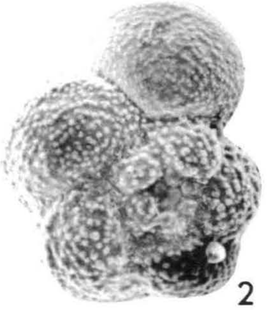
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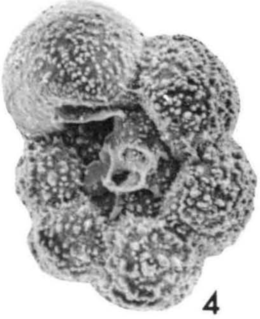
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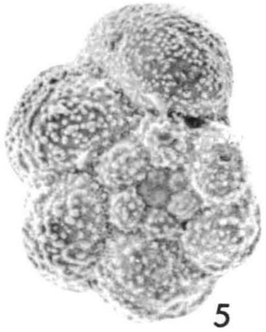
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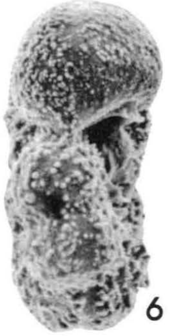
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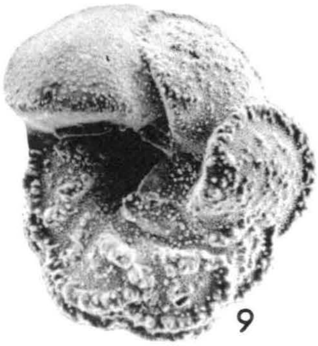
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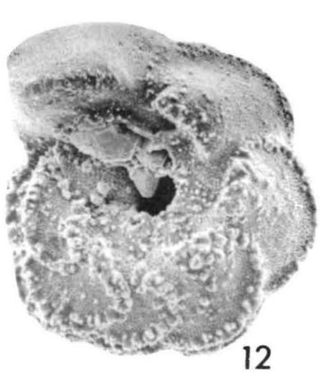
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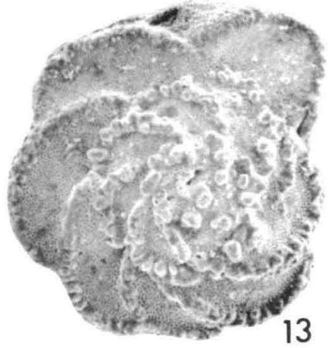
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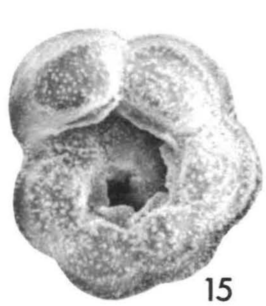
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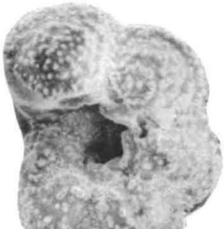
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PLATE 3

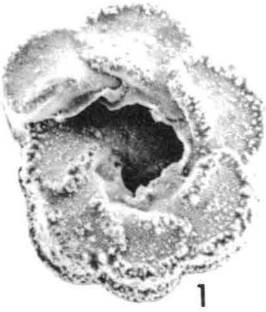
All figures × 80

Figs.

1–14 **Globotruncana pseudolinneiana** (Pessagno)
1–3, CPC 22120: 1, ventral view; 2, dorsal view; 3, edge view.
4–5, CPC 22121: 4, ventral view; 5, edge view.
6–7, CPC 22122: 6, ventral view; 7, edge view.
8–9, CPC 22123: 8, ventral view; 9, edge view.
10–11, CPC 22124: 10, ventral view; 11, edge view.
12–14, CPC 22125: 12, ventral view; 13, dorsal view; 15, edge view.

15–17 **Globotruncana renzi** Gandolfi
CPC 22126: 15, ventral view; 16, dorsal view; 17, edge view.

18–20 **Globotruncana ventricosa** White
CPC 22127: 18, ventral view; 19, dorsal view; 20, edge view.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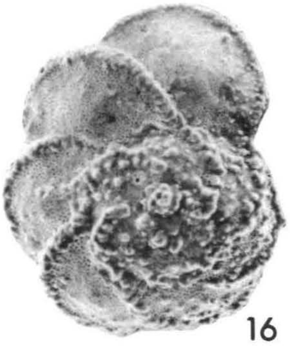
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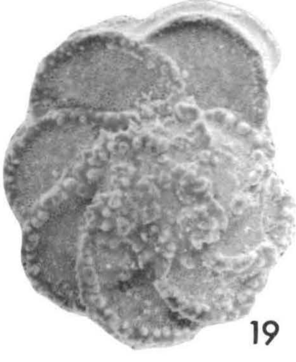
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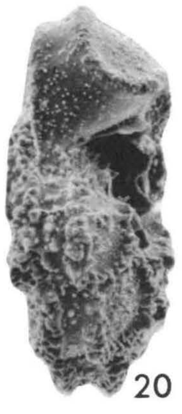
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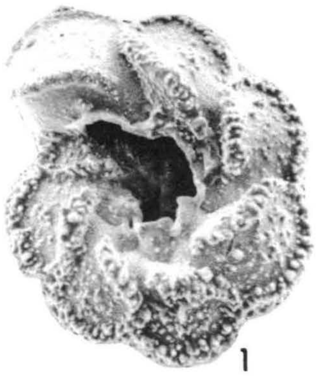
PLATE 4

All figures × 80

Figs.	
1–8	**Globotruncana ventricosa** White 1–2, CPC 22128: 1, ventral view; 2, edge view. 3–5, CPC 22129: 3, ventral view; 4, dorsal view; 5, edge view. 6–8, CPC 22130: 6, ventral view; 7, dorsal view; 8, edge view.
9–11	**Globotruncana** sp. 1 CPC 22131: 9, ventral view; 10, dorsal view; 11, edge view.
12–14	**Globotruncana** sp. 2 CPC 22132: 12, ventral view; 13, dorsal view; 14, edge view.
15–17	**Globotruncana** sp. 3 CPC 22133: 15, ventral view; 16, dorsal view; 17, edge view.
18–20	**Globotruncana** sp. 4 CPC 22134: 18, ventral view; 19, dorsal view; 20, edge view.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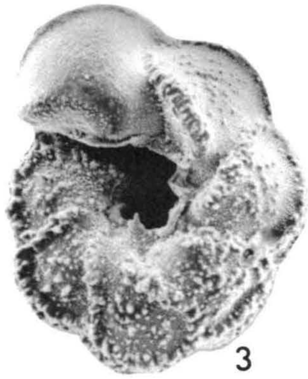
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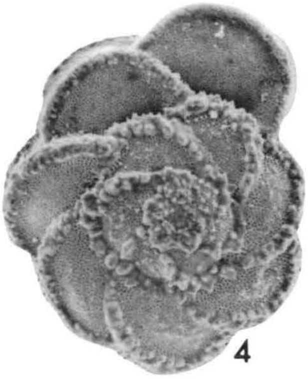
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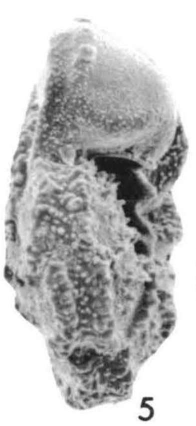
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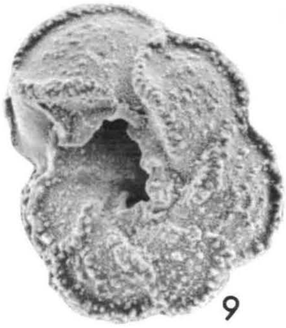
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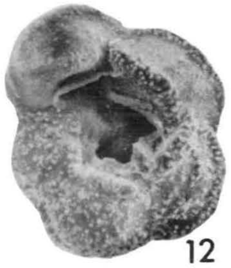
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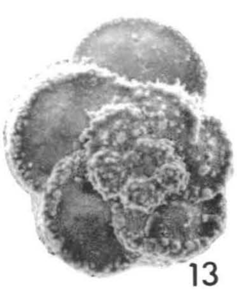
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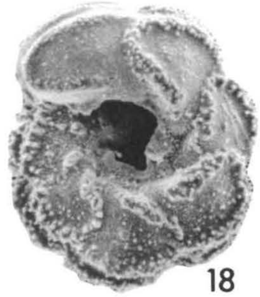
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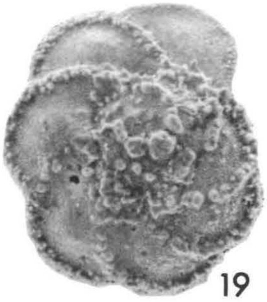
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PLATE 5

All figures × 80

Figs.	
1–3	**Globotruncana** sp. 5 CPC 22135: 1, ventral view; 2, dorsal view; 3, edge view.
4–7	**Globigerinelloides alvarezi** (Eternod Olvera) 4–5, CPC 22136: 4, side view; 5, edge view. 6–7, CPC 22137: 6, side view; 7, edge view.
8–10	**Hedbergella simplicissima** (Magné & Sigal) CPC 22138: 8, ventral view; 9, dorsal view; 10, edge view.
11–16	**Hedbergella delrioensis** (Carsey) 11–13, CPC 22139: 11, ventral view; 12, dorsal view; 13, edge view. 14–16, CPC 22140: 14, ventral view; 15, dorsal view; 16, edge view.
17–19	**Hedbergella** sp. 1 CPC 22141: 17, ventral view; 18, dorsal view; 19, edge view.
20–21	**Heterohelix papula** (Belford) 20, CPC 22142: side view. 21, CPC 22143: side view.


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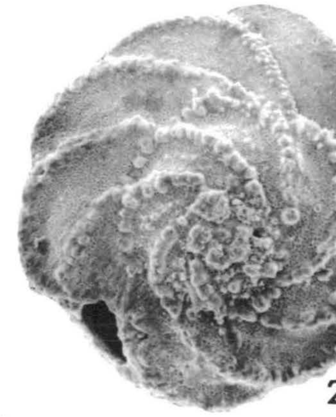
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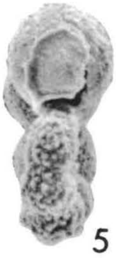
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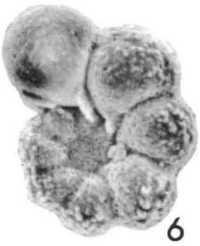
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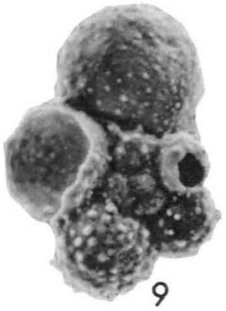
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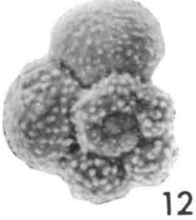
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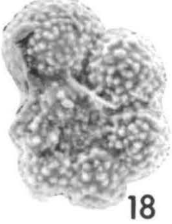
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Globigerina praealta, new name for *Globigerina edita* Belford, 1981, preoccupied

D. J. Belford

BELFORD, D. J., 1983—*Globigerina praealta,* new name for *Globigerina edita* Belford, 1981, preoccupied; *in* Palaeontological papers 1983. *Bureau of Mineral Resources, Australia, Bulletin* 217, 29.

I am informed that *Globigerina edita* Belford, 1981 is preoccupied by *Globigerina edita* Subbotina, 1953, and wish to thank those of my colleagues who have brought this to my attention.

The new name *Globigerina praealta* is proposed here for *Globigerina edita* Belford, 1981 (not Subbotina, 1953). The specific name is from the Latin *praealtus,* very high, referring to the high trochospiral coiling.

REFERENCES

BELFORD, D. J., 1981—Co-occurrence of middle Miocene larger and planktic smaller foraminifera, New Ireland, Papua New Guinea; *in* Palaeontological Papers 1981. *Bureau of Mineral Resources Australia, Bulletin,* 209. 1-7.

SUBBOTINA, N. N., 1953—Fossil foraminifera of the USSR: Globigerinidae, Hantkeninidae and Globorotaliidae. *Trudy VNIGRI,* new series, 76, 1-296 (in Russian).

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Tertiary larger foraminiferids from the northwestern margin of the Queensland Plateau, Australia

George C. H. Chaproniere

CHAPRONIERE, G. C. H., 1983—Tertiary larger foraminiferids from the northwestern margin of the Queensland Plateau, Australia; *in* Palaeontological papers 1983. *Bureau of Mineral Resources, Australia, Bulletin* 217, 31–57.

ABSTRACT

Sixteen species of larger foraminiferids (those with complicated internal structures) have been recorded from four localities on the northwest margin of the Queensland Plateau. The assemblages are from Tertiary a_3 (early Middle Eocene), Tertiary lower *e*, and Tertiary upper *e* (Late Oligocene to Early Miocene). This represents the first record of Tertiary a_3 from Australia. The Tertiary upper *e* assemblage is a new one for this region. One species, *Sherbornina carteri*, is described as new.

INTRODUCTION

Five samples of shallow-water limestone containing larger foraminiferids were dredged from the western margin of the Queensland Plateau, south of Osprey Reef (Fig. 1), on a geological sampling cruise of the RV *Sonne* during December 1980 and January 1981. All samples were recovered in either a pipe dredge (TD) or chain-bag dredge (KD; Fig. 1). The ages of the samples are expressed in terms of the East Indian Letter Classification (Adams, 1970), and, where possible, in terms of the planktic foraminiferal zonal scheme of Blow (1969, 1979; see Fig. 2). All type and figured specimens are housed in the Commonwealth Palaeontological Collection (CPC) at the Bureau of Mineral Resources, Canberra.

BIOSTRATIGRAPHY

Eocene

Sample So16–10TD–A contains a limited and poorly preserved (recrystallised) planktic foraminiferal fauna. The overlap between *Acarinina bullbrooki* (Bolli) and *Globigerapsis ?subconglobata* (Shutskaya) indicates a correlation with Zones P.10 to P.11 (early Middle Eocene), which is equivalent to Tertiary a_3 according to Adams (1970). Of the large foraminiferids, none are age diagnostic; *Asterocyclina incisuricamerata* Cole and *Operculina pacifica* Whipple have been recorded only from Tertiary *b* (Cole, 1957a, b, 1970), and *Gypsina discus* Goës is long-ranging. Larger foraminiferal faunas from this level are rare from the southeast Asian part of the Pacific; only isolated occurrences have

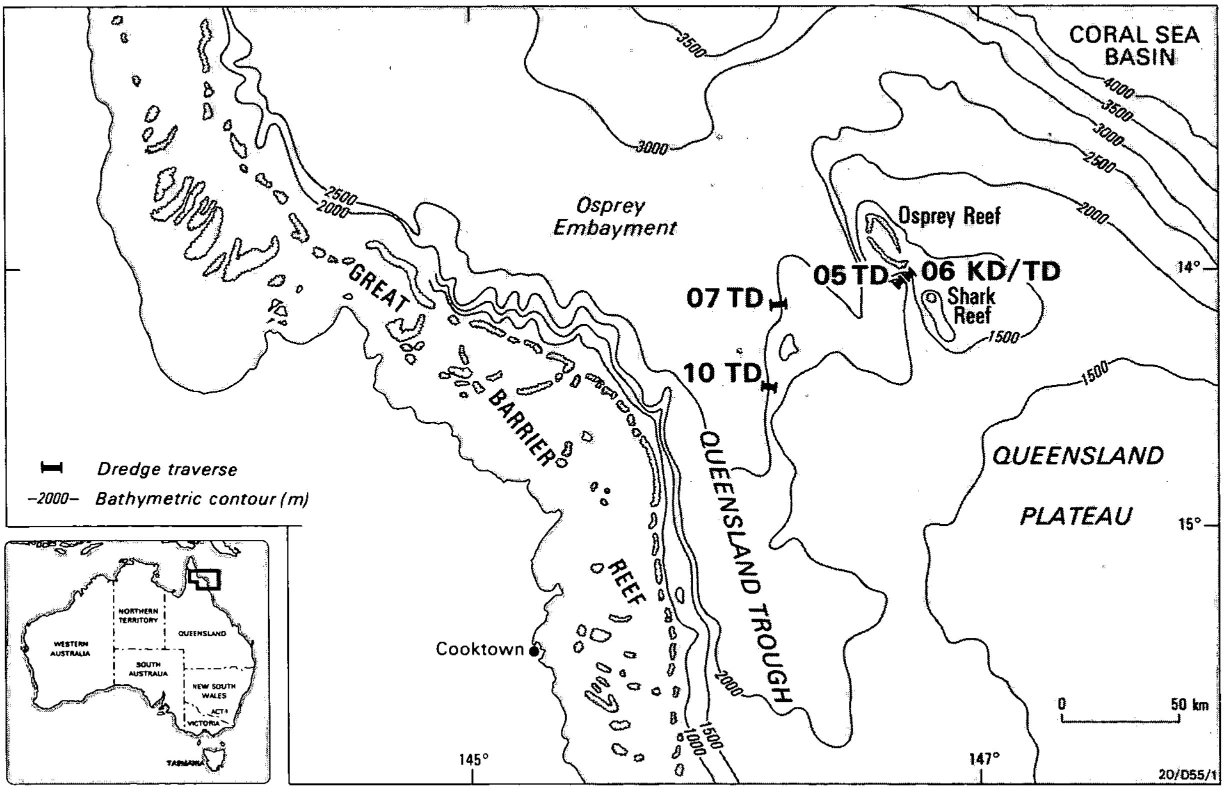

Fig. 1. Location map.

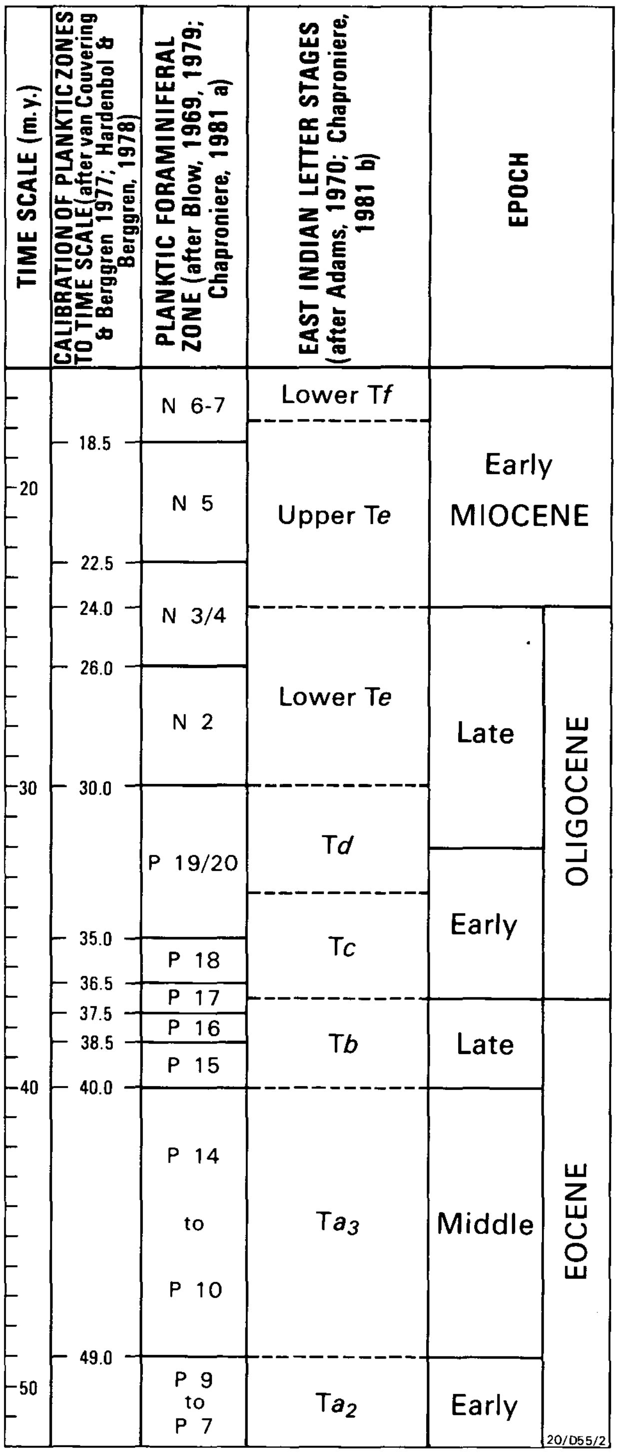

Fig. 2. The biostratigraphic scheme used in this study.

been recorded in Java, Timor, and Papua New Guinea (Adams, 1970). No other record of similar faunas is known from Australia.

Late Oligocene–Early Miocene

Sample So16–05TD–C contains a good larger foraminiferal fauna, but no planktic forms. *Heterostegina borneensis* van der Vlerk dominates the sample (46%) and *Lepidocyclina* (*Eulepidina*) *ephippioides* Jones & Chapman (21%) and *L.* (*Nephrolepidina*) *sumatrensis* (Brady) (21%) are also common; *Amphistegina mamilla* (Fichtel & Moll), *Gypsina globula* (Reuss), *G. howchini* Chapman, *Operculina complanata* (Defrance), and smaller benthic forms (mainly discorbids, rotaliids, and elphidiids) constitute the remainder. This fauna is almost identical with that of the *L.* (*Eulepidina*) *ephippioides-Heterostegina borneensis* association (Chaproniere, 1975, 1981b) from the Bullara Limestone in the North West Cape area of Western Australia (Chaproniere, 1976); unlike this association, however, it lacks *Austrotrillina striata* Todd & Post, and contains *Amphistegina mamilla* instead of *A. bikiniensis* Todd & Post. Chaproniere (1975) concluded that this association was probably typical of a seagrass community at water depths of less than 12 m in a sheltered situation. The fauna from So16–05TD–C probably represents the same environmental setting.

The presence of *Heterostegina borneensis* supports a correlation with a level in Tertiary lower *e*. Biometric results for both subgenera of *Lepidocyclina* (see below) imply that this sample is somewhat older than CB1 (from Zone N.3/4; see Chaproniere, 1980) and must be from a level within the early part of Tertiary lower *e*. The mean value for parameter A (see below) for *L.* (*Nephrolepidina*) *sumatrensis* from this sample is 37.54, which is very close to the values given by van der Vlerk & Postuma (1967) from the equivalent of Zones N.2 or N.3 from Indonesia. This sample is probably from a level within planktic Zone N.2.

Samples So16–06TD–A, So16–06KD–A, and So16–07TD–B contain a similar larger foraminiferal fauna and have almost certainly been obtained from the same horizon. This fauna is more diverse than that from sample So16–05TD–C. So16–07TD–B could not be disaggregated, and the fauna was studied only in random thin sections. *Lepidocyclina* (*Nephrolepidina*) *sumatrensis* (18%) and *L.* (*Eulepidina*) *ephippioides* (8%) dominate the larger foraminiferids; *Spiroclypeus margaritatus* (Schlumberger) (7%) and *Miogypsina* (*Miogypsinoides*) *bantamensis* Tan (7%) are the next most abundant; and *Operculina complanata*, *Heterostegina borneensis*, *Miogypsina* (*M*) *tani* Drooger, *Gypsina globula*, *G. howchini*, and *Cycloclypeus* (*Cycloclypeus*) *eidae* Tan (only in So16–06) and *Austrotrillina striata* (only in So16–07) together constitute less than 5%. Smaller benthic foraminiferids are the most numerous (47%) and *Amphistegina mamilla* constitutes 8% of the fauna. Rare planktic forms (either *Globigerina* or *Globigerinoides*) are visible in some random thin sections, but free specimens have not been seen. This association has not previously been recorded from Australia, although similar assemblages are known from Guam (Adams, 1970) and Christmas Island (Adams & Belford, 1974). *Lepidocyclina* (*Nephrolepidina*), *Miogypsina* (*Miogypsinoides*), and *Cycloclypeus eidae* are present in the *Lepidocyclina* (*Nephrolepidina*) *howchini-Cycloclypeus eidae/carpenteri* association from the Cape Range of Western Australia (Chaproniere, 1975, 1981b) above the last appearance level of *L.* (*Eulepidina*). *M.* (*Miogypsinoides*) is rare in that association, and occurs only at lower levels; at higher levels it is replaced by *M.* (*Lepidosemicyclina*). This evidence suggests that the association from So16–06TD–A, So16–06KD–A, and So16–07TD–B may be a precursor of the *L.* (*Nephrolepidina*) *howchini–Cycloclypeus eidae/carpenteri* association and is therefore from a similar environmental setting; that is, a seagrass community at depths of less than 12 m, in an open situation. The open situation is supported by the presence of planktic foraminiferids.

Adams & Belford (1974) considered that the association of *Heterostegina borneensis*, *L.* (*Eulepidina*) *ephippioides*, *M.* (*Miogypsinoides*) *bantamensis* and *Spiroclypeus margaritatus* was indicative of Tertiary lower *e*. However, in So16–06 and So16–07, the presence of rare *M.* (*Miogypsina*) *tani*, which—in the specimens studied here—is difficult to distinguish from *M. bantamensis* on external characters, suggests a correlation with Tertiary upper *e* (Adams, 1970). Because these samples contain a population of *Miogypsina* that is probably transitional between *M.* (*Miogypsinoides*) and *M.* (*Miogypsina*), the fauna must lie very close to the Tertiary lower *e*/upper *e* boundary, but the rarity of *H. borneensis* and the presence of *M.* (*Miogypsina*) indicate that it should be assigned to the earliest part of Tertiary upper *e*. This is probably equivalent to the latest part of Zone N.3/4 or the basal part of Zone N.5. Biometric results (see below) for *Lepidocyclina* suggests that So16–05TD–C is slightly older than So16–06KD–A.

BIOMETRIC STUDIES

Biometric studies have been made on populations of *Heterostegina borneensis*, *Spiroclypeus margaritatus*, *Miogypsina* (*Miogypsinoides*) *bantamensis*/*M.* (*Miogypsina*) *tani*, *Lepidocyclina* (*Eulepidina*) *ephippioides*, and *L.* (*Nephrolepidina*) *sumatrensis* using the univariate techniques outlined by Chaproniere (1980, in press). This is the first such study of *Spiroclypeus margaritatus*, and, since this species is probably related to *Heterostegina borneensis*, the same variable that Chaproniere (1980, in press) studied for the latter have been used. The results are presented in Figures 3 to 10 and Tables 1 to 3, and are discussed below.

SYSTEMATIC PALAEONTOLOGY

Order FORAMINIFERIDA Eichwald
Suborder MILIOLINA Delage & Hérouard
Superfamily MILIOLACEA Ehrenberg
Family MILIOLINIDAE Ehrenberg
Genus **Austrotrillina** Parr

Type species: *Trillina howchini* Schlumberger, 1893.

Austrotrillina striata Todd & Post, 1954

(Pl. 2, fig. 1)

1954 *Austrotrillina striata* Todd & Post, p. 555, pl. 198, fig. 9.

Remarks. A few specimens with coarse, simple alveoli occur in one sample.

Distribution. Restricted to sample So16–07TD–B, from earliest Tertiary upper *e*.

Suborder ROTALIINA Delage & Hérouard
Superfamily ROTALINACEA Ehrenberg
Family ROTALIIDAE Ehrenberg
Subfamily CHAPMANIINAE Thalmann
Genus **Sherbornina** Chapman

Type species: *Sherbornina atkinsoni* Chapman, 1922.

Sherbornina carteri sp. nov.

(Pl. 1, figs. 1–3; Pl. 2, figs. 2–11)

Diagnosis. A species of *Sherbornina* showing asymmetrical chevron-shaped septa in vertical section, poorly developed retral processes, and an asymmetrical test.

Name. After Dr A. N. Carter, in recognition of his work with *Sherbornina* and other Victorian foraminiferids.

Holotype. CPC 22277

Paratypes. CPC 22278 to CPC 22294

Number of specimens. 37: 22 free specimens (of which 8 were thin-sectioned) and 15 specimens in random sections.

Description. External: The test is free, discoidal, asymmetric, and roughly circular in outline. One surface is convex (dorsal) and the other flat or slightly concave (ventral). The convex surface rarely has a slight depression and is smooth; the concave side is generally pustulate in the central region. The periphery is subangled. Apertures or pores are not visible.

Internal: The embryoconch is centrally located. Two types of embryoconch are present. The most common type (type 1—77%) has a smaller protoconch (38 to 50 μm) and is followed by seven or eight chambers arranged in a planispiral coil; the chambers lengthen tangentially until the final embryonic chamber almost completely envelopes the rest of the embryoconch; the precyclic chambers give way to cyclic chambers which are characteristic of the adult test. The other type of embryoconch (type 2—23%) is made up of two precyclic, nephrolepidine chambers; the protoconch is generally larger (50 to 60 μm) than that of the type 1 embryoconch. The crenulations, which mark the position of the radial canal system, are confined to the top and bottom surfaces of the chambers; they are first seen in the final one to four precyclic chambers (their appearance marks the neanic stage of Wade & Carter, 1957), and are also typical of the cyclic chambers. The radial and vertical canal systems are densest on the convex side and are only weakly developed on the concave side; the radial canals alternate from chamber to chamber. The vertical canals seem to open to the exterior, but surface pores have not been seen.

In most specimens the adult stage is entirely composed of cyclic chambers, but planorbuline-like chambers are developed in a few individuals. The planorbuline chambers first appear in the final part of the pre-cyclic stage and continue into the adult part of the test, where they may or may not be followed by normal cyclic chambers.

In vertical section the septa of the embryonic stage are broadly rounded. These give way to the asymmetrically chevron-shaped septa of the adult part of the test; the longer side of the 'V' is on the convex side. The lateral test wall is laminated; successive laminae are laid down with each chamber added. Retral processes lie on the concave side of some of the chambers, and are best developed in the peripheral chambers.

The test diameter ranges from 330 to 910 μm, and thickness from 50 to 240 μm. Microspheric generation is not known.

Discussion. All observations are based on specimens treated with hydrofluoric acid (see Carter, 1964). Butt (1966) recorded a two-chambered embryoconch in a population of *Cycloloculina annulata*; Hayward (1978) regarded this population as *Sherbornina atkinsoni*, and the two-chambered forms as variant A. These are almost identical with specimens of *S. carteri* with type 2 embryoconchs. Butt (1966) found that the number of precyclic chambers varied from two to 11, though none of his specimens had three or four chambers. When he plotted the number of precyclic chambers against the diameter of the protoconch (Butt, 1966, fig. 10), no clear distinction between the two-chambered and multichambered embryoconchs was obvious. This led him to conclude that no clear distinction could be made between microspheric and megalospheric generations in his material. Similar plots (Fig. 3i, ii) for *S. carteri* give a clear distinction between the two forms; both Figure 3ii and Butt's (1966) figure 10 show that the two-chambered (type 2) embryoconchs plot within the larger-diameter part of the field. In comparison with Butt's (1966) figures, the number of precyclic chambers for the type 1 embryoconch is considerably less variable in *S. carteri* (7 or 8, Fig. 3i) than in *S. atkinsoni* (5 to 11), and this is borne out by information presented by Wade & Carter (1957).

Distinct microspheric forms have been recorded for only a few species of *Sherbornina*. Wood & Haque (1956) described three types within *S. glabra*: microspheric, small megalospheric, and large megalospheric forms; Wade & Carter (1957), however, recognised a microspheric and only one megalospheric type within *S. atkinsoni*, *S. crassata*, and *S. cuneimarginata*. Comparison of these data indicates that the two-chambered embryoconchs found in *S. atkinsoni* and *S. carteri* are probably equivalent to the large megalospheric forms found in *S. glabra*; the type 1 embryoconch is equivalent to the macrospheric (= megalospheric) form recorded by Wade & Carter (1957) and to the small megalospheric form of *S. glabra*. No specimens similar to the microspheric form recorded by Wade & Carter (1957) and by Wood & Haque (1956) have been found in populations of *S. carteri*.

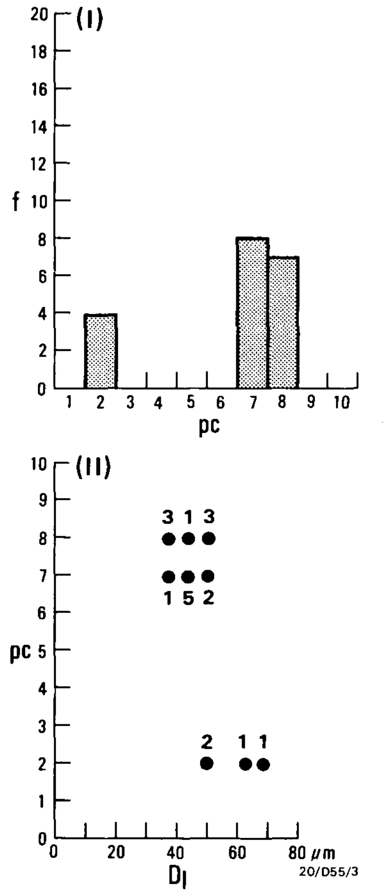

Fig. 3. (i) Frequency histogram for the number of precyclic chambers (pc) in *Sherbornina carteri* sp. nov.; (ii) plot of pc against the maximum diameter of the protoconch (D_I) for *Sherbornina carteri* sp. nov.

The planorbuline-like forms in *S. carteri* have also been recorded in *S. atkinsoni* by Hayward (1978), and are nearly identical with *Tenisonina tasmaniae* described by Quilty (1980). In *S. carteri* these are clearly variants of the forms with type 1 embryoconchs. Hayward (1978, p. 235) suggested that such forms may represent a 'schizogonous resting stage in the life cycle . . . similar to the planorbulinoid forms of *Cibicides lobatulus* (Nyholm, 1961)'. Even though Nyholm's (1961) conclusions have yet to be verified by laboratory culturing, it would seem that environmental factors may be involved. As noted by Quilty (1980) *Tenisonina tasmaniae* is clearly closely related to *Sherbornina*, and the absence of forms without the planorbuline chambers in samples studied by Quilty (1980) suggests that there may also be some genetic control involved, at least at higher stratigraphic levels.

Comparisons between *S. carteri* and other species of *Sherbornina* are difficult because of the paucity of biometric data. The specimens of *S. carteri* with the type 1 embryoconchs appear to differ from similar forms of *S. atkinsoni*, *S. crassata*, and *S. cuneimarginata* in having a much lower variation and a lower mean number of precyclic chambers, more weakly developed retral processes, and chevron-shaped rather than rounded septal walls in vertical section. The type 1 form is similar to *S. glabra* in the number of precyclic chambers, but differs in having a more complex canal system and a thicker test; no vertical sections of *S. glabra* are illustrated, so comparison with *S. carteri* on this aspect cannot be made. *S. costellata* seems to have a similar number of precyclic chambers (Heron-Allen & Earland, 1908; Le Calvez, 1949), but it differs from *S. carteri* in its thin flat test and right-angled chambers in vertical view.

Hayward (1978) briefly discussed the evolution within this genus. He noted (p. 239) that there 'is an evolutionary trend . . . from a simple, symmetric, unornamented ancestral form (*S. glabra*) through the externally ornate, sometimes asymmetric forms (*S. atkinsoni, S. costellata, S. crassata*) to the most strongly ornamented and asymmetric form (*S. cuneimarginata*)'. The data presented above indicate an additional trend toward a greater number of, and wider variation in the number of, precyclic chambers. Furthermore, the markedly asymmetric test appears to have developed on two separate occasions (Middle Eocene and Early Miocene).

Occurrence and age. This species is recorded only from sample So16–10TD–A, from Zones P.10–11, Tertiary a_3, early Middle Eocene.

Type locality. Sample So16–10TD–A, southwest of Osprey Reef, Queensland Plateau.

Family NUMMULITIDAE de Blainville
Genus **Operculina** d'Orbigny

Type species: *Lenticulites complanatus* Defrance, 1822.

Operculina complanata (Defrance, 1822)

1822 *Lenticulites complanatus* Defrance, p. 453.

Distribution. This species is rare in the faunas studied, and is restricted to samples So16–05TD–C, So16–06TD–A, and So16–06KD–A. It is rare in samples containing *Heterostegina borneensis* (Chaproniere, in press); this may imply some environmental control. It is present only in Tertiary *e* sediments.

Operculina pacifica Whipple, 1932
(Pl. 2, figs. 12, 13; Pl. 3, fig. 5)

1932 *Operculina pacifica* Whipple, p. 83, pl. 20, figs. 1, 8.

1970 *Camerina pacifica* (Whipple). Cole, p. 3–4, pl. 2, figs. 1, 5 (with synonymy).

Remarks. Cole (1970) regarded this species as the senior synonym for two species (*O. eniwetokensis*, *O. saipanensis*) that he had described from Tertiary *b* limestones from Saipan and Eniwetok Islands. As the few specimens from the Queensland Plateau seem little different from those figured by Cole (1957a, b, 1960, 1963, 1970) they are assigned to this species.

Distribution. This species was found only in sample So16–10TD–A, from Tertiary a_3. This is slightly older than previously recorded.

Genus **Cycloclypeus** Carpenter
Subgenus **Cycloclypeus** Carpenter

1932 *Cycloclypeus eidae* Tan, pp. 59–62.

Cycloclypeus (Cycloclypeus) eidae Tan, 1932
(Pl. 2, figs. 17, 18)

Type species: *Cycloclypeus mammilatus* Carter, 1861.

Remarks. The results of biometric studies made on specimens from So16–06KD–A are listed in Table 1. The parameter having most taxonomic significance is pc (Chaproniere, 1980), and the mean value of pc for this population (N = 5) is 21.21; values range from 19 to 26. Tan (1932, table 1) listed a range of values for pc (including both initial chambers) of 6 to 23 for *C. eidae*; this species was separated from *C. koolhoveni*, which had similar values of pc, by the small size of the protoconch. In the specimens studied, parameter D_I varies from 63 to 113 μm with a mean of 85.86 μm, well within the range of values given for *C. eidae* (Tan, 1932). Statistical comparison indicates that this population is more primitive than that recorded from the North West Cape area (CB10, in Chaproniere, 1980), and that the difference in the mean values for pc is significant at the 95% level of confidence, using the t-test (t = 4.6651).

TABLE 1. STATISTICAL RESULTS FOR PARAMETERS STUDIED IN A POPULATION OF *CYCLOCLYPEUS EIDAE* FROM SAMPLE So16–06KD–A

	pc	Spc_{4+5}	Sc_1	D_I	Log D_I
m	21.21	4.50	29.50	85.86	1.93
s	2.86	0.58	9.19	18.69	0.09
V	13.49	12.89	31.15	21.78	4.90
R	19–26	4–5	23–36	63–113	1.80–2.05
N	5	4	2	5	5

m = mean; s = standard deviation; V = Pearson's coefficient of variation; R = observed range; N = number; statistical parameters after Chaproniere (1980).

Plots made for the mean values of pc and log D_I for the Australian and New Zealand populations (Fig. 4) have similar regression values to those of MacGillavry (1962), and the majority fall in the field of his 'mixed *eidae* and *carpenteri*' populations; the population from So16–06TD–A falls at the primitive *eidae* end of the field.

Distribution. This species was found only in samples So16–06TD–A and So16–06KD–A, which are assigned to the earliest part of Tertiary upper *e*.

Genus **Heterostegina** d'Orbigny

Type species: *Heterostegina depressa* D'Orbigny, 1826.

Heterostegina borneensis van der Vlerk, 1929
(Pl. 3, fig. 4; Pl. 4, figs. 1–3, 8–10)

1929 *Heterostegina borneensis* van der Vlerk, p. 16, figs. 6a–c, 25a–b.

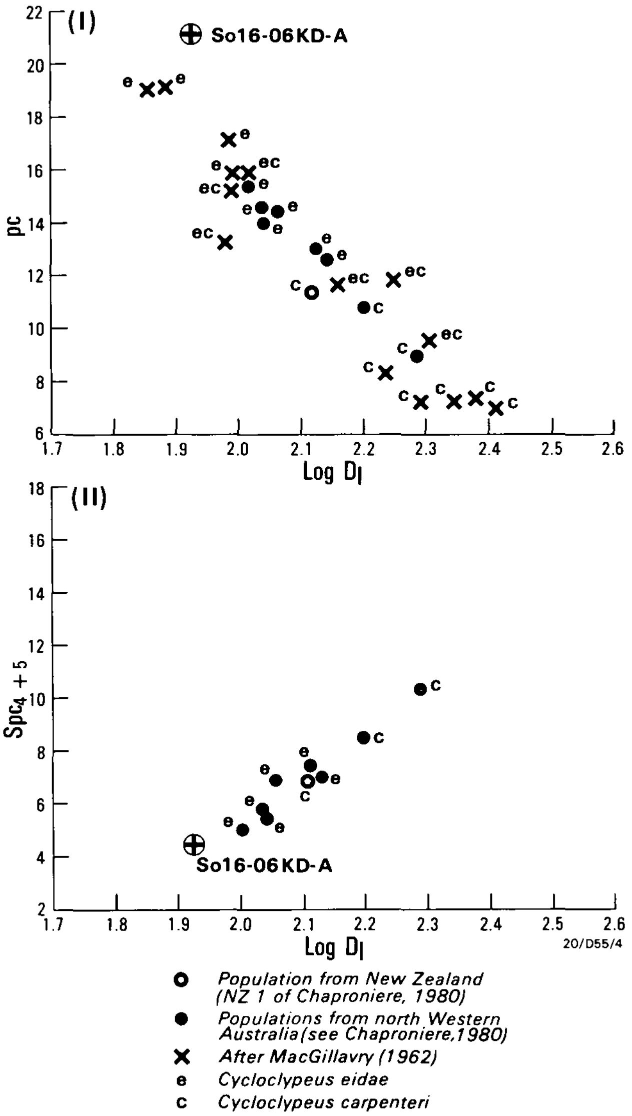

Fig. 4. (i) Plot of parameter pc against parameter log D_I, and (ii) plot of parameter Spc_{4+5} against log D_I, for *Cycloclypeus eidae*. The population from So16-06KD-A is plotted with populations from Australia and New Zealand (from Chaproniere, 1980) and with populations studied by MacGillavry (1962).

Remarks. The results of biometric studies made on specimens from So16–05TD–C are summarised in Table 2. Chaproniere (1980, in press) found that populations assigned to *H. borneensis* have a variable number of operculine chambers (parameter N_O) ranging from 2 to 5, but the majority has 3. In the original description, van der Vlerk (1929) considered *H. borneensis* to have a single operculine chamber ($N_O = 3$). The population from So16–05TD–C suggests that the number of operculine chambers in *H. borneensis* is more variable than van der Vlerk (1929) believed, because no population yet studied by the writer has specimens with values of $N_O = 3$ only. Parameter S_{4+5} (see Chaproniere, 1980) is also similar to that of other populations of *H. borneensis*. Statistical comparison between the population from So16–05TD–C and others (see Chaproniere, 1980, in press) indicates that the differences between the means for parameters N_O and S_{4+5} are not significant at the 95% level of confidence (Figs. 5i, ii).

TABLE 2. STATISTICAL RESULTS FOR PARAMETERS STUDIED IN POPULATIONS OF *HETEROSTEGINA BORNEENSIS* AND *SPIROCLYPEUS MARGARITATUS*

		N_O	S_{4+5}	D_I	D_{II}
Heterostegina	m	3.14	4.94	170.69	102.64
borneensis	s	0.35	1.17	39.55	25.79
	V	11.15	23.68	23.17	25.13
	R	3–4	3–8	115–250	70–175
So16–05TD–C	N	36	36	36	36
		N_O	S_{4+5}	D_I	D_{II}
Spiroclypeus	m	3.00	6.68	156.95	97.80
margaritatus	s	0.39	2.30	48.99	26.55
	V	13.00	34.43	31.21	27.15
	R	2–4	3–12	65–280	55–145
So16–06KD–A	N	41	41	41	41

Distribution. H. borneensis is the dominant larger foraminiferid in So16–05TD–C, but is rare in So16–06TD–A and So16–06KD–A. It is present in Tertiary lower *e* (abundant) and basal Tertiary upper *e* (rare).

Genus **Spiroclypeus** Douvillé

Type species: *Spiroclypeus orbitoideus* Douvillé, 1905.

Spiroclypeus margaritatus (Schlumberger, 1902)

(Pl. 3, fig. 3; Pl. 4, figs. 4–7, 11, 12)

1902 *Heterostegina margaritatus* Schlumberger, p. 252, 253, pl. 7, fig. 4.

1969 *Spiroclypeus margaritatus* (Schlumberger). Cole, pp. 8–10, pl. 2, figs. 1–20; pl. 3, figs. 9–14, 19.

Remarks. Cole (1969) drew attention to the large variation within post-Eocene *Spiroclypeus*. According to Cole (1969) the several species described could be distinguished on the size of the embryoconch, on the characteristics of the lateral chambers as seen in vertical section, and on the shape of the test in vertical view. Studies by Chaproniere (1975, 1980, in press) have suggested that lateral chamber characters and shell form may be largely controlled by environmental factors in *Miogypsina* and *Lepidocyclina* and so support the conclusions made by Cole (1969). Furthermore, there is good evidence that the size of the protoconch may also vary owing to environmental factors in some groups of larger foraminiferids (Cole, 1969; Drooger & Raju, 1973; Chaproniere, 1975, 1980, in press). Biometric studies on *Heterostegina borneensis*, a form which differs from *S. margaritatus* mainly on its lack of lateral chambers, strongly suggest that the large variation in protoconch diameter (parameter D_I), as shown by the high standard deviations and coefficients of variation (see Table 2; Chaproniere, 1980, in press), is related to other than genetic factors. The present study, based on free specimens of *S. margaritatus*, is the first such biometric study known to the writer; the results are given in Table 2, using the same parameters as for *Heterostegina*. The results show that *H. borneensis* and *S. margaritatus* from the So16 samples are similar, and, on the basis of the t-test (Figs. 5i, ii), the differences are not significant at the 95% level of confidence. *S. margaritatus* tends to have fewer specimens with more than one operculine chamber ($N_O = 3$) and a larger number of subdivisions in the 4th and 5th chambers (S_{4+5}) than in *H. borneensis*. In both species, the results from five populations of *H. borneensis* and one of *S. margaritatus* indicate a strong negative correlation between N_O and S_{4+5}. The close similarity of the two forms implies a relationship. As noted by Chaproniere (in press) the stratigraphic occurrence of the two species suggests that *H. borneensis* may have been ancestral to *S. margaritatus*. The lower values for N_O and the higher values of S_{4+5} support such a conclusion.

Distribution. S. margaritatus occurs in samples So16–06TD–A, So16–06KD–A, and So16–07TD–B, from earliest Tertiary upper *e*.

Family MIOGYPSINIDAE Vaughan

Genus **Miogypsina** Sacco

Subgenus **Miogypsina** Sacco

Type species: *Nummulina globulina* Michelotti, 1841.

Miogypsina (Miogypsina) tani Drooger, 1952

(Pl. 4, figs. 17–18)

1952 *Miogypsina* (*Miogypsina*) *tani* Drooger, pp. 26–27, pl. 2, figs. 20–24; pl. 3, figs. 2a, b.

Remarks. Of the 34 specimens of *Miogypsina* which were sectioned in the equatorial plane, four have lateral chambers and are referable to the subgenus *Miogypsina*. The mean value for parameter X of these four is 8.00, which places it within the range of *M.* (*M.*) *tani* given by Drooger (1952) and de Bock (1976). Other than the presence of the lateral chambers, specimens of this species are indistinguishable from those of *M.* (*Miogypsinoides*) *bantamensis* (see below).

The results of the biometric studies are summarised in Table 3. Plots of D_I against X (Fig. 6) provide similar results to those obtained by Raju (1974, fig. 33); that is, the *Miogypsinoides* constituent falls very close to the *bantamensis* field, and that of *Miogypsina* s.s., close to the *tani* field. Raju (1974) noted that the protoconch diameter in those forms with lateral chambers tended to be smaller than in those without—a feature of the population from So16–06. The frequency distributions of X and D_I (Fig. 7) suggest that there may be two constituents within the population (one of *tani*; the other of *bantamensis*); this possible bimodality could instead be only an apparent effect due to the small sample size (N = 34). Even so, the removal of the four specimens of *Miogypsina* s.s. from the histogram for X would remove

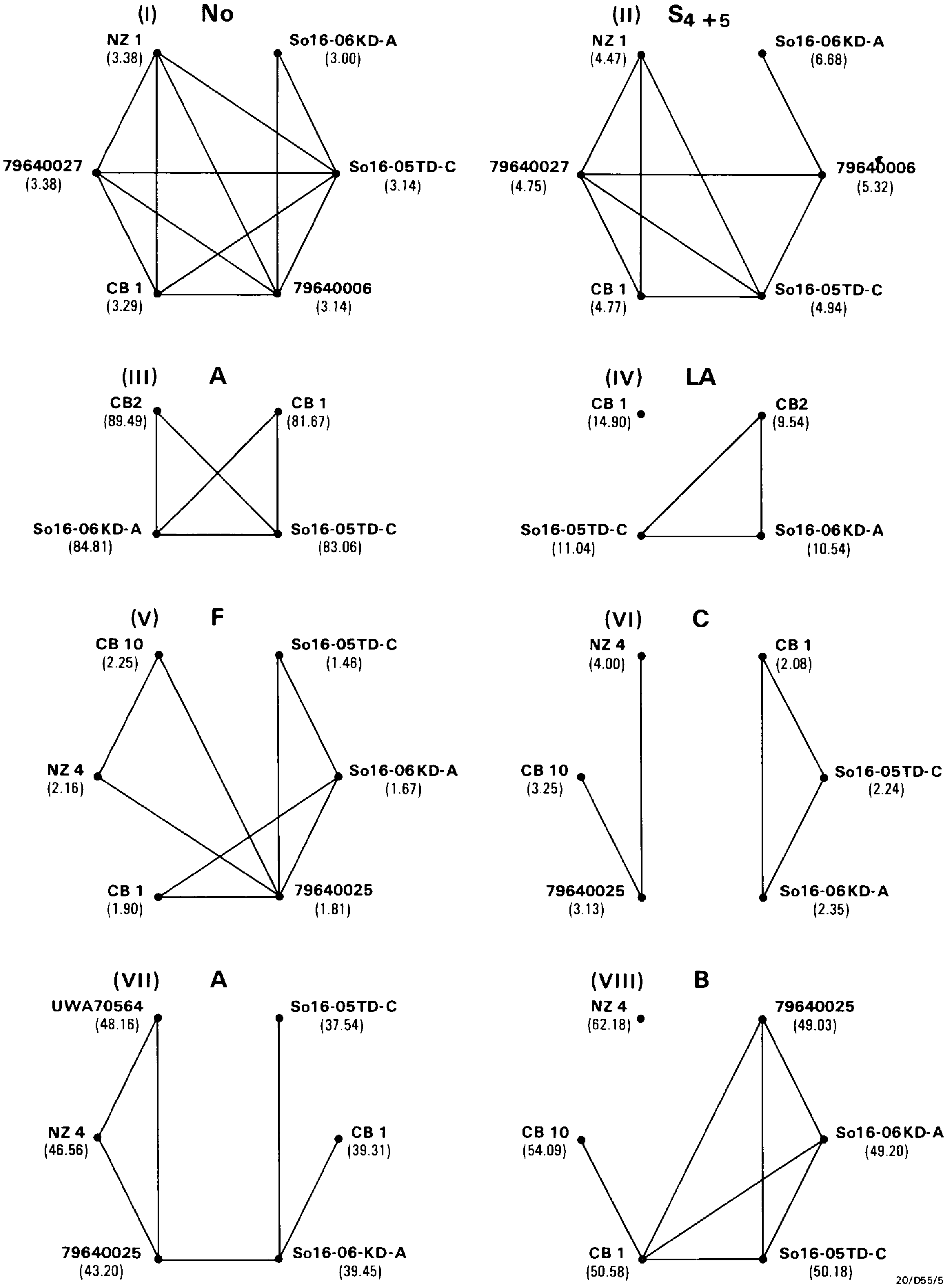

Fig. 5. T-test diagrams for parameters N_0 (i) and S_{4+5} (ii) for *Heterostegina borneensis* (all populations except So16-06KD-A) and *Spiroclypeus margaritatus* (So16-06KD-A); for parameters A (iii) and LA (iv) for *Lepidocyclina (Eulepidina) ephippioides*; for parameters F (v), C (vi), A (vii), and B (viii) for *L. (Nephrolepidina) sumatrensis*. Populations from elsewhere in Australia and New Zealand (from Chaproniere, 1980, in press) from similar stratigraphic levels have been introduced for comparison. Lines connecting populations indicate that the differences between the means are not significant at the 95% level of confidence. The means are given in parentheses.

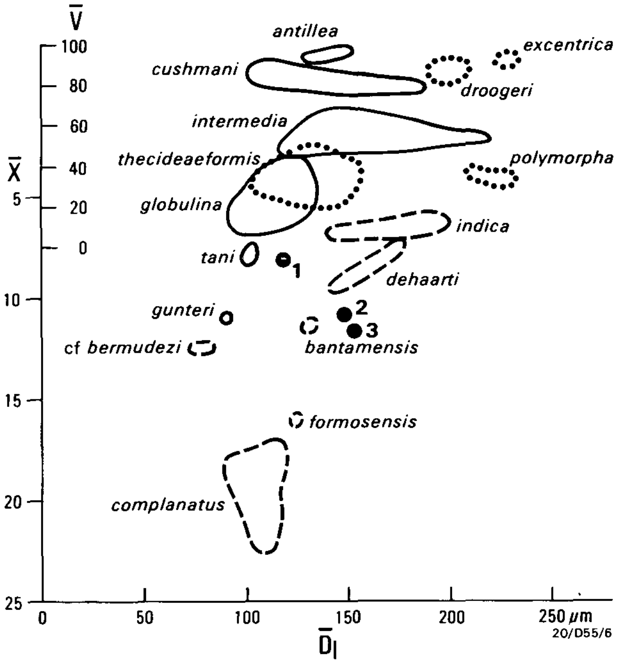

Fig. 6. The relation between $\bar{D}_I$ and $\bar{X}$ and $\bar{V}$ for the population of *Miogypsina* studied. The fields for other populations from the Indo-Pacific region (after Drooger & Raju, 1973; Raju, 1974) are included for comparison. That part of the population identified as *M. (Miogypsina) tani* (1) falls near the *tani* field; that part identified as *M. (Miogypsinoides) bantamensis* (3) falls near the *bantamensis* field, and so does the total population (2). In all specimens, the value for $\bar{D}_I$ is greater than that previously recorded in the figure for the two species. Lines drawn around the fields are solid for *M. (Miogypsina)*, dashed for *M. (Miogypsinoides)*, and dotted for *M. (Lepidosemicyclina)*.

much of the apparent bimodality, but it would have little effect on the histogram for D_I. It thus seems probable that only a few of the specimens with lateral chambers in the studied population were observed owing to the poor state of preservation. Consequently, the value for $\bar{X}$ (8.00) for the *Miogypsina* s.s. constituent is probably too low, and a value of greater than 9 would have been expected following the results of Drooger (1963), Raju (1974), and de Bock (1976). The work of de Bock (1976) highlights the difficulty in separating early *Miogypsina* s.s. from *Miogypsinoides.* De Bock (1976, pl. 30) illustrated forms transitional between the two subgenera; in the less advanced specimens, only the later parts of the test have small, poorly developed lateral chambers, which would be difficult to observe in sectioned, poorly preserved material. Thus, it seems likely that only the most advanced part of the *Miogypsina* s.s. population was observed in the material from So16–06—a feature supported by the results.

On morphologic grounds the two taxa are obviously closely related, and the sample is probably from a level near the initial appearance of *M.* (*Miogypsina*) *tani.* Even though Drooger (1963) derived *M.* (*Miogypsina*) *tani* from *M.* (*Miogypsinoides*) *dehaarti*, the results of this study indicate that *M.* (*Miogypsinoides*) *bantamensis* (based on the mean value for X for this population, but specimens with values for X typical of *dehaarti* are also present) is the ancestral form.

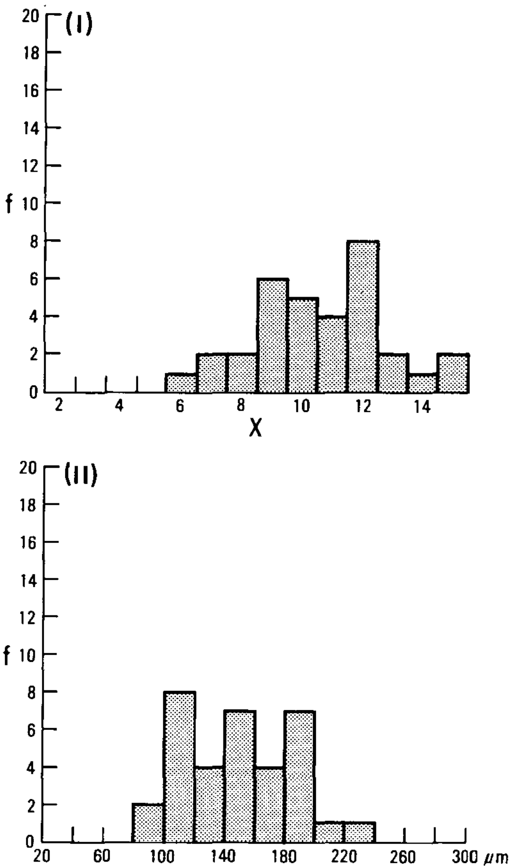

Fig. 7. Frequency histograms for parameters X (i) and D_I (ii) for *Miogypsina* from So16-06KD-A.

Environment and evolution. As noted elsewhere (Chaproniere, in press), the size and shape of the test as well as the lateral chambers are related to environmental rather than genetic factors.

Chaproniere (1975) pointed out that the production of lateral chambers and pillars provided a strong test that would have been able to resist erosion, and at the same time maintained thin lateral walls that allowed easy penetration of light; thus the production of lateral chambers was probably only of environmental rather than genetic significance in the older populations of mixed *Miogypsina* s.s. and *Miogypsinoides.* The biometric studies suggest that those forms with small-diameter protoconchs were more likely to develop lateral chambers than those without, implying some environmental influence at work (see Drooger & Raju, 1973). It is obvious, however, that the presence of lateral chambers was of distinct evolutionary advantage.

Distribution. M. (*Miogypsina*) *tani* is restricted to So16–06TD–A, So16–07TD–B, and So16–06KD–A, where it occurs as part of the *M.* (*Miogypsinoides*) *bantamensis* population. It is from the earliest part of Tertiary upper *e* in the area studied.

Subgenus **Miogypsinoides** Yabe & Hanzawa

Type species: *Miogypsina dehaarti* van der Vlerk, 1924.

Miogypsina (Miogypsinoides) bantamensis Tan 1936

(Pl. 3, figs. 1, 2; Pl. 4, figs. 13–16)

TABLE 3. STATISTICAL RESULTS FOR PARAMETERS STUDIED IN POPULATIONS OF *MIOGYPSINA (MIOGYPSINOIDES) BANTAMENSIS* AND *MIOGYPSINA (MIOGYPSINA) TANI* FROM SAMPLE So16–06KD–A

		γ	X	Y	Z	D_{I}	D_{II}	D
Miogypsina	m	−116.50	10.94	4.32	6.88	147.41	117.71	1.27
(Miogypsinoides)	s	71.76	2.92	1.95	2.47	35.08	30.72	0.16
bantamensis/tani	V	61.60	26.69	45.14	35.90	23.80	26.10	12.60
	R	−328–+4	6–22	1–11	4–16	93–220	67–180	1.00–1.72
So16–06KD–A	N	34	34	34	34	34	34	34
	ELD = 25.6980							
		γ	X	Y	Z	D_{I}	D_{II}	D
Miogypsina	m	−127.13	11.33	4.50	7.13	151.20	120.20	1.28
(Miogypsinoides)	s	69.34	2.83	2.00	2.49	33.19	30.95	0.16
bantamensis	V	54.54	24.98	44.35	34.87	21.95	25.75	12.78
	R	−328–+19	7–22	1–11	4–16	93–220	67–180	1.00–1.72
So16–06KD–A	N	30	30	30	30	30	30	30
		γ	X	Y	Z	D_{I}	D_{II}	D
Miogypsina	m	−36.75	8.00	3.00	5.00	119.00	99.00	1.19
(Miogypsina) tani	s	31.17	1.83	0.82	1.41	40.88	24.32	0.14
	V	84.82	22.88	27.22	28.28	34.35	24.56	11.88
	R	−52–+4	6–10	2–4	4–7	93–180	80–133	1.03–1.35
So16–06KD–A	N	4	4	4	4	4	4	4

1936 *Miogypsinoides complanata* forma *bantamensis* Tan, pp. 48–50, pl. 1, fig. 13.

1963 *Miogypsina (Miogypsinoides) bantamensis* Tan. Drooger, pp. 315–349.

1976 *Miogypsina (Miogypsinoides) bantamensis* Tan. De Bock, p. 15, pls. 1–14, 26, 33, 41.

Remarks. Populations of *Miogypsinoides* with mean values for parameter X between 13 and 10 are referred to this species (Drooger, 1963; de Bock, 1976). The mean value for X for the population from So16–06KD–A is 11.33, which falls within the range given for *M.* (*M.*) *bantamensis*. This assessment is also supported by the plot of $\overline{X}$ against $\overline{D}_{\mathrm{I}}$, which falls close to the *bantamensis* field given by Raju (1974) (see Fig. 6). Biometric results are given in Table 3, and have been discussed under *M.* (*M.*) *tani*.

De Bock (1976) described structures in the equatorial chambers of some species of *Miogypsinoides*; he termed them needles. Identical structures have been observed in the population from So16–06 (Pl. 4, figs. 14–16). The function of this structure is not known.

Distribution. This species is present in samples So16–06TD–A, So16–06KD–A (common), and So16–07TD–B (rare), from the earliest part of Tertiary upper *e*.

Superfamily ORBITOIDACEA Schwager

Family AMPHISTEGINIDAE Cushman

Genus **Amphistegina** d'Orbigny

Type species: *Amphistegina vulgaris* d'Orbigny, 1826.

Amphistegina mammilla (Fichtel & Moll, 1798)

(Pl. 2, fig. 16; Pl. 3, fig. 6)

1798 *Nautilus mammilla* Fichtel & Moll, p. 53, figs. vi, a–d.

1978 *Amphistegina mammilla* (Fichtel & Moll). Larsen, p. 224, pl. 1, figs. 8, 9, 11; pl. 6, fig. 3; pl. 7, fig. 4.

Remarks. Larsen (1978) has studied the many species of *Amphistegina*. Most of the So16 specimens closely resemble *A. mammilla* as described by him, though some are thicker.

Distribution. This species occurs in samples So16–05TD–C, So16–06TD–A, So16–06KD–A, and So16–07TD–B from Tertiary lower and upper *e*.

Family ACERVULINIDAE Schultze

Genus **Gypsina** Carter

Type species: *Polytrema plana* Carter, 1876.

Gypsina discus Goës, 1896

(Pl. 2, figs. 14, 15; Pl. 3, fig. 7)

1896 *Gypsina vesicularis* var. *discus* Goës, p. 74, pl. VII, figs. 4–6.

1947 *Gypsina discus* Goës. Bursch, pp. 40–42, pl. 3, figs. 2, 4, 13, 17, 22; pl. 5, figs. 6, 7; text-figs. 15, 20.

Remarks. Most of the So16 specimens referred to this species have a single strong central pillar and are similar to the individual figured by Bursch (pl. 3, fig. 4) in vertical section. Furthermore, the embryonic chambers appear to be identical with the specimen figured by Bursch (1947, pl. 3, fig. 22).

G. discus differs from *G. howchini* in having a distinct equatorial layer.

Distribution. This species was found only in So16–10TD–A, from Tertiary a_3.

Gypsina globula (Reuss, 1848)

1848 *Ceriopora gobulus* Reuss, p. 33.

1965 *Gypsina globula* (Reuss). Todd, pp. 55–56, pl. 22, fig. 5 (with synonymy).

Distribution. This species occurs rarely in So16–05TD–C, So16–06TD–A, So16–06KD–A, and So16–07TD–B, from Tertiary *e*.

Gypsina howchini Chapman, 1910

1910 *Gypsina howchini* Chapman, pp. 291–292, pl. 2, figs. 4a, b; pl. 3, figs. 3–5.

Remarks. This species differs from *G. discus* in lacking a distinct equatorial layer.

Distribution. This species occurs in samples So16–05TD–C, So16–06TD–A, So16–06KD–A, and So16–07TD–B, from Tertiary *e*.

Family DISCOCYCLINIDAE Galloway

Genus **Asterocyclina** Gümbel

Type species: *Asterodiscus pentagonalis* Schafhäutl, 1863.

Asterocyclina incisuricamerata Cole, 1957

(Pl. 3, figs. 8, 9; Pl. 5, figs. 1–4)

1957a *Asterocyclina incisuricamerata* Cole, p. 349, pl. 117, figs. 1–5.

Remarks. In his initial description, Cole (1957a) stated that this species had four rays, but in a later paper (1957b) he also referred to five-rayed forms. The protoconch is slightly enveloped by the deuteroconch, and the periembryonic chambers form a ring of elongate rectangular chambers around the embryoconch (Cole, 1957a, b).

Owing to the poor preservation of the specimens studied here, it is difficult to discern the periembryonic chambers; in one specimen, however, they seem to be very similar to those figured by Cole (1957a, pl. 117, fig. 4). Both four and five-rayed forms are present. The radially elongate chambers in the rays, and the square or tangentially elongate chambers of the inter-ray areas, conform to the description by Cole (1957b). The overall internal characters are closest to those given by Cole (1957a, b) for *A. incisuricamerata.*

Cole (1970) seemed to consider that the species of *Asterocyclina* could be recognised on the basis of the embryonic apparatus and the arrangement of lateral chambers. The latter character is not considered to be of taxonomic significance because lateral chambers may be modified by environmental factors (see Chapproniere, 1975, in press). Cole (1957b) described two species, *A. centripilaris* and *A. praecipua*, but failed to make a comparison with the similar *A. incisuricamerata.* The differences seem to be based on the size of the protoconch (*centripilaris* having the smallest), on test size (*centripilaris* being the smallest), on the number and size of pillars as seen in vertical section (a single large central pillar in *centripilaris*; few strong ones in the central area in *incisuricamerata*; well-formed pillars irregularly scattered throughout the test in *praecipua*), and on external test characters. Variable characters of the embryoconch and equatorial chambers seem to overlap in the three species, but any decision about synonymy should be reserved until faunas in addition to the type material have been studied.

Distribution. The specimens are restricted to Sol6–10TD–A, from Tertiary a_3. Though there are many records of *Asterocyclina* from Tertiary *b* in the Pacific region, the only previous records from Tertiary a_3 are those of *A. centripilaris* from the New Hebrides Trench area (Chaproniere, 1978), and *A. speighti* from New Zealand (Cole, 1962, 1967).

Family LEPIDOCYCLINIDAE Scheffen

Genus **Lepidocyclina** Gümbel

Type species: *Nummulites mantelli* Morton, 1833.

Subgenus **Eulepidina** Douvillé

Type species: *Orbitoides dilatata* Michelotti, 1861.

Lepidocyclina (Eulepidina) ephippioides Jones & Chapman, 1900

(Pl. 3, fig. 10; Pl. 5, figs. 5–8; Pl. 6, fig. 11)

1900 *Lepidocyclina ephippioides* Jones & Chapman, pp. 250–251, pl. 20, fig. 9.

1974 *Lepidocyclina (Eulepidina) ephippioides* Jones & Chapman. Adams & Belford, pp. 500–502, pl. 74, figs. 4–6, 9, 12, 14; text-fig. 12.

Remarks. The biometric results (Table 4) indicate that the two populations (Sol6–05TD–C and Sol6–06KD–A) of *L.* (*Eulepidina*) conform closely to the author's concept of this species (Chaproniere, in press). For parameter A (Fig. 8; Chaproniere, 1980) the differences between the means of the two Sol6 populations and CB1 (*ephippioides*; Fig. 5iii) are not significant at the 95% level of confidence (using the t-test); there is, however, a significant difference between the two Sol6 populations and CB2 (*badjirraensis*). However, for parameter LA (Chaproniere, 1980), the differences between the means of the two Sol6 populations and CB2 are not significant at the 95% level of confidence (Fig. 5iv); yet there is a significant difference between these two populations and CB1. The results for parameter A were to be expected, since the ages of the populations from the Queensland Plateau and of CB1 (from the Bullara Limestone, North West Cape area) are similar or identical, but the population from CB2 (from the Mandu Calcarenite, North West Cape area) is younger. For parameter LA the results should have been the same as for parameter A; the reason for this apparent divergence from the predicted result is not known, but parameter LA may not be as reliable as parameter A for biostratigraphic use. Even so, the results for both parameters indicate that Sol6–05TD–C is older than Sol6–06KD–A, and accord with other biostratigraphic evidence.

Adams & Belford (1974) restudied specimens of *L.* (*E.*) *ephippioides* from Christmas Island (the type

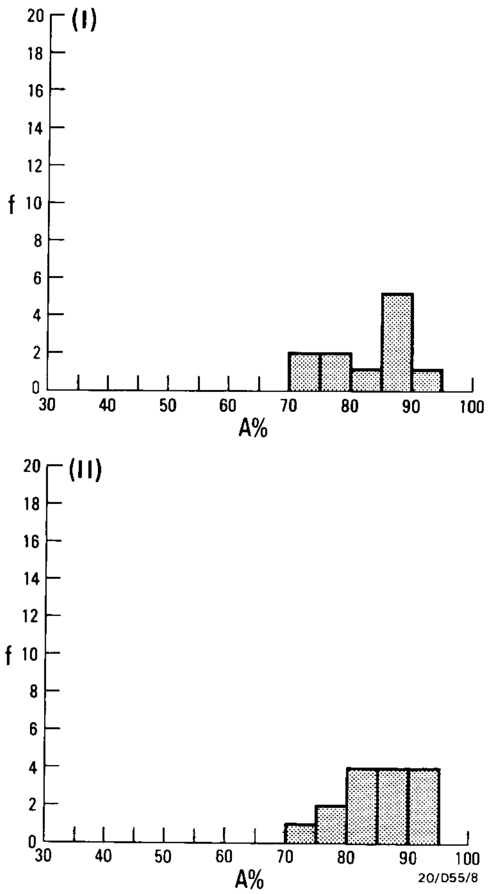

Fig. 8. Frequency histograms for parameter A for *Lepidocyclina (Eulepidina) ephippioides* from Sol6-05TD-C (i) and Sol6-06KD-A (ii).

TABLE 4. STATISTICAL RESULTS FOR PARAMETERS STUDIED IN FOUR POPULATIONS OF *LEPIDOCYCLINA (EULEPIDINA)*

Population	*A*				*LA*				
Number	*m*	*s*	*V*	*R*	*m*	*s*	*V*	*R*	*N*
So16–05TD–C	83.06	7.54	9.08	71.01–93.64	11.04	4.44	40.22	5.47–19.42	11
So16–05KD–A	84.81	5.91	6.97	74.47–94.90	10.54	3.55	33.66	4.82–15.29	15
CB1*	81.67	7.66	9.38	71.40–95.10	14.90	4.71	31.61	5.80–22.70	26
CB2*	89.49	8.06	9.01	64.90–96.70	9.54	6.10	63.94	2.20–27.10	18

Population	*D*				*D*I				
Number	*m*	*s*	*V*	*R*	*m*	*s*	*V*	*R*	*N*
So16–05TD–C	1.79	0.18	9.94	1.46–2.05	554.64	74.49	13.43	447–640	11
So16–06KD–A	1.91	0.21	10.99	1.63–2.31	240.40	132.54	55.13	127–533	15
CB1*	1.86	0.30	16.13	1.08–2.59	308.22	91.82	29.79	218–596	26
CB2*	1.84	0.21	11.41	1.40–2.32	490.08	103.92	21.20	348–703	18

Population	D_{II}				
Number	*m*	*s*	*V*	*R*	*N*
So16–05TD–C	986.09	106.69	10.82	800–1120	11
So16–06KD–A	443.93	209.37	47.16	233– 867	15
CB1*	553.11	80.02	14.47	434– 654	26
CB2*	889.35	145.10	16.32	558–1159	18

* from Chaproniere, 1980 (corrected).

area). These specimens seem to be similar morphologically to those found in this study. However, as there is no biometric information for these specimens, a complete comparison is not possible.

Distribution. L. (E.) ephippioides occurs in samples So16–05TD–C, So16–06TD–A, So16–06KD–A, and So16–07TD–B, from Tertiary lower and upper *e*.

Subgenus **Nephrolepidina** Douvillé

Type species: *Nummulites marginata* Michelotti, 1841.

Lepidocyclina (Nephrolepidina) sumatrensis (Brady, 1875)

(Pl. 3, figs. 11, 12; Pl. 5, figs. 9–12; Pl. 6, figs. 1–10)

1895 *Orbitoides sumatrensis* Brady, p. 536, pl. 14, figs. 3a, b.

Remarks. Frequency histograms for parameters A, B, C, and F are given in Figures 9 and 10. Chaproniere (in press) based his concepts of Australian and New Zealand species of *L. (Nephrolepidina)* on parameter F (see Chaproniere, 1980, 1981b). In that study *L. (N.) sumatrensis* was considered to be ancestral to the *L. (N.) howchini* lineage; *L. (N.) sumatrensis* was based on mean values for F of less than 2. For the two populations studied from the Queensland Plateau (Table 5) both have values for $\overline{F}$ of less than 2—1.60 for So16–05TD–C and 1.75 for So16–06KD–A; these are the lowest values so far encountered in the Australasian region. Though values of F are lowest for the sample considered to be oldest (So16–05TD–C) and so are compatible with other biostratigraphic evidence, the values are lower than expected for So16–06KD–A. Sample So16–05TD–C is from a level close to CB1 (Tertiary lower *e*), but the difference between the means for the two populations is significant according to the t-test (t = 3.1807) at the 95% level of confidence (Fig. 5v). This result contrasts with that for

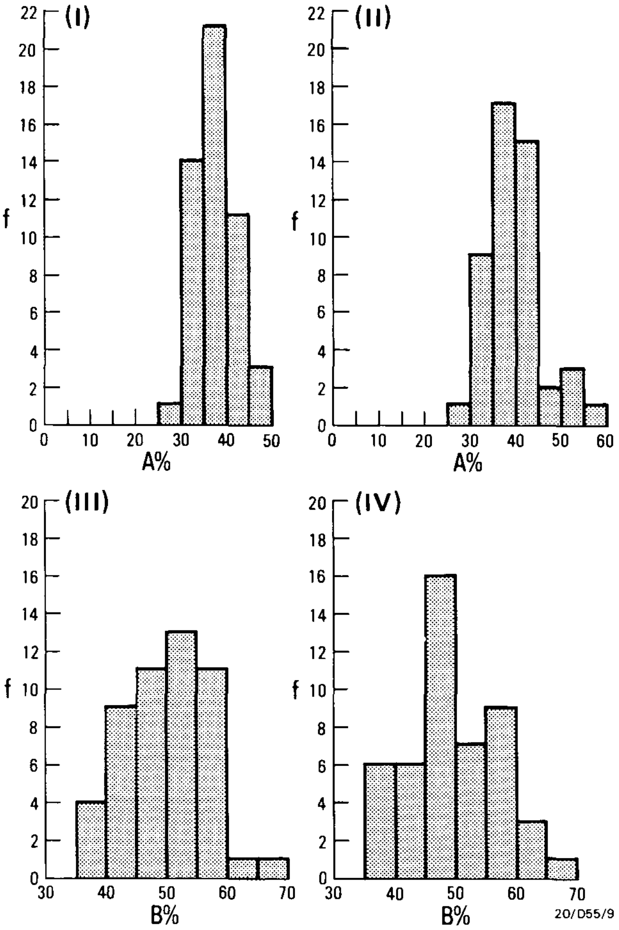

Fig. 9. Frequency histograms for parameters A and B for *Lepidocyclina (Nephrolepidina) sumatrensis* **from So16-05-TD-C (i, iii) and So16-06KD-A (ii, iv).**

L. (*E.*) *ephippioides*, which shows no significant difference between the means for parameter A for the same two populations (Fig. 5iii). Even so, the biometric evidence strongly supports the conclusion that So16–05TD–C is older than CB1. There is no significant difference (t = 1.2137—Fig. 5v) between the values for $\overline{F}$ of the populations of *L.* (*Nephrolepidina*) from So16–06KD–A and CB1, implying little difference in age between the two samples. This suggests that, even though the value for $\overline{F}$ for So16–06KD–A should be higher, no biostratigraphic significance can be inferred from this result. This is supported by the mean value for parameter A for So16–06KD–A, which is slightly higher than that of (indicating that it is slightly younger than) CB1 (Fig. 5vii).

The mean value for parameter A for the population from So16–05TD–C is very close to that given by van der Vlerk (1966) for *L.* (*N.*) *isolepidinoides*. However, as there is little other biometric data available for this species, the population from So16–05TD–C is best referred to *L.* (*N.*) *sumatrensis* at this time. As noted above, the population from So16–06KD–A has similar $\overline{A}$ and $\overline{F}$ values to CB1, and so is placed with *L.* (*N.*) *sumatrensis*.

Distribution. This is the only species of *L.* (*Nephrolepidina*) recognised in this study, and occurs in samples So16–05TD–C, So16–06TD–A, So16–06KD–A, and So16–07TD–B; all are from Tertiary *e*.

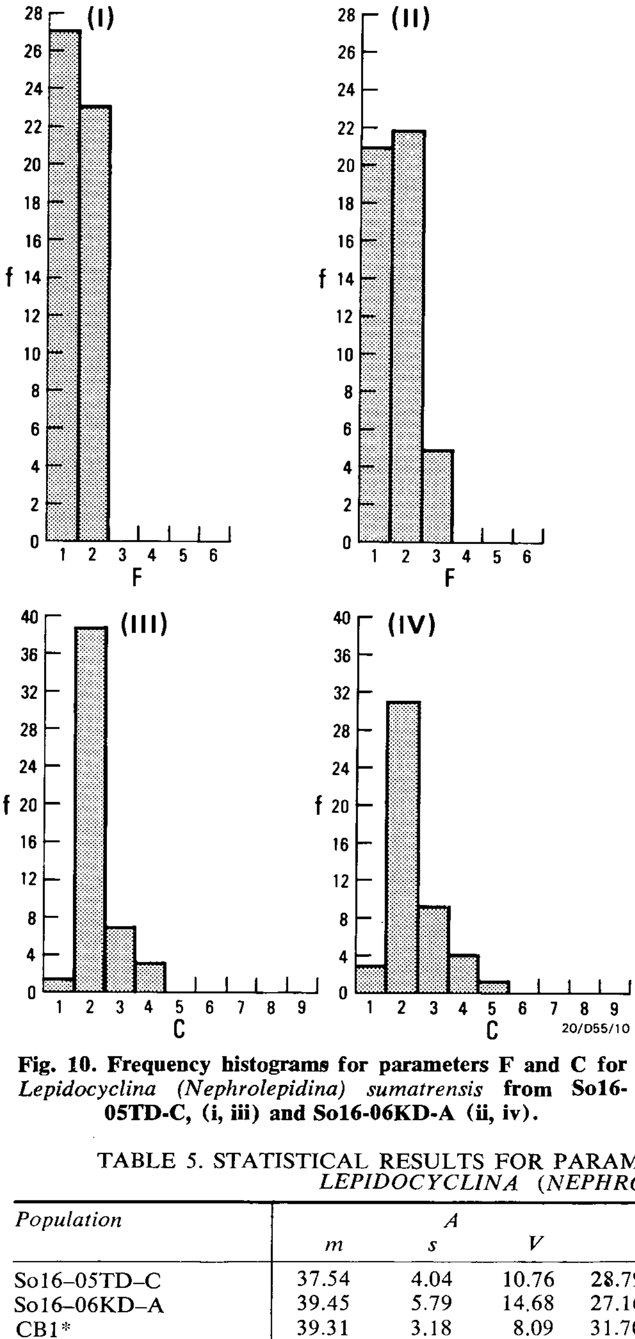

Fig. 10. Frequency histograms for parameters F and C for ***Lepidocyclina (Nephrolepidina) sumatrensis*** **from So16-05TD-C, (i, iii) and So16-06KD-A (ii, iv).**

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TABLE 5. STATISTICAL RESULTS FOR PARAMETERS STUDIED IN FIVE POPULATIONS OF *LEPIDOCYCLINA* (*NEPHROLEPIDINA*) *SUMATRENSIS*

Population		*A*				*dc*			
	m	*s*	*V*	*R*	*m*	*s*	*V*	*R*	*N*
So16–05TD–C	37.54	4.04	10.76	28.79–48.00	18.21	6.15	33.77	5.43–34.15	50
So16–06KD–A	39.45	5.79	14.68	27.16–55.88	19.88	7.73	38.88	8.22–48.08	48
CB1*	39.31	3.18	8.09	31.70–47.70	18.13	5.00	27.58	7.60–30.90	40
NZ4*	46.56	5.85	12.56	36.30–58.90	28.62	13.09	45.74	5.60–58.70	25
79640025†	43.20	5.34	12.36	35.71–52.33	30.73	11.06	35.99	19.61–51.43	8

Population		*E*				*B*			
	m	*s*	*V*	*R*	*m*	*s*	*V*	*R*	*N*
So16–05TD–C	24.57	8.20	33.38	6.94–47.92	50.18	6.92	13.79	35.63–69.23	50
So16–06KD–A	27.23	10.13	37.20	12.50–58.14	49.20	7.15	14.53	37.16–65.85	48
CB1*	23.86	6.65	27.87	12.90–41.90	50.58	6.58	13.01	38.10–65.20	40
NZ4*	38.50	14.55	37.79	8.70–68.80	62.18	8.61	13.85	48.90–85.30	25
79640025†	36.32	9.07	24.97	27.03–52.94	49.03	8.55	17.44	40.51–62.50	8

Population		*A+B*				*D*			
	m	*s*	*V*	*R*	*m*	*s*	*V*	*R*	*N*
So16–05TD–C	87.68	8.31	9.48	70.46–104.85	1.41	0.13	9.22	1.08–1.67	50
So16–06KD–A	88.66	10.94	12.34	71.39–115.88	1.35	0.16	11.85	1.02–1.73	48
CB1*	89.89	8.45	9.40	73.10–106.70	1.45	0.14	9.66	1.01–1.77	40
NZ4*	108.74	11.85	10.90	85.20–135.20	1.73	0.21	12.14	1.28–2.21	25
79640025†	92.23	12.16	13.18	77.84–110.33	1.58	0.08	5.06	1.48–1.75	8

TABLE 5. *(continued)*

Population	D_I				D_{II}				
	m	*s*	*V*	*R*	*m*		*V*	*R*	*N*
So16–05TD–C	269.30	44.97	16.70	187–373	380.52	71.03	18.67	260–533	50
So16–06KD–A	181.06	42.35	23.39	110–280	244.21	64.20	26.29	150–427	48
CB1*	221.43	34.52	15.59	135–313	319.68	45.68	14.29	219–410	40
NZ4*	237.32	38.34	16.16	171–338	406.44	62.19	15.30	279–544	25
79640025†	274.13	42.76	15.60	233–353	430.88	57.94	13.45	387–533	8

Population	C				F				
	m	*s*	*V*	*R*	*m*	*s*	*V*	*R*	*N*
So16–05TD–C	2.24	0.59	26.39	1–4	1.60	0.49	30.63	1–2	50
So16–06KD–A	2.35	0.82	34.89	1–5	1.75	0.70	40.00	1–3	48
CB1*	2.08	0.57	24.40	1–4	1.90	0.38	20.00	1–3	40
NZ4*	4.00	1.15	28.75	2–7	2.16	0.47	21.76	1–3	25
79640025†	3.13	1.13	36.10	2–5	1.81	0.35	18.62	1–2	8

* from Chaproniere (1980).
† from Chaproniere (in press).

REFERENCES

Adams, C. G., 1970—A reconsideration of the East Indian Letter Classification of the Tertiary. *Bulletin of the British Museum (Natural History) Geology*, 19, 85-137.

Adams, C. G., & Belford, D. J., 1974—Foraminiferal biostratigraphy of the Oligocene-Miocene limestones of Christmas Island (Indian Ocean). *Palaeontology*, 17, 475-506.

Blow, W. H., 1969—Late middle Eocene to Recent planktonic foraminiferal biostratigraphy; *in* Proceedings of the First International Conference on planktonic microfossils, Volume 1. *E. J. Brill, Leiden*, 199-421.

Blow, W. H., 1979—THE CAINOZOIC FORAMINIFERIDA, Volumes I and II. *E. J. Brill, Leiden.*

Brady, H. B., 1875—On some fossil foraminifera from the West Coast District, Sumatra. *Geological Magazine, new series, decade 2*, 2, 532-539.

Bursch, J. G., 1947—Mikropaläontologische unterschungen des Tertiärs von Gross Kei (Molukken). *Schweizerischen Palaeontologischen, Abhandlungen* 65, 1-69.

Butt, A. A., 1966—LATE OLIGOCENE FORAMINIFERA FROM ESCORNEBEOU, SW FRANCE. *Schotanus & Jens, Utrecht.*

Carter, A. N., 1964—Tertiary foraminifera from Gippsland, Victoria, and their stratigraphic significance. *Geological Survey of Victoria, Memoir* 23.

Chapman, F., 1910—A study of the Batesford Limestone. *Proceedings of the Royal Society of Victoria*, 22, 263-314.

Chaproniere, G. C. H., 1975—Palaeoecology of Oligo-Miocene larger Foraminiferida. *Alcheringa*, 1, 37-58.

Chaproniere, G. C. H., 1976—The Bullara Limestone, a new rock-stratigraphic unit from the Carnarvon Basin, Western Australia. *BMR Journal of Australian Geology & Geophysics*, 1, 171-174.

Chaproniere, G. C. H., 1978—A record of 'Lepidocyclina' (Foraminiferida) from DSDP Leg 30, Site 286, Western Pacific Ocean. *Journal of Paleontology*, 52, 928-939.

Chaproniere, G. C. H., 1980—Biometrical studies of early Neogene larger Foraminiferida from Australia and New Zealand. *Alcheringa*, 4, 153-181.

Chaproniere, G. C. H., 1981a—Late Oligocene to early Miocene planktic Foraminiferida from Ashmore Reef No. 1 Well, northwest Australia. *Alcheringa*, 5, 103-131.

Chaproniere, G. C. H., 1981b—Australasian mid-Tertiary larger foraminiferal associations and their bearing on the East Indian Letter Classification. *BMR Journal of Australian Geology & Geophysics*, 6, 145-151.

Chaproniere, G. C. H., in press—Oligocene and Miocene larger Foraminiferida from Australia and New Zealand. *Bureau of Mineral Resources, Australia, Bulletin* 188.

Cole, W. S., 1957a—Larger foraminifera [of Saipan, Mariana Islands]. *United States Geological Survey, Professional Paper* 280-I, 321-360.

Cole, W. S., 1957b—Larger foraminifera from Eniwetok drill holes. *United States Geological Survey, Professional Paper* 260-U, 743-784.

Cole, W. S., 1960—Upper Eocene and Oligocene foraminifera from Viti Levu, Fiji. *United States Geological Survey, Professional Paper* 374A, 1-7.

Cole, W. S., 1962—*Asterocyclina* from New Zealand and the Chatham Islands. *Bulletins of American Paleontology*, 44, 343-357.

Cole, W. S., 1963—Tertiary larger foraminifera from Guam. *United States Geological Survey, Professional Paper* 403-E, 1-28.

Cole, W. S., 1967—Additional data on New Zealand *Asterocyclina* (Foraminifera). *Bulletins of American Paleontology*, 52, 1-17.

Cole, W. S., 1969—Larger foraminifera from deep drill holes on Midway Atoll. *United States Geological Survey, Professional Paper* 680-C, 1-15.

Cole, W. S., 1970—Larger foraminifera of late Eocene age from Eua, Tonga. *United States Geological Survey, Professional Paper* 640-B, 1-17.

de Bock, J. F., 1976—Studies on some *Miogypsinoides-Miogypsina* s.s. associations with special reference to morphological features. *Scripta Geologica*, 36, 1-135.

Defrance, M. J. L., 1822—Mineralogie et geologie; *in* DICTIONNAIRE DE SCIENCES NATURELLES. *F. G. Levrault, Paris*, 25, 453.

Drooger, C. W., 1952—STUDY OF AMERICAN MIOGYPSINIDAE. *Thesis, University of Utrecht. Vonk & Co., Ziest.*

Drooger, C. W., 1963—Evolutionary trends in the Miogypsinidae; *in* von Koenigswald, G. H. R., Emeis, J. D., Buning, W. L., & Wagner, C. W. (Editors)—EVOLUTIONARY TRENDS IN FORAMINIFERA. *Elsevier, London*, 315-349.

Drooger, C. W., & Raju, D. S. N., 1973—Protoconch diameter in the Miogypsinidae. *Proceedings Koninklijke Nederlandse Akademie van Wetenschappen, Series B*, 76, 206-216.

Fichtel, L., von, & Moll, J. P. C., von, 1978—TESTACEA MICROSCOPICA, ALIAQUE MINUTA EX GENERIBUS ARGONAUTA ET NAUTILUS, AD NATURAM PICTA ET DESCRIPTA (MICROSCOPISCHE UND ANDERE KLEIN SCHALTHIERE AUS DEN GESCHLECHTERN ARGONAUTE UND SCHIFFER). *Canesina, Vienna.*

Goës, A., 1896—Reports on the dredging operations carried on by the U.S. Fish Commission Steamer 'Albatross' during 1891—the foraminifera. *Harvard College, Museum of Comparative Zoology, Bulletin* 29, 1-104.

HARDENBOL, J., & BERGGREN, W. A., 1978—A new Paleogene numerical time scale; *in* COHEER, G. V., GLAESSNER, M. F., & HEDBERG, H. D. (Editors)—Contributions to the Geological Time Scale. *American Association of Petroleum Geologists, Studies in Geology,* 6, 214-234.

HAYWARD, B. W., 1978—Foraminifera of the genera *Cycloloculina* Heron-Allen and Earland 1908, and *Sherbornina* Chapman, 1922. *Journal of Foraminiferal Research,* 8, 225-240.

HERON-ALLAN, E., & EARLAND, A., 1908—On *Cycloloculina,* a new generic type of foraminifera, with a preliminary study of the foraminiferous deposits and shore-sands of Selsey Bill. *Journal of the Royal Microscopical Society,* 529-543.

JONES, T. R., & CHAPMAN, F., 1900—On the foraminifera of the orbitoidal limestones and reef rocks of Christmas Island; *in* ANDREWS, C. W.—A MONOGRAPH OF CHRISTMAS ISLAND (INDIAN OCEAN). *British Museum of Natural History, London,* 226-264.

LARSEN, A. R., 1978—Phylogenetic and paleobiogeographical trends in the foraminiferal genus *Amphistegina. Revista Española de Micropaleontologia,* 10, 217-243.

LE CALVEZ, Y., 1949—Révision des foraminifères Lutétiens du Bassin de Paris. II—Rotaliidae et familles affines. *Memoires pour servir à l'explication de la carte géologique détailée de la France, Paris,* 1-54.

MACGILLAVRY, H. J., 1962—Lineages in the genus *Cycloclypeus* Carpenter (Foraminifera), parts I and II. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B,* 65, 429-458.

NYHOLM, K. G., 1961—Morphogenesis and biology of the foraminifer *Cibicides lobatulus. Zoologiska Bidrag fran Uppsala,* 33, 157-196.

QUILTY, P., 1980—New rotalid foraminiferids from the Oligo-Miocene of Tasmania. *Alcheringa,* 4, 299-311.

RAJU, D. S. N., 1974—Study of Indian Miogypsinidae. *Utrecht Micropaleontological Bulletins,* 9.

REUSS, A. E., 1848—Die fossilen Polyparien des Wiener Tertiarbeckens. *Naturwissenschaften Abhandlungen, Wien,* 2, 1-109.

SCHLUMBERGER, C., 1902—Note sur un Lepidocyclina nouveau de Borneo. *Sammlungen des Geologischen Reichsmuseums in Leiden, Series 1,* 6, 250-253.

TAN SIN HOK, 1932—On the genus *Cycloclypeus* Carpenter. Part I, and an appendix on the heterostegines of Tjimanggae, South Bantam, Java. *Dienst van den Mijnbouw in Nederlandsch-Indië, Wetenschappelijke Mededeelingen,* 19, 1-194.

TAN SIN HOK, 1936—Zur Kenntnis der Miogypsinidae. *Ingenieur in Nederlandsch-Indie, Mijnbouw en Geologisch,* 3, 45-61.

TODD, R., 1965—The foraminifera of the tropical collections of the 'Albatross' (1899-1900). Part 4, Rotaliform families and planktonic families. *United States National Museum, Bulletin* 161.

TODD, R., & POST, R., 1954—Smaller foraminifera from Bikini drill holes. *United States Geological Survey, Professional Paper* 260-N, 547-568.

VAN COUVERING, J. A., & BERGGREN, W. A., 1977—Biostratigraphical basis of the Neogene time scale; *in* KAUFFMAN, E. G., & HAZEL, J. E. (Editors)—CONCEPTS AND METHODS OF BIOSTRATIGRAPHY. *Dowden, Hutchinson and Ross, Stroudsberg,* 283-306.

VAN DER VLERK, I. M., 1929—Groote Foraminiferen van N.O. Borneo. *Dienst van der Mijnbouw in Nederlandsch-Indie, Wetenschappelijke Mededeelingen,* 9, 1-44.

VAN DER VLERK, I. M., 1966—Stratigraphie du Tertiaire des domaines Indo-Pacifique et Mesogeen. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B,* 69, 336-344.

VAN DER VLERK, I. M., & POSTUMA, J. A., 1967—Oligo-Miocene lepidocyclinas and planktonic foraminifera from East Java and Madura, Indonesia. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B,* 70, 391-398.

WADE, M., & CARTER, A. N., 1957—The foraminiferal genus *Sherbornina* in south-eastern Australia. *Micropaleontology,* 3, 155-164.

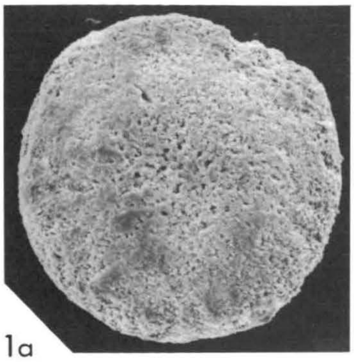
WHIPPLE, G. L., 1932—Eocene foraminifera; *in* HOFFMEISTER, J. E.—Geology of Eua Tonga. *Bernice P. Bishop Museum, Bulletin* 96, 79-90.

WOOD, A., & HAQUE, A. F. M. M., 1956—The genus *Cycloloculina* (Foraminifera) with a description of a new species from Pakistan. *Records of the Geological Survey of Pakistan,* 8, 41-44.

PLATE 1

All figures × 70

Figs.	
1–3	**Sherbornina carteri** sp. nov. a, dorsal view—convex side; b, ventral view—flat on concave side; c, side view. From So16–10TD–A. 1, holotype, in stereo pairs. CPC 22277. 2, paratype; type 2 specimen. CPC 22278. 3, paratype; planorbuline form. CPC 22279.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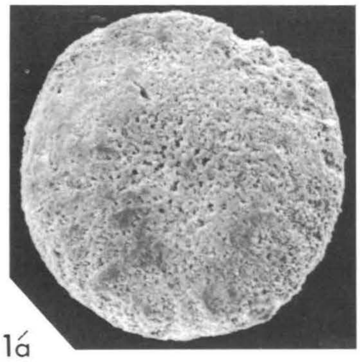
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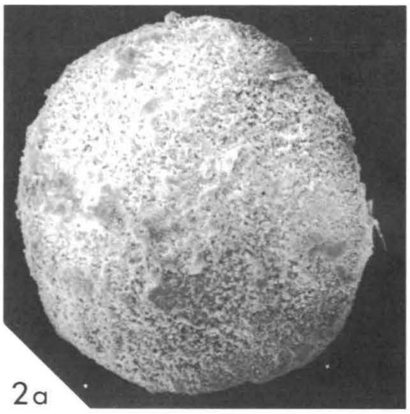
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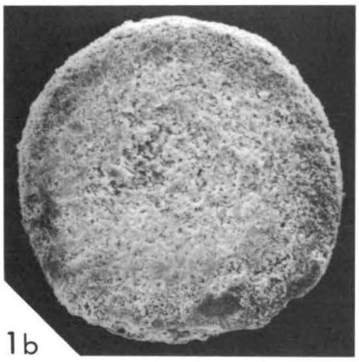
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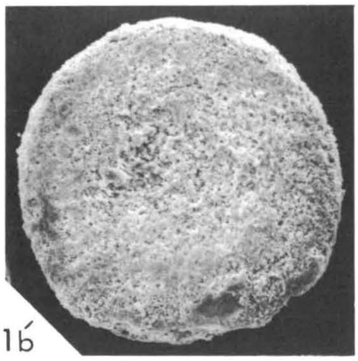
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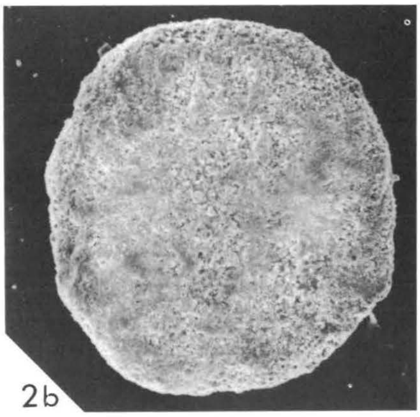
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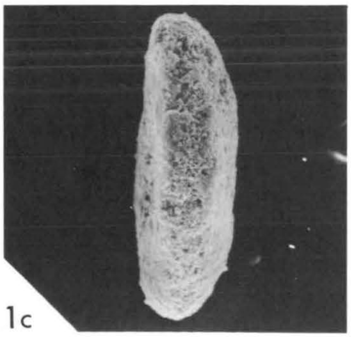
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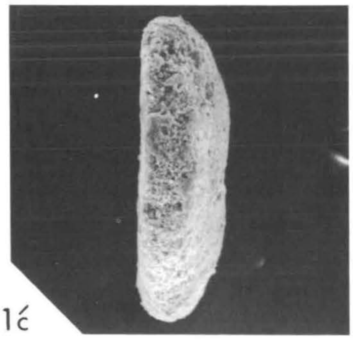
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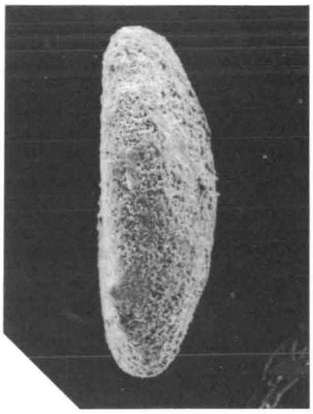

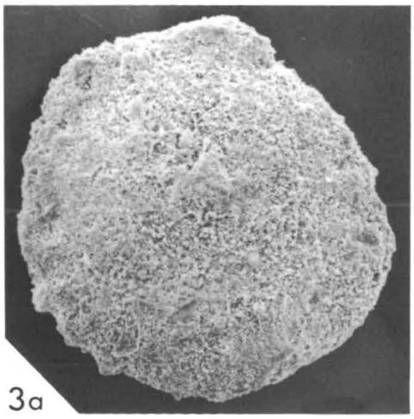
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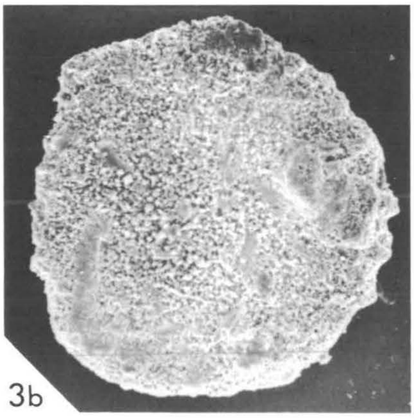
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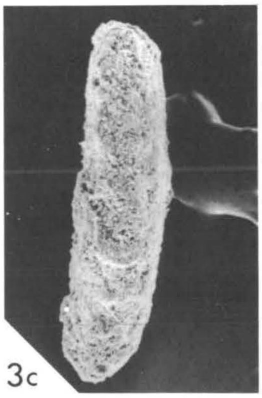
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PLATE 2

Figs.

1 **Austrotrillina striata** Todd & Post
Fragment in limestone from So16–07TD–B. CPC 22276; x70.

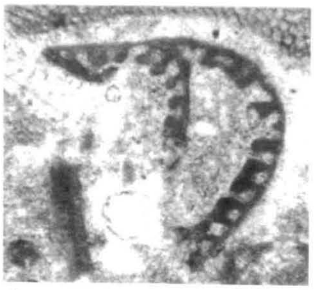
2–11 **Sherbornina carteri** sp. nov.
Paratypes from So16–10TD–A.
2, random vertical section showing alar prolongations and pores to outside. CPC 22280; x70.
3, vertical section through embryoconch. CPC 22281; x70.
4, vertical section through embryoconch; b, x70 enlargement of a (x40), showing laminated wall. CPC 22282.
5, equatorial section of type 1 form; b, x70 enlargement of a (x40), showing detail of embryoconch. CPC 22283.
6–8, specimens treated with hydrofluoric acid and viewed from dorsal (convex) side; b, x70 enlargement of a (x40), showing detail of embryonic stage.
6, CPC 22284; 7, CPC 22285; 8, CPC 22286.
9, equatorial section of type 2 form with nephrolepidine embryoconch; b, x70 enlargement of a (x40), showing detail of embryoconch. CPC 22287.
10, type 2 specimen after treatment with hydrofluoric acid, and viewed from dorsal side; b, x70 enlargement of a (x40), showing detail of embryoconch. CPC 22288.
11, planorbuline form viewed from convex side; b, x70 enlargement of a (x40), showing detail of embryonic stage and adult chamber arrangement. CPC 22289.

12–13 **Operculina pacifica** Whipple
12, equatorial section. CPC 22295; x20.
13, vertical section. CPC 22296; x40.
From So16–10TD–A.

14–15 **Gypsina discus** Goës
14, equatorial section; b, x100 enlargement of a (x40), showing detail of embryonic stage. CPC 22324.
15, vertical section. CPC 22325; x40.
From So16–10TD–A.

16 **Amphistegina mamilla** (Fichtel & Moll)
Random vertical section in limestone from So16–06KD–A. CPC 22322; x40.

17–18 **Cycloclypeus eidae** Tan Sin Hok
Equatorial sections. 17, CPC 22312; 18, CPC 22313; x20.
From So16–06KD–A.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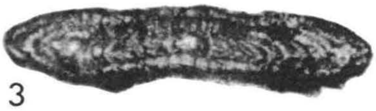
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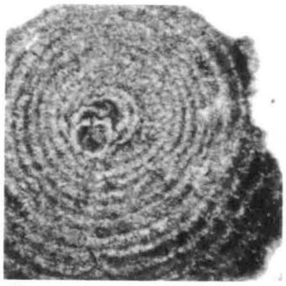
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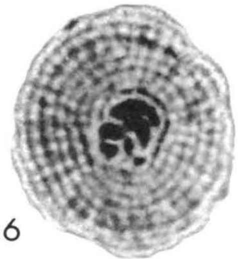
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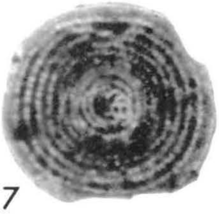
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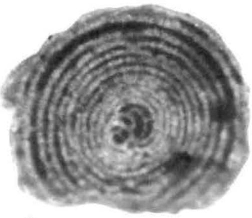
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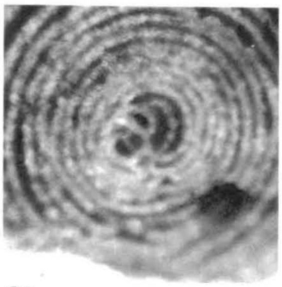
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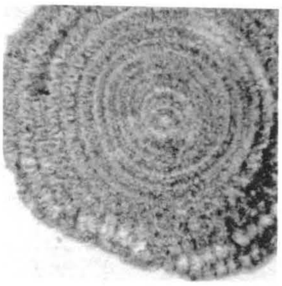
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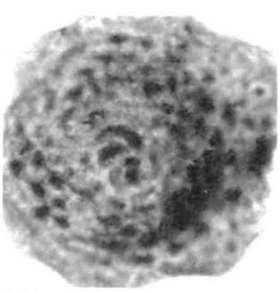
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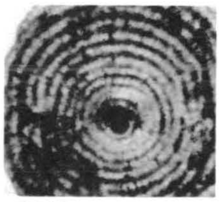
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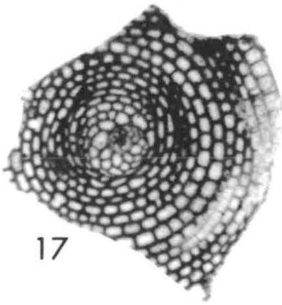
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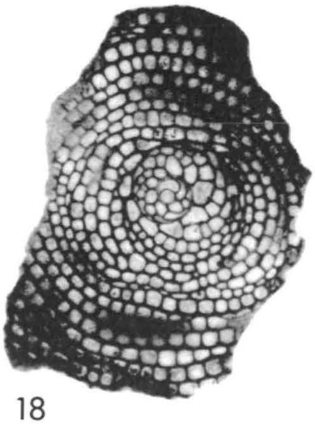
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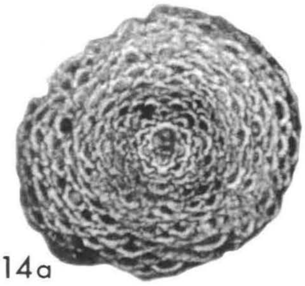
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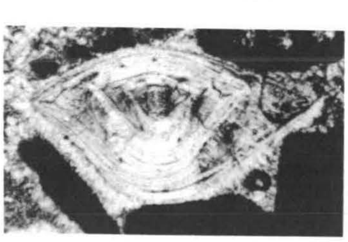
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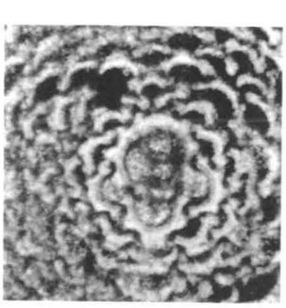
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PLATE 3

Figs.

1–2 **Miogypsina (Miogypsinoides) bantamensis** Tan Sin Hok
1, specimen with strong pillar development. CPC 22316; x30.
2, specimen with no obvious pillar development. CPC 22317; x30. From So16–06KD–A.

3 **Spiroclypeus margaritatus** (Schlumberger)
External view. CPC 22305; x20. From So16–06KD–A.

4 **Heterostegina borneensis** van der Vlerk
External view. CPC 22298; x20. From So16–05TD–C.

5 **Operculina pacifica** Whipple
External view. CPC 22297; x45. From So16–10TD–A.

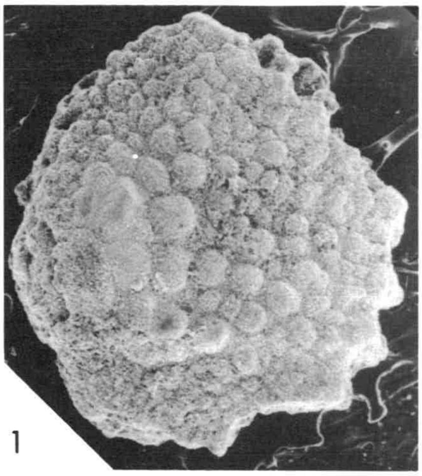
6 **Amphistegina mamilla** (Fichtel & Moll)
External view. CPC 22323; x30. From So16–05TD–C.

7 **Gypsina discus** Goës
External view. CPC 22326; x50. From So16–10TD–A.

8–9 **Asterocyclina incisuricamerata** Cole
External views.
8, specimen with weakly developed pillars. CPC 22327; x45.
9, specimen with pillars in central region. CPC 22328; x25. From So16–10TD–A.

10 **Lepidocyclina (Eulepidina) ephippiodes** Jones & Chapman
External view. CPC 22333; x7. From So16–05TD–C.

11–12 **Lepidocyclina (Nephrolepidina) sumatrensis** (Brady)
External views, x25. 11, CPC 22339; 12, CPC 22340. From So16–05TD–C.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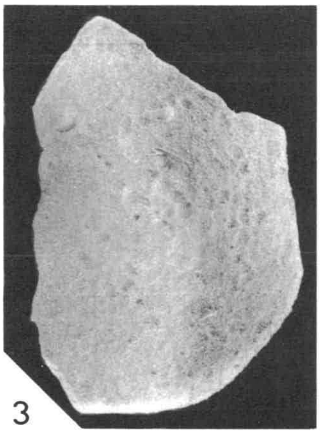
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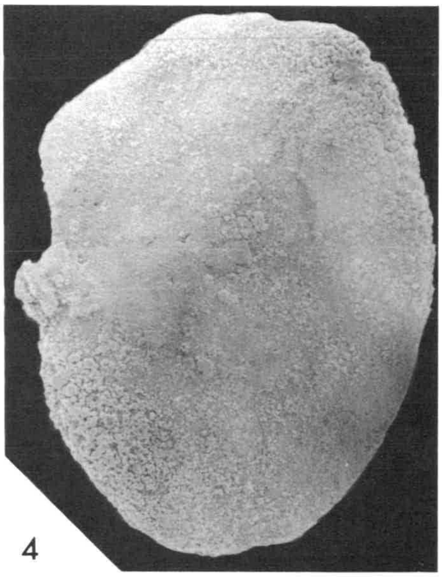
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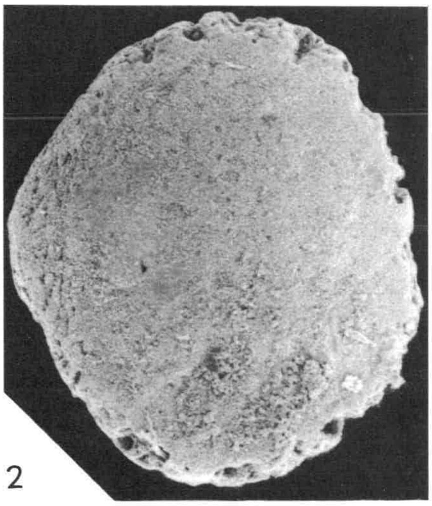
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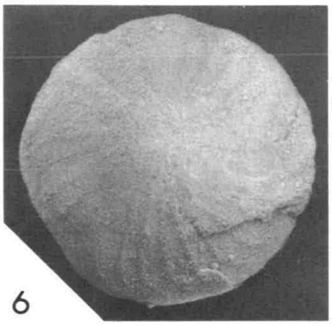
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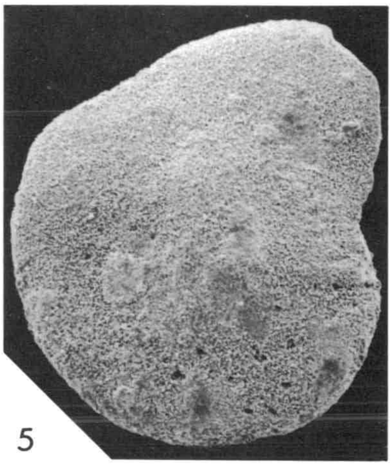
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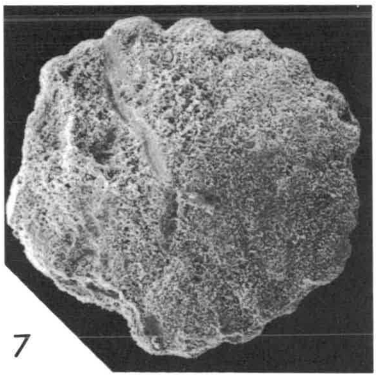
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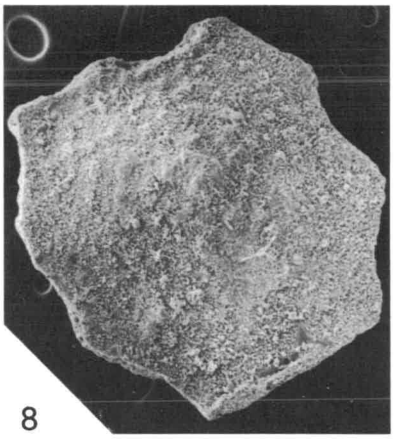
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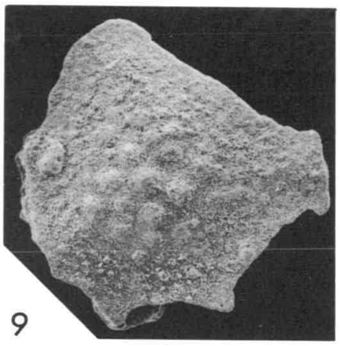
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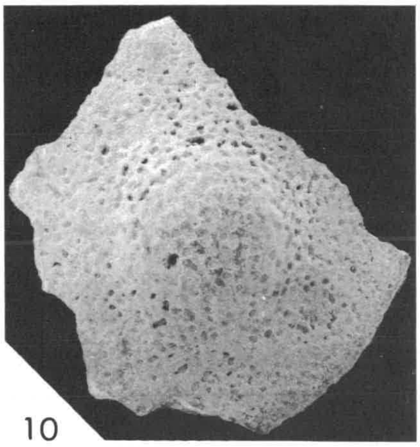
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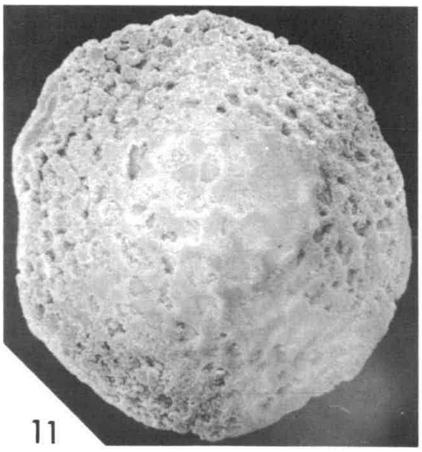
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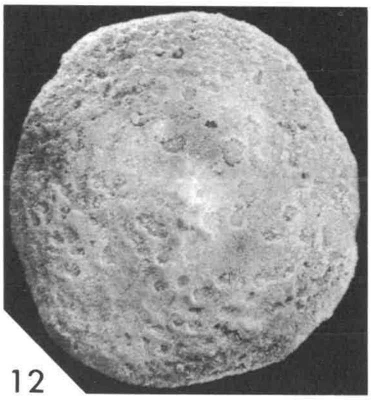
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PLATE 4

All figures × 20

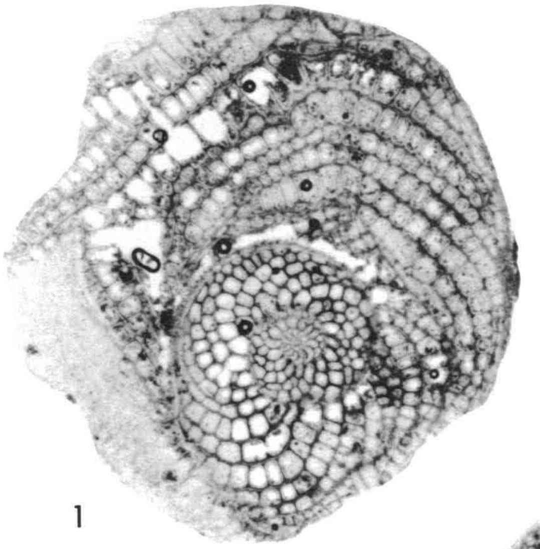
Figs.

1–3, 8–10 **Heterostegina borneensis** van der Vlerk
1–3, equatorial sections; 8–10, vertical sections.
1, microspheric form. CPC 22299. From So16–05TD–C.
2, 3, megalospheric forms: 2, with larger protoconch, CPC 22300; 3, with smaller protoconch, CPC 22301.
8, complanate form associated with *Spiroclypeus*. CPC 22304. From So16–06KD–A.
9–10, specimens not associated with *Spiroclypeus*, 9, CPC 22302; 10, CPC 22303. Both from So16–06TD–C.

4–7, 11–12 **Spiroclypeus margaritatus** (Schlumberger)
4–7, equatorial sections; 11–12, vertical sections. All from So16–06KD–A.
6, probably microspheric form with four operculine chambers ($N_0 = 6$). CPC 22308.
4, 5, 7, megalospheric forms with no or one operculine chamber ($N_0 = 2$ or 3). Note range of size of protoconch. 4, CPC 22306; 5, CPC 22307; 7, CPC 22309.
11, random section in limestone, showing a form in which the height of the lateral chambers is greater than the thickness of the walls. CPC 22310.
12, specimen with thick chamber walls and slit-like lateral chambers. CPC 22311.

13–16 **Miogypsina (Miogypsinoides) bantamensis** Tan Sin Hok
13, vertical section showing pillar development and surface pustules. CPC 22318.
14–16, equatorial sections, showing range in size of embryoconch and development of needles. 14, CPC 22319; 15, CPC 22320; 16, CPC 22321.
All from So16–06KD–A.

17–18 **Miogypsina (Miogypsina) tani** Drooger
17, vertical section, showing lateral chambers and poor pillar development. CPC 22314.
18, equatorial section. CPC 22315.
From So16–06KD–A.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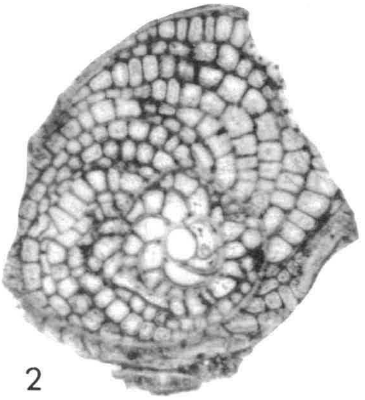
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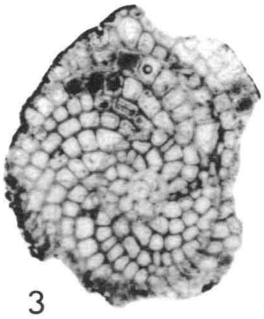
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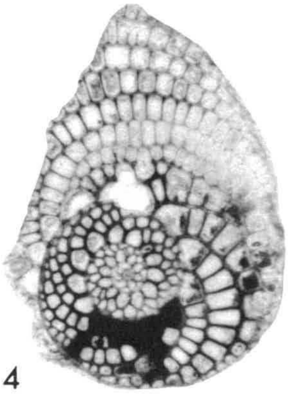
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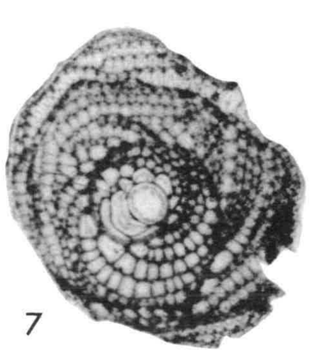
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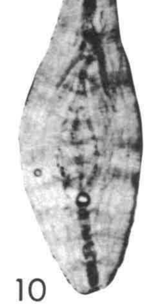
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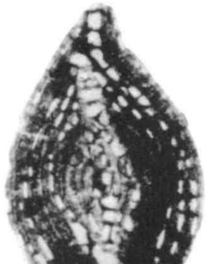
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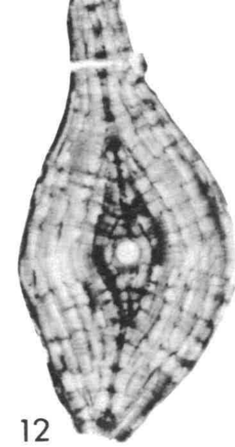
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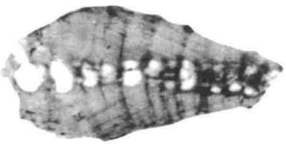
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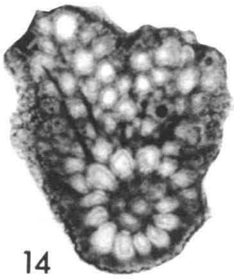
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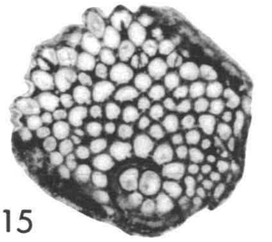
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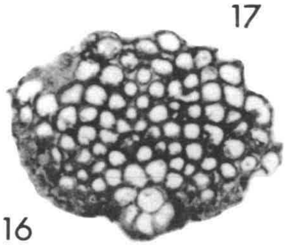
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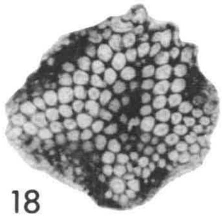
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PLATE 5

Figs.

1–4 **Asterocyclina incisuricamerata** Cole

1, equatorial section of five-rayed form. CPC 22329; x40.

2, equatorial section of four-rayed form; b, c, x70 enlargements of a (x20), showing b, detail of embryoconch, and c, detail of equatorial chambers. CPC 22330.

3, vertical section of megalospheric form. CPC 22331; x40.

4, vertical section of microspheric form. CPC 22332; x40. All from So16–10TD–A.

5–8 **Lepidocyclina (Eulepidina) ephippioides** Jones & Chapman

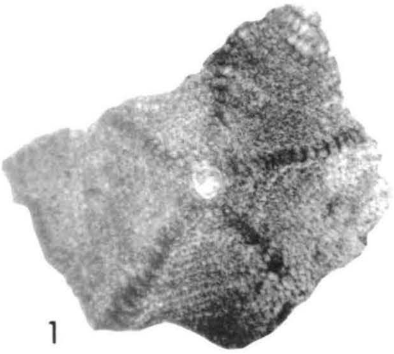
5, vertical section. CPC 22334; x20.

6–8, equatorial sections showing range of variation. 6, CPC 22335; 7, CPC 22336; 8, CPC 22337; all x20. All from So16–06KD–A.

9–12 **Lepidocyclina (Nephrolepidina) sumatrensis** (Brady)

9, 10, vertical sections. From So16–06KD–A. 9, CPC 22341; 10, CPC 22342; both x20.

11, 12, equatorial sections of microspheric forms. 11, from So16–05TD–C, CPC 22343; 12, from So16–06KD–A, CPC 22344; both x20.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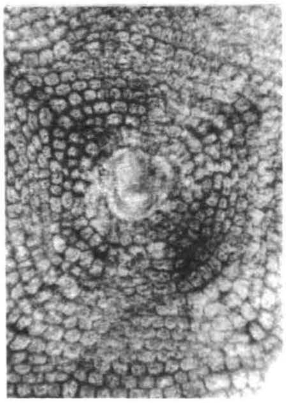
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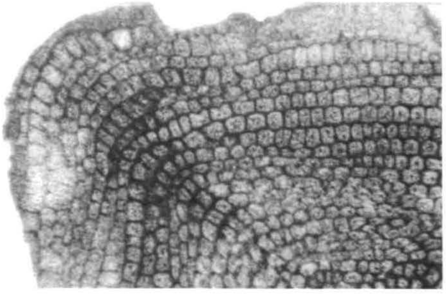
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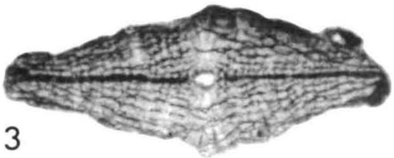
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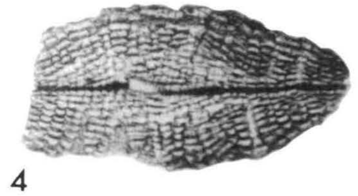
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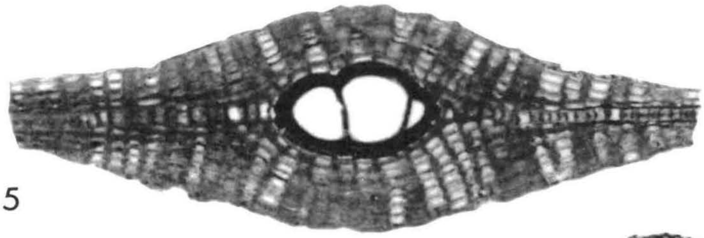
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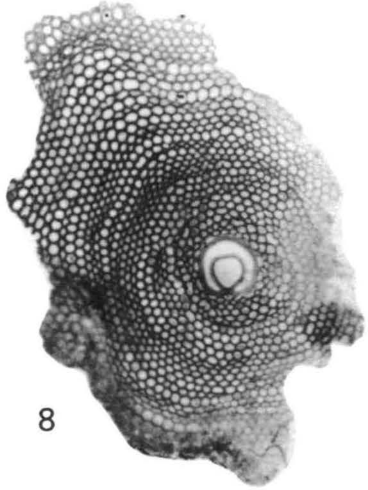
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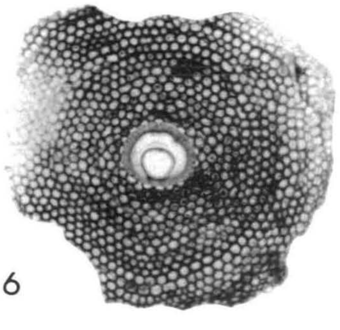
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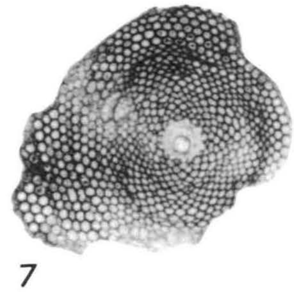
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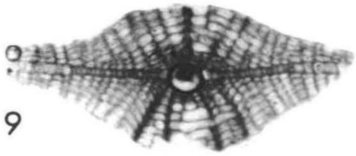
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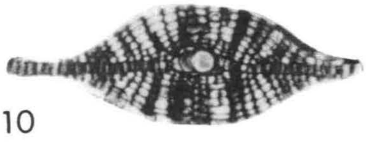
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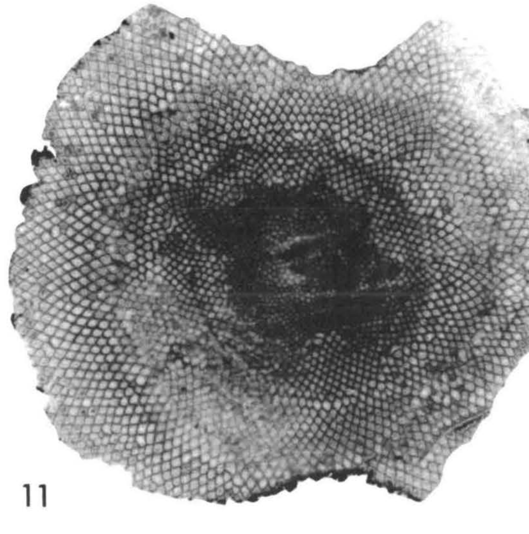
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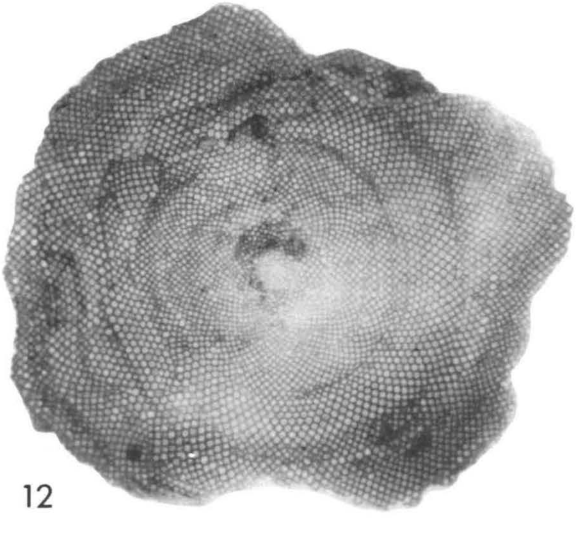
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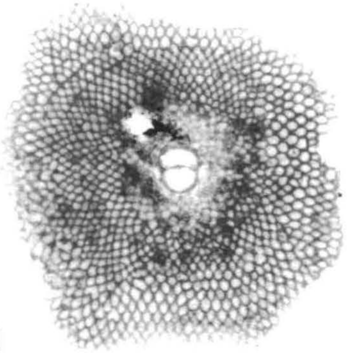
PLATE 6

Figs.

1–10 **Lepidocyclina (Nephrolepidina) sumatrensis** (Brady)
1–7, equatorial sections; 1–5, showing range of variation in embryoconchs from two samples; 1–3, from So16–05TD–C; 4–5, from So16–06KD–A; 6, twinned individual from So16–05TD–C; 7, specimen from So16–06KD–A with external features similar to 9.
8–10, external views: 8, most common form; 9, specimen with weak undulations in flange; 10, specimen with complex folds in flange. From So16–06KD–A.
1, CPC 22345; 2, CPC 22346; 3, CPC 22347; 4, CPC 22348; 5, CPC 22349; 6, CPC 22350; 7, CPC 22351; 8, CPC 22352; 9, CPC 22353; 10, CPC 22354; all x20.

11 **Lepidocyclina (Eulepidina) ephippioides** Jones & Chapman
External view showing wide flange. CPC 22338; x7. From So16–05TD–C.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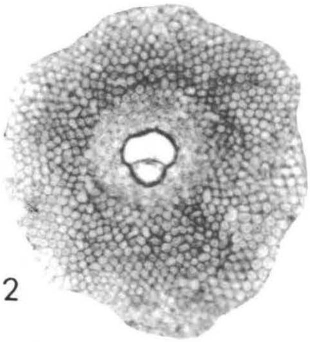
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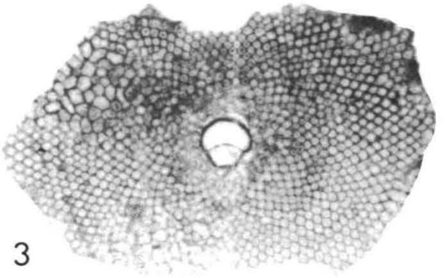
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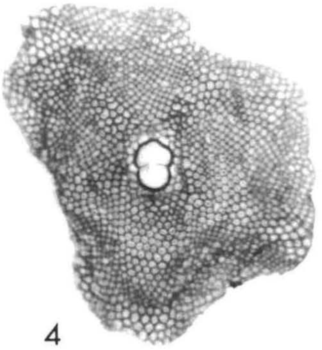
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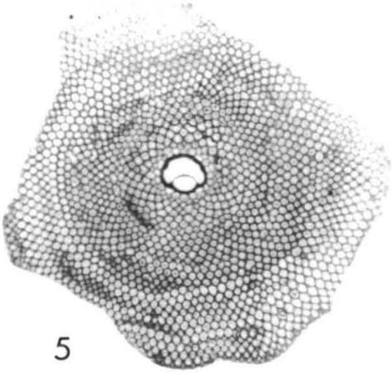
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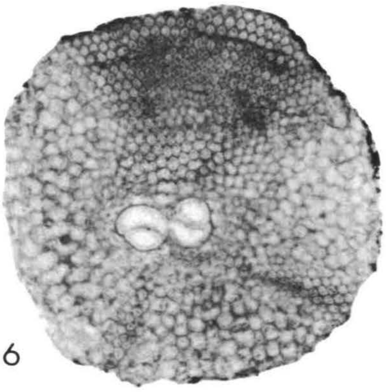
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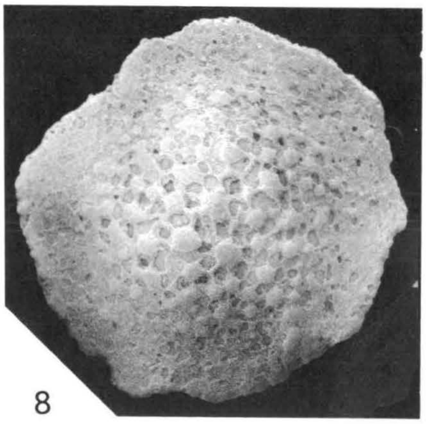
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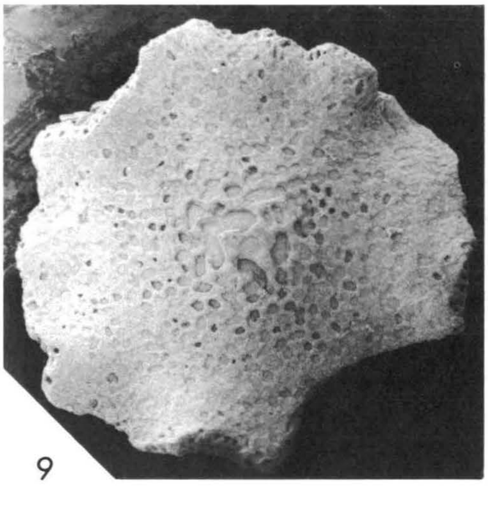
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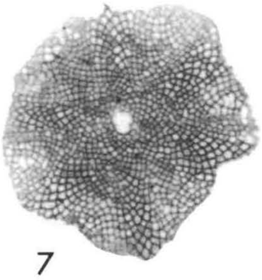
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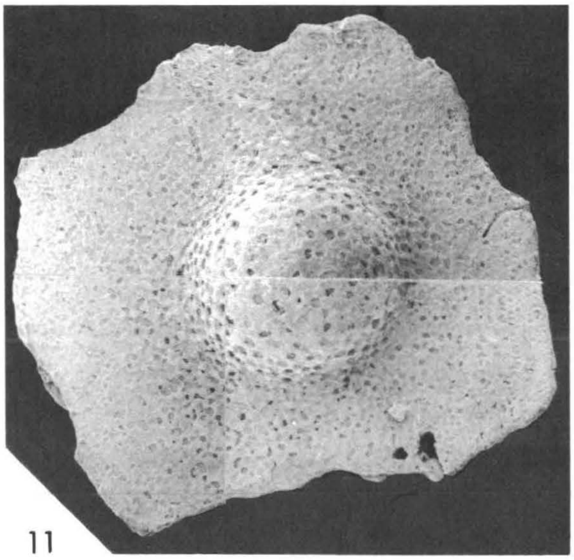
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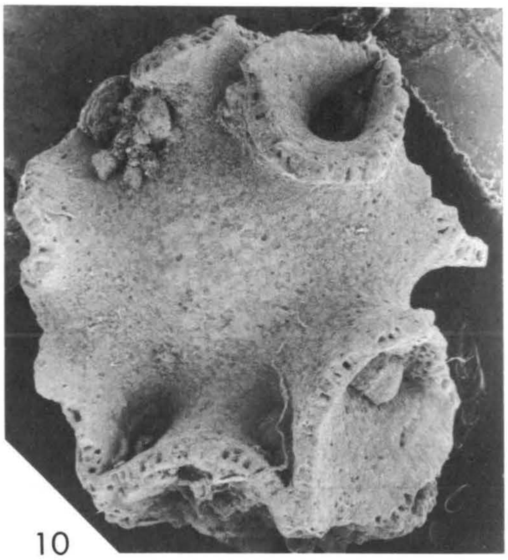
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Posidoniella, Atomodesma, the origin of the Eurydesmidae, and the development of the pelecypod ligament

J. M. Dickins

DICKINS, J. M., 1983—*Posidoniella, Atomodesma,* the origin of the Eurydesmidae, and the development of the pelecypod ligament; *in* Palaeontological papers 1983. *Bureau of Mineral Resources, Australia, Bulletin* 217, 59–65.

ABSTRACT

A small but distinct anterior ear and byssal notch are described in right valves of *Posidoniella*. These features are considered to confirm the close relationship of *Posidoniella* and *Atomodesma*, and suggest that a *Posidoniella*-like form may be an ancestor of the Eurydesmidae.

The ligament structure of *Atomodesma, Eurydesma,* and the Ambonychiidae is discussed. It is concluded that these shells may have a ligament of primitive or primary type or may be duplivincular or multivincular. The relationship of *Atomodesma*, the Ambonychiidae, and the Inoceramidae, and parallel evolutionary development of the ligament in the Ambonychiacea, the Pteriacea, and the Pectinacea, are confirmed.

INTRODUCTION

Lower Carboniferous specimens assigned to *Posidoniella vetusta* (J. de C. Sowerby) 1829 (the type species—see Ramsbottom, 1959) in the British Museum (Natural History), London, show a small but distinct anterior ear in the right valve. This ear is analogous to the small ear in right valves of *Atomodesma* from the Permian, and its similarity to the 'dental process' found in right valves of *Eurydesma* suggests that *Eurydesma* may have been derived from a *Posidoniella*-like form. *Eurydesma* is found possibly in the Upper Carboniferous of Argentina and is widespread in the Lower Permian of India and the southern hemisphere.

POSIDONIELLA DE KONINCK, 1885

Posidoniella has been regarded as closely related to or possibly even congeneric with *Atomodesma* (Dickins, 1963). Important characters of the genus, however, are still unknown or remain obscure. According to Ramsbottom (1959) 'the hinge, though not clearly seen, is apparently not striate and is edentulous'. This description comes close to that of the hinge of *Atomodesma* (Dickins, 1963; Waterhouse, 1963; Kauffman & Runnegar, 1975). A shell from the Upper Carboniferous of New South Wales that Runnegar (1972) assigned to *Posidonia* is apparently also closely related; he wrote (p. 301): 'the specimen has a hinge of the type found in *Atomodesma* and a prismatic shell, but has subterminal beaks and appears to lack an umbonal septum'. It was assigned to *Posidonia* apparently because the umbos are subterminal, although *Posidonia* apparently has a quite different hinge (Newell, 1938). Kauffman & Runnegar (1975, p. 35) referred to the gape and ligament of *Posidonia*, but Dr B. Runnegar (Department of Geology, University of New England, personal communication 23 August 1979) would now interpret these differently. The nature of the hinge and shell structure are, therefore, still not clear.

Although the two specimens from the British Museum (Natural History)—32865 from the Lower Carboniferous at Visé, Belgium (Pl. 1, figs. 4–5; Fig. 1A) and 97123 from the Gilbertson Collection from an unrecorded Lower Carboniferous locality (Pl. 1, figs. 1–3)—do not show the hinge or shell structure, both have a distinct anterior ear and associated byssal notch in the right valve. In the left valve the margin is apparently smooth. The character of the ear and the byssal notch is so similar to that illustrated for *Atomodesma* (Dickins, 1963, pl. 10, fig. 5, and refigured here —Fig 1B) as to argue for a close relationship. The ear, however, is larger than that known in *Atomodesma*, and it would seem a basis for keeping *Posidoniella* separate from *Atomodesma* at the generic level.

ATOMODESMA BEYRICH, 1864

Atomodesma has been discussed most recently by Kauffman & Runnegar (1975) and Waterhouse (1979), and it is not proposed to discuss here the taxonomic subdivisions considered by these authors. The use of *Atomodesma* in the broad sense with a number of subgenera followed by Kauffman & Runnegar is accepted for this paper.

Characteristically the ligament occupies an elongate shallow U-shaped groove with parallel lines which have been interpreted as growth lines (Fig. 2C; Dickins, 1963; Waterhouse, 1963; Kauffman & Runnegar, 1975). The nature of the ligament has been a puzzle, and *Atomodesma* was earlier referred to the Myalinidae (Newell, 1942; Dickins, 1956, 1963) or, more recently, directly related to the Ambonychiidae, which have a duplivincular ligament (parallel ligament grooves), and to the Inoceramidae, which have a multivincular ligament (multiple ligament pits). The ligament of *Atomodesma* has a relatively wide area, and indeed, unless it is duplivincular, would seem to be composed of a thick layer of fibrous ligament covered by a single outer lamellar sheet (Kauffman & Runnegar, 1975, p. 45).

Two *Atomodesma*-like specimens from the Permian of the Sydney Basin, eastern Australia, however, have been shown to have pits along the hinge and appear to be multivincular (Browne & Newell, 1966; Waterhouse, 1970; Kauffman & Runnegar, 1975). I agree with these authors that these pits are probably analogous to the multivincular ligament pits of inoceramids. My examination of specimens in the Australian

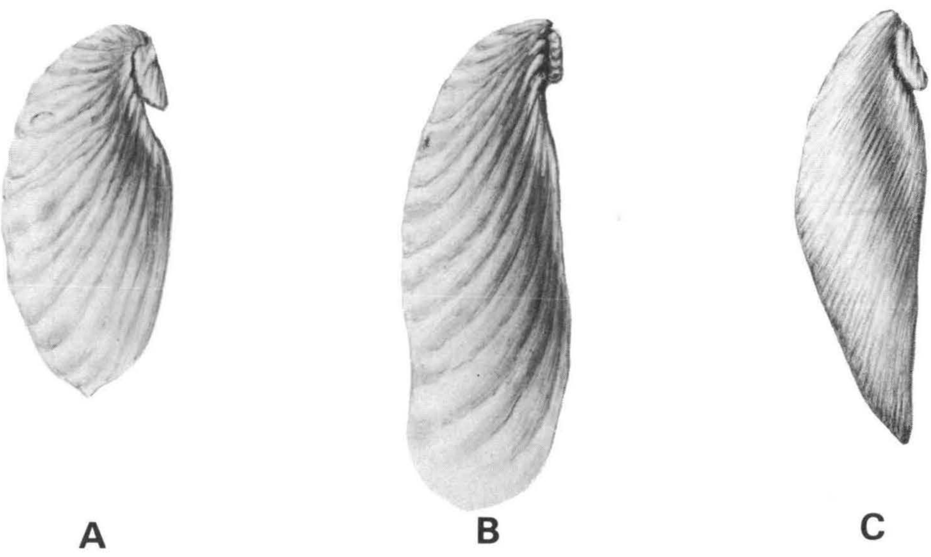

Fig. 1. Anterior ears x 1. A. *Posidoniella vetusta* **(J. de C. Sowerby), 1829, BM (NH) 32865 (see also pl. 1, figs. 4–5). B.** *Atomodesma mytiloides* **Beyrich, 1864 (see also Dickins, 1963, pl. 10, fig. 5). C.** *Eurydesma playfordi* **Dickins, 1957 (p. 33, pl. 5, figs. 1–11).**

Museum, Sydney, suggests to me that the two specimens otherwise are part of a series of shells which all belong in the same species—*A.* (*Aphanaia*) *mitchelli.* The change from a ligament with an elongate shallow groove—'normal'—to a multivincular ligament, apparently within a species, appears to represent the rarely recorded event of a macromutation over a short period of time as suggested by Kauffman & Runnegar (1975) and Newell & Boyd (1978). The question of the 'normal' structure of the *Atomodesma* ligament, however, still remains open.

As indicated by Kauffman & Runnegar, the change to a multivincular ligament would appear to be more difficult if the hinge of *Atomodesma* is made up of a single sheet of fibrous ligament and a single lamellar layer, rather than if a number of such sheets were present as in the duplivincular ligament of the ambonychiids. However, they considered it unlikely that a duplivincular ligament is present in *Atomodesma* because traces of growth lines and shell prisms show on the surface of the area. Despite this remark of Kauffman & Runnegar it seems likely that the ligament is composed in one of three ways:

1. A single sheet of fibrous ligament with an outer lamellar sheet.
2. A number of sheets of fibrous and lamellar ligament (duplivincular ligament) in which the lamellar sheets are not lodged on grooves as is commonly the case. The growth lines on the hinge would serve for the firmer attachment of the ligament.
3. A simple ligament in which there has been no differentiation into fibrous and lamellar ligament.

Pojeta (1978) has shown that *Cyrtodonta*, a genus of the Ambonychiidae, has both a hinge like that of 'normal' *Atomodesma* (Fig. 2A) and one with multiple parallel ligament grooves (Fig. 2B). He concluded (p. 236) that the ligament in the Ambonychiidae with parallel grooves cannot be duplivincular because the grooves and ridges are parallel to the dorsal margin—not inclined to it. In myalinids, which he regarded as duplivincular, he considered that the grooves and ridges are inclined to the dorsal margin; however, in some specimens the grooves are so nearly parallel to the margin (Newell, 1942; and Pl. 1, fig. 6) that the parallelism seems no argument against the presence of a duplivincular ligament. The specimen of *Cyrtodonta huronensis*, whose ligament Pojeta suggested is inserted only in the lowest groove on the area, has a ligament area like that in *Atomodesma.* Thus in some ambonychiids a fairly ready transition seems posible between shells with ligaments of this type and others with a number of parallel ligament grooves.

Support for this conclusion comes from leiopteriid shells—from the 'Finis Formation' and the 'Jacksboro Shale' of the Upper Pennsylvanian—in the American Museum of Natural History, New York, and in the Natural History Museum (Smithsonian Institution), Washington. The ligamental grooves of these shells are V-shaped under the umbo but are parallel to the dorsal margin behind the umbo (Pl. 1, fig. 7). Thus when the groove is first formed it is inclined to the dorsal margin but later it becomes parallel. I conclude that the relationship of the grooves—whether they are inclined to the margin of the ligament area, parallel to it, or even run off along the upper margin—has little relevance to the interpretation of a ligament as duplivincular or otherwise.

In a letter dated 22 July 1981, Norman D. Newell wrote 'some groups (e.g. arcoids and cyrtodonts) display both duplivincular ligaments and something similar to that of *Atomodesma* and *Eurydesma* (parvincular?).

'Apart from this, the grooves in some of my material are indeed parallel with the dorsal margin for much of the length of the hinge but they nevertheless intersect the hinge and consecutively as in *Glycimeris* and *Anadara.* I think that I can demonstrate that the ambonychiids and myalinids had essentially the same kind of ligament.'

Photographs of two specimens sent by Professor Newell are figured (Pl. 1, figs. 6, 7).

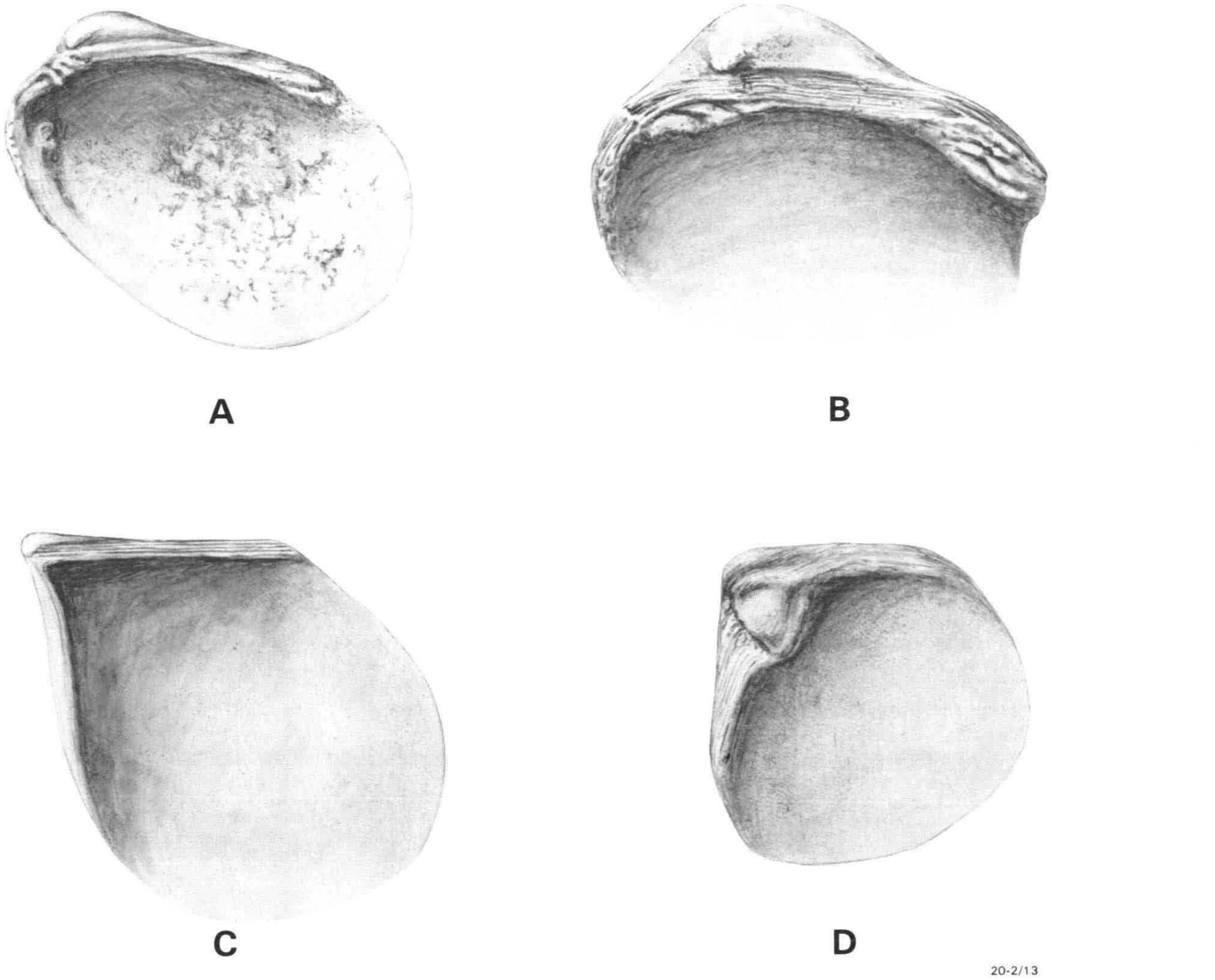

Fig. 2. Ligament areas. A. *Cyrtodonta huronensis* **Billings, x 1 (after Pojeta, 1978, pl. 8, fig. 2), simple ligament groove. B.** *Cyrtodonta saffordi* **(Hall), x 1½ (after Pojeta, 1978, pl. 7, fig. 8) interpreted as multiple ligament grooves. C.** *Atomodesma* **sp., x 1 (after composite restoration, Kauffman & Runnegar, 1975), interpreted as a single ligament groove but with growth ridges in groove. D.** *Eurydesma playfordi,* **x 1 (after Dickins, 1957, pl. 5, fig. 8), single ligament groove.**

EURYDESMA MORRIS, 1845

The relationships of *Eurydesma* have been the cause of considerable speculation (see Runnegar, 1970), and its recognition in a separate family the Eurydesmidae is an indication of its distinctiveness. In the most recent treatment of the problem, Runnegar (1970) considered that *Eurydesma* is related to the pectinids, but information that has now come to hand suggests that the ligament is of the type found in 'normal' *Atomodesma* and the Ambonychiidae. Runnegar indicated that in a few specimens (one of which is refigured by Waterhouse, 1980, fig. 6) there are traces of an anterior depression which may correspond to a chondrophore although there is no distinctly marked-off area. In the large majority of specimens, however, no depression can be observed, and the presence of a chondrophore seems unlikely. From the discussion on *Atomodesma* it might be suspected that the ligament of these shells was rather pliable in the upper Palaeozoic, and a chondrophore might be present in some specimens of *Eurydesma.* A chondrophore appears to be developed in the Timor Triassic form *Krumbeckiella* Ichikawa, 1958 (replacement name for *Timoria* Krumbeck, 1924, p. 218); this has not hitherto been grouped with *Eurydesma* or *Atomodesma,* which it resembles apart from its possession of a ligament pit. It seems likely that *Krumbeckiella* is closely related to *Eurydesma* and perhaps to *Atomodesma.*

In right and left valves the hinge of *Eurydesma* shows analogy with that of *Atomodesma* and *Posidoniella,* especially in species of *Eurydesma* where the dental process of the right valve is less well developed (Figs. 1C, 2D).

Shell structure has not been identified so far in *Posidoniella.* In the European specimens that I have examined, the shell structure has apparently been destroyed during diagenesis. Both *Atomodesma* and *Eurydesma* have an inner nacreous layer, but they differ in the outer shell layer. *Atomodesma* has a distinctive prismatic outer layer (Dickins, 1963; Kauffman & Runnegar, 1975), whereas *Eurydesma* has a more complicated lamellate structure (Dickins, 1957;

Runnegar, 1970). In the absence of information on *Posidoniella*, the shell structure throws no light on the relationship of these shells.

CONCLUSIONS

The close relationship of *Posidoniella* to *Atomodesma* is confirmed by the recognition of a small ear and byssal sinus in right valves of *Posidoniella*. Further, the Eurydesmidae may be derived from a *Posidoniella*-like form.

After consideration of the ligament of *Atomodesma*, *Eurydesma*, and the ambonychiids, I conclude that shells of this group may be of primitive or primary type (transitional of Trueman, 1969) duplivincular or multivincular. Whether the grooves run off the lower margin of the ligament area, the back, or upper margin is considered irrelevant in identifying a duplivincular ligament. The relationship of the Ambonychiidae and *Atomodesma* to the Inoceramidae, and parallel ligament development ('convergence') in the Ambonychiacea, Pteriacea, and Pectinacea (Dickins, 1960; Kauffman & Runnegar, 1975), are confirmed.

ACKNOWLEDGEMENTS

I am grateful to Dr A. W. Ball, Keeper of Palaeontology, who has made the rich resources of the British Museum (Natural History) open to me. I am grateful also to Dr N. J. Morris, who has guided me through the collections at the British Museum and helped in many other ways. R. J. Cleevely, also of the British Museum has been a constant source of information, and organised the loan of specimens. With Dr Bruce Runnegar of the Department of Geology, University of New England, and Professor N. D. Newell of the American Museum of Natural History, New York, I have discussed many of these problems, and thank them for this and help in many other directions.

REFERENCES

BROWNE, I. A., & NEWELL, N. D., 1966—The genus *Aphanaia* Koninck, 1877, Permian representative of the Inoceramidae. *American Museum Novitates*, 2252.

DICKINS, J. M., 1956—Permian pelecypods from the Carnarvon Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 29.

DICKINS, J. M., 1957—Lower Permian pelecypods and gastropods from the Carnarvon Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 41.

DICKINS, J. M., 1960—The Permian leiopteriid *Merismopteria* and the origin of the Pteriidae. *Palaeontology*, 3(3), 387-391.

DICKINS, J. M., 1963—Permian pelecypods and gastropods from Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 63.

ICHIKAWA, K., 1958—Zur Taxonomia und Phylogenie der Triadischen 'Pteriidae' (Lamellibranch). *Palaeontographica*, 111(A), 131-212.

KAUFFMAN, E. G., & RUNNEGAR, BRUCE, 1975—*Atomodesma* (Bivalvia), and Permian species of the United States. *Journal of Paleontology*, 49(1), 23-51.

KRUMBECK, L., 1924—Die Brachiopoden, Lamellibranchiaten und Gastropoden der Trias von Timor II. Palaeontologischer Teil. *Palaontologie von Timor*, 13, 143-417.

NEWELL, N. D., 1938—Late Paleozoic pelecypods: Pectinacea. *Kansas Geological Survey*, 16(1).

NEWELL, N. D., 1942—Late Paleozoic pelecypods: Mytilacea. *Kansas Geological Survey*, 10(2).

NEWELL, N. D., & BOYD, D. W., 1978—A palaeontologist's view of bivalve phylogeny. *Philosophical Transactions of the Royal Society of London, B*, 284, 203-215.

POJETA, J. JR, 1978—The origin and early taxonomic diversification of pelecypods. *Philosophical Transactions of the Royal Society of London, B*, 284, 225-246.

RAMSBOTTOM, W. H. C., 1959—Distinctions between the Carboniferous lamellibranch genera *Caneyella*, *Posidonia* and *Posidoniella*. *Palaeontology*, 1(4), 405-406.

RUNNEGAR, BRUCE, 1970—*Eurydesma* and *Glendella* gen. nov. (Bivalvia) in the Permian of eastern Australia; *in* Palaeontological Papers 1968. *Bureau of Mineral Resources, Bulletin* 116, 83-118.

RUNNEGAR, BRUCE, 1972—Late Palaeozoic Bivalvia from South America: provincial affinities and age. *Anais da Academia Brasileira de Ciencias*, 44 (Suplemento).

TRUEMAN, A. E., 1969—General features of Bivalvia: ligament. TREATISE OF INVERTEBRATE PALEONTOLOGY (N) 1 MOLLUSCA 6, BIVALVIA. *Geological Society of America Inc., and University of Kansas*, 58-64.

WATERHOUSE, J. B., 1963—New Zealand species of the Permian bivalve *Atomodesma* Beyrich. *Palaeontology*, 6(4), 699-717.

WATERHOUSE, J. B., 1970—*Permoceramus*, a new inoceramid bivalve from the Permian of Australia and New Zealand. *New Zealand Journal of Geology and Geophysics*, 13(3), 760-766.

WATERHOUSE, J. B., 1979—New members of the Atomodesminae (Bivalvia) from the Permian of Australia and New Zealand. *Department of Geology, University of Queensland, Papers*, 9(1).

WATERHOUSE, J. B., 1980—A new bivalve species (Buchiidae) from the Early Triassic of New Zealand. *Alcheringa*, 4(1-2), 1-10.

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PLATE 1

Figs.	
	Posidoniella vetusta (J. de C. Sowerby) 1829
1–3	BM(NH)—British Museum (Natural History) London, 97123, right valve x 1, side, front, and tilted view to show anterior ear. Carboniferous Limestone, Gilbertson Collection.
4–5	BM(NH) 32865, right valve x 1, side and front views. Lower Carboniferous, Visé, Belgium. De Koninck Collection.
	Selinimyalina quadrata
6	From Pennsylvanian of Kansas (photograph from N. D. Newell); x 4.
	Leptodesma sp.
7	From the 'Finis shale' near Jacksboro, Texas (photograph from N. D. Newell); x 3.


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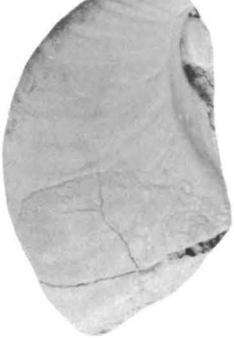
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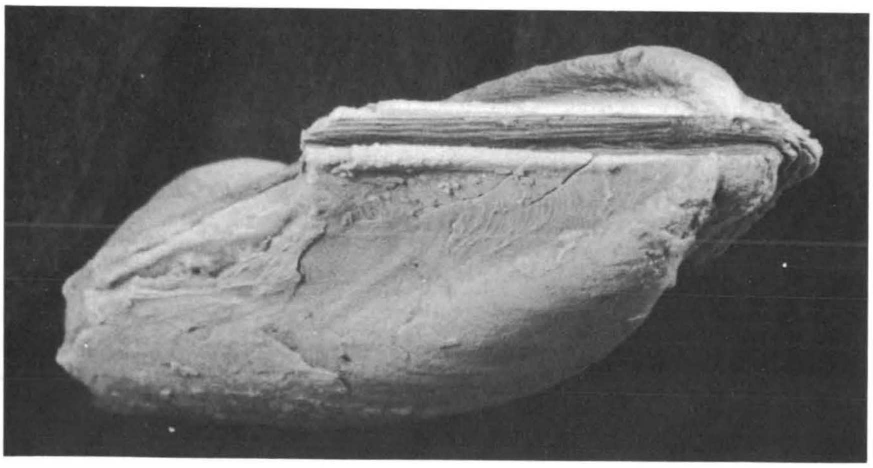
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Somareoides hastatus (Skwarko), a new Late Triassic bivalve from Papua New Guinea

S. K. Skwarko

SKWARKO, S. K., 1983—*Somareoides hastatus* (Skwarko), a new Late Triassic bivalve from Papua New Guinea; *in* Palaeontological papers 1983. *Bureau of Mineral Resources, Australia, Bulletin* 217, 67–71.

ABSTRACT

Recently collected additional material from central Papua New Guinea helps to establish the identity of the Triassic bivalve *Permophorus? hastatus* Skwarko, 1967 as a new genus, *Somareoides,* whose dentition is similar to that of the New Zealand Otamitan (Carnian) *Triaphorus* Marwick, 1953. *Somareoides hastatus* belongs to the Permophoridae van de Poel, 1959.

The original description of the bivalve is supplemented with a description of its internal structure.

INTRODUCTION

In 1967 I described *Permophorus? hastatus* from the external impressions of four mostly incomplete shells collected from the Upper Triassic Jimi Greywacke in central Papua New Guinea. More recently, additional specimens were collected, including some which are impressions of the inside of the shell. Examination of the internal structures—most importantly the dentition —has now enabled the phylogeny of *hastatus* to be determined, and the generic name has been changed to *Somareoides.*

The original specimens were collected at localities M29, H176, and H575 in the Ramu 1:250 000 Sheet area (Skwarko, 1967, fig. 5). The more recent material was collected near the original localities.

At the three original localities, *Somareoides hastatus* is associated with:

bivalves —	*Nuculana?* cf. *semicrenulata* (Trechmann, 1918) *Spia simbaiana* (Skwarko, 1967) *Costatoria melanesiana* Skwarko, 1967 *Bakevellia bundiensis* Skwarko, 1967
a gastropod —	*Rhaphistomella? kumbrufensis* Skwarko, 1967
brachiopods —	*Rhynchonella* cf. *mutabilis* Stoliczka *Spiriferina* cf. *abichi* Oppel, 1865

This assemblage was dated Carnian-Norian mainly on the association in other localities of some of the above genera and species with the ammonite *Sirenites* cf. *malayicus* Welter, 1914. However, it is possible that the age may in fact be pinpointed to Carnian, as another member of the Jimi Greywacke assemblage, the bivalve *Gervillancea coxiella,* may in fact belong to the somewhat enigmatic European Carnian genus *Hoernesiella* Gugenberger, 1934.

The specimens of *S. hastatus* are associated with *C. melanesiana* at one of the new localities, and with a mass of shell fragments possibly referable to *B. bundiensis* and *S. simbaiana* at the other.

PHYLOGENY

The two original specimens of *hastatus* showed only the external features of the bivalve, and the species was referred tentatively to *Permophorus* on the basis of its overall shape (Skwarko 1967, p. 67). The newly found specimens show that the dentition of *hastatus* does in fact place it in Permophoridae because of its similarity to that of *Triaphorus* Marwick, 1953. *Triaphorus,* however, differs basically in the overall shape of the shell.

The differences in the dentition between *Triaphorus* and *Somareoides* are only those which are a reflection of, and dictated by, the different shapes of the shells. Thus, both 3a and 4b are practically identical in both genera, while both 2 and 3a are much more attenuated in *Somareoides,* reflecting the anteriorly produced front part of the shell.

In overall shape, *Triaphorus* and *Somareoides* are similar owing to considerable rearward extension; both shells also have an oblique post-umbonal ridge, and similar ornament. However, *Triaphorus* is ovate, whereas *Somareoides* is laterally straight and rather angular; in *Triaphorus* the beaks are practically terminal, and the shell is produced virtually only to the back, whereas in *Somareoides* the beak is some distance from the anterior margin because of the anteriorly produced front part of the shell.

SYSTEMATIC DESCRIPTION

BIVALVIA

Family PERMOPHORIDAE van de Poel, 1959 (1895)

Subfamily PERMOPHORINAE van de Poel, 1959 (1895)

Genus **Somareoides** gen. nov.

Type species: *Permophorus? hastatus* Skwarko, 1967.

Diagnosis: The new genus is characterised by a combination of laterally elongate and rather angular overall shape, beaks slightly behind the anterior shell margin, and permophorid dentition in which 2 and 3a are attentuated because of the anteriorly produced front part of the shell.

Somareoides hastatus (Skwarko, 1967)

(Pl. 1, figs. 1–9; Fig. 1i, ii)

Permophorus? hastatus Skwarko, 1967, pp. 66–67, pl. 9, figs. 1, 3.

Material: Two external impressions of mature right valves, one complete, and one incomplete with fragment of hinge impression; three external impressions of mature incomplete left valves; two external impressions of immature left and right valves; one incomplete internal impression of a left valve and a similar one of a right valve.

Holotypes: CPC 5099 (Skwarko, 1967, pl. 9, fig. 2)

Paratypes: CPC 5098 (Skwarko, 1967, pl. 9, fig. 1); CPC 22144 (Pl. 1, figs. 1, 5; Fig. 1i); CPC 22145 (Pl. 1, figs. 2, 7); CPC 22146 (Pl. 1, fig. 3); CPC 22147 (Pl. 1, fig. 4); CPC 22148 (Pl. 1, fig. 6; Fig. 1ii).

Diagnosis: The shell is elongate subtriangular in outline, ribbed with rather fine regularly spaced costae which follow the outline of the shell. Growth-rugae are common but of low relief and not very prominent.

Supplemented description: The shell is very inequilateral, weakly inflated, equivalve, and produced anteriorly and much more prominently posteriorly. The height of the shell decreases abruptly in front of the umbo, resulting in a tightly convex anterior extremity. Behind the umbo the height increases gradually.

The posterior cardinal margin is straight. The posterior shell-margin is gently and regularly convex. The ventral margin is gently arched in young forms, straight or gently convex posteriorly, and increases in convexity forward from beneath the umbo in mature forms. The anterior cardinal margin is gently convex. The junction of the posterior cardinal margin with the posterior margin is moderately arched, that of the posterior margin with the ventral margin closely arched, and that of the ventral margin with the anterodorsal margin more closely arched.

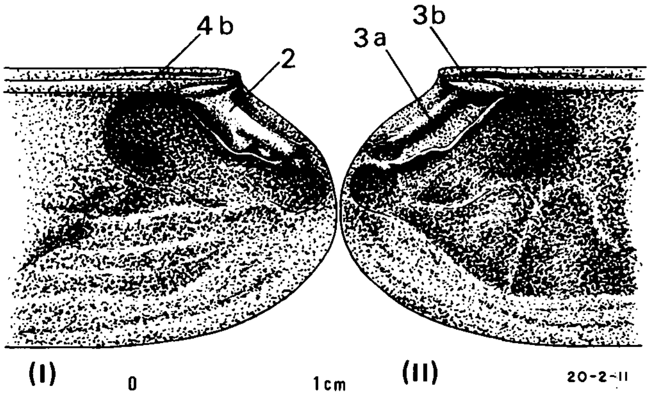

Fig. 1. ***Somareoides hastatus*** **(Skwarko, 1967): internal views of the antero-proximal parts of the right (i) and left (ii) valves, showing detail of dentition and musculature.**

A weak carina joins the umbo with the postero-ventral corner of the shell. The umbo is angular and obtuse.

Ornamentation is confined to concentric riblets and growth constrictions, both of which follow the outline of the shell. Riblets are closely spaced, narrow, about the same width as the interspaces, and rounded in cross-section. The constrictions are fairly regularly spaced and are much deeper than the interspaces.

Dentition on the left valve consists of, behind the umbo, an elongate and attenuated 4b, which gradually tapers to a point anteriorly and fits into a corresponding elongate groove behind the umbo of the right valve; and, in front of and below the umbo, a thin curved 2, which is probably weakly transversely striated and fits into a corresponding transversely striated elongate hollow in front of and below the umbo on the right valve.

Dentition on the right valve consists of a narrow, elongate, and triangular 3b directed posteroventrally from the umbo; and of an elongate ridge-like curved narrow 3a in front of and below the umbo.

The anterior adductor scar is round, moderately deeply incised, and situated below the anterior extremity of the hinge plate.

Etymology: Named after the Right Honourable Michael Thomas Somare, C.H.M.P., the first Prime Minister of Papua New Guinea.

REFERENCE

Skwarko, S. K., 1967—First Upper Triassic and ?Lower Jurassic marine Mollusca from New Guinea; *in* Skwarko, S. K.—Mesozoic Mollusca from Australia and New Guinea. *Bureau of Mineral Resources, Australia, Bulletin* 75, 39-84, 6 plates.

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PLATE 1

All figures are of latex casts at natural size, coated with ammonium chloride, and photographed in lateral view, unless stated to the contrary.

Figs.

1–9 **Somareoides hastatus** (Skwarko, 1967).

1, 5, paratype, CPC 22144: impression of front part of inside of immature left valve, x 1 and x 2.

2, 7, paratype, CPC 22145: detail of part of hinge-plate of right valve and incomplete impression of right valve.

3, paratype, CPC 22146: almost complete external impression of immature right valve.

4, paratype, CPC 22147: almost complete external impression of immature left valve.

6, paratype, CPC 22148: internal impression of inside of anterior part of right valve, x 2.

8, paratype, CPC 5098: incomplete external impression of left valve.

9, HOLOTYPE, CPC 5099: external impression of right valve.

Carnian. Ramu 1:250 000 Sheet area, Papua New Guinea.

SOMAREOIDES HASTATUS, PNG

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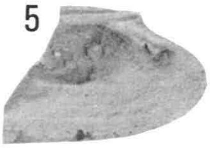

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Cenomanian (Late Cretaceous) Mollusca from Mountnorris Bay, Arnhem Land, northern Australia

S. K. Skwarko

SKWARKO, S. K., 1983—Cenomanian (Late Cretaceous) Mollusca from Mountnorris Bay, Arnhem Land, northern Australia; *in* Palaeontological papers 1983. *Bureau of Mineral Resources, Australia, Bulletin* 217, 73–83.

ABSTRACT

Four small collections of fossil mulluscs from Mountnorris Bay, Northern Territory, make up an assemblage consisting of six bivalves, three gastropods, three cephalopods, and a scaphopod. Their middle or late Cenomanian age is based on the presence of ammonites such as the cosmopolitan *Turrilites costatus* Lamarck, and *Sciponoceras* sp., the possible presence of the North American gastropod *Architectonica (Granosolarium) coffea* Sohl, and the presence of bivalves—such as *Inoceramus* sp. indet. aff. *concentricus* Parkinson, 1819—which have not been reworked from older sediments. Correlation with the fauna from the south coasts of Bathurst and Melville Islands, 250 km to the west, additionally supports the Cenomanian age.

The new species described and named are the bivalve *Nemocardium (Pratulum) arnhemense* and a gastropod *?Arrhoges (Latiala) mountnorrisi.*

INTRODUCTION

The fossils described below were collected in 1973 and 1974 in the course of, and immediately after, the regional geological mapping of the 'top end' of the Northern Territory by the Bureau of Mineral Resources. They were collected from the low coastal cliffs of Mountnorris Bay, near the base of the Cobourg Peninsula, west Arnhem Land (Fig. 1).

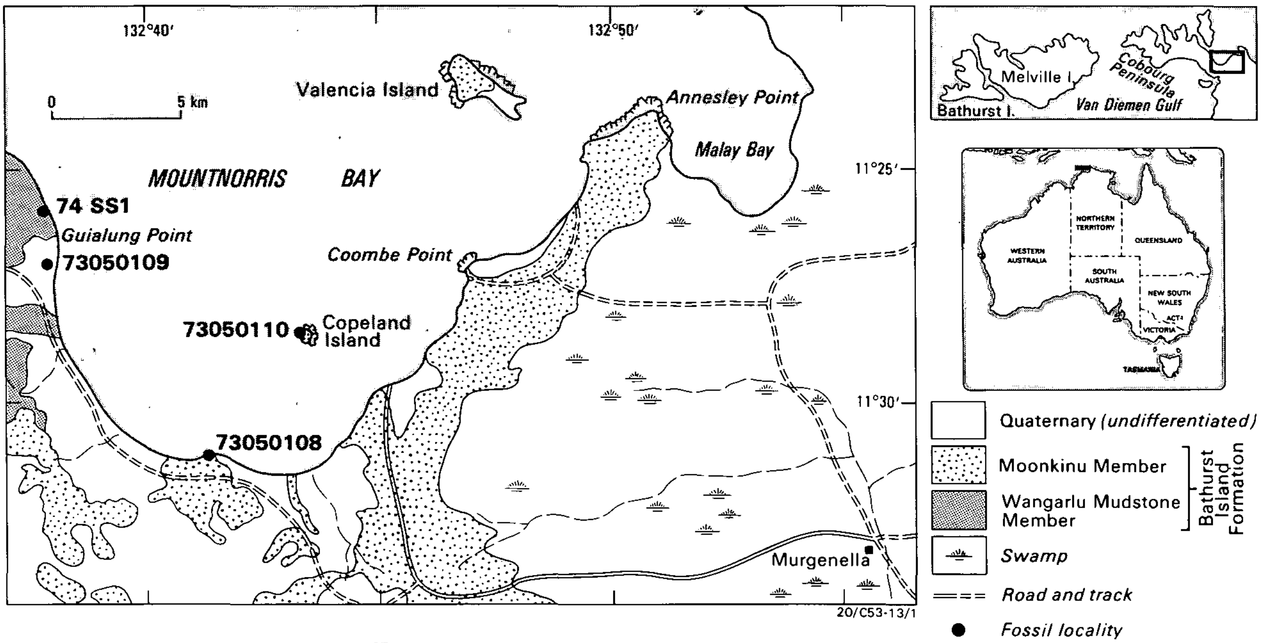

Fig. 1. Fossil-bearing localities, Mountnorris Bay.

Four collecting sites are represented; their descriptions and fossil contents are as follows:

73050108: South Mountnorris Bay. Moonkinu Member. Collected by R. Hughes, 10 July 1973.

Nemocardium (*Pratulum*) *arnhemense* sp. nov.
Panopea sp. indet. aff. *aramacensis* (Etheridge Jr, 1892)
?Arrhoges (*Latiala*) *mountnorrisi* sp. nov.
Bathraspira sp. nov.? cf. *brightoni* Abbas, 1973
Sciponoceras sp.
Turrilites (*Turrilites*) *costatus* Lamarck, 1801
?Architectonica (*Granosolarium*) *coffea* Sohl 1964

73050109: Guialung Point, west coast of Mountnorris Bay. Wangarlu Mudstone Member. Collected by R. Hughes, 16 July 1973.

'Nuculana' sp. juv.
Inoceramus sp. indet. aff. *concentricus* Parkinson, 1819
?Arrhoges (*Latiala*) *mountnorrisi* sp. nov.
Bivalve shell fragments
?Borissiakoceras sp.
Dentalium (*Dentalium*) sp. nov.?

73050110: Copeland Island, Mountnorris Bay. Moonkinu Member. Collected by R. Hughes, 10 July 1973.
Inoceramus sp. juv.

74 SS 1: 2 km north of Guialung Point, west coast of Mountnorris Bay. Moonkinu Member. Collected by S. K. Skwarko, 6 July 1974.
'*Nuculana*' sp.
Inoceramus sp. indet. aff. *concentricus* Parkinson, 1819
Thracia (*Thracia*) sp. indet. aff. *primula* Hudleston, 1840
Large bivalve fragments indet.
Small bivalve fragments indet.
?Arrhoges (*Latiala*) *mountnorrisi* sp. nov.
Turrilites (*Turrilites*) *costatus* Lamarck, 1801

ACKNOWLEDGEMENTS

I thank Dr W. J. Kennedy, University Museum, Oxford, UK, for the critical reading of the manuscript and for the suggestions regarding the identity of some of the ammonites, and Dr Tomoki Kase, Department of Palaeontology, National Science Museum, Tokyo, Japan, for a particularly valuable discussion on the described gastropods.

CRETACEOUS STRATIGRAPHY IN THE BATHURST ISLAND-MOUNTNORRIS BAY AREA

The geology of the northern part of the Northern Territory has recently been described (Hughes, 1978). The interpretation of the stratigraphy of its Upper Jurassic and Cretaceous sediments is surer and clearer now than in the past, being in part based on the subsurface data from stratigraphic drilling unavailable to earlier workers.

The correlation of the recently erected stratigraphic units in the Darwin/Bathurst Island/Mountnorris Bay area (Hughes, 1978; see below) with the earlier erected units for the Cretaceous sediments which crop out farther south (Skwarko, 1966; 1973) is somewhat less clear, and consequently open to discussion. However, as the rocks farther south are of only Early Cretaceous age, the question of their correlation has but marginal bearing on the topic at hand, and its discussion is postponed for another occasion.

In the area which stretches from Bathurst Island in the west to the Mountnorris Bay area in the east, all the Cretaceous sediments have been grouped in the Bathurst Island Formation. Four members are recognised: at the base the Darwin Member with its lateral equivalent the Marligur Member; overlying them the Wangarlu Mudstone Member; and higher still the Moonkinu Member.

The Darwin Member crops out in the Darwin area and is present in the subsurface in the Bonaparte Gulf and Timor Sea, beneath Bathurst and Melville Islands, and in the East Alligator River area. It consists of up to 42 m of epicontinental, mainly fine argillaceous rocks with a conglomerate at the base. Its age is regarded as late? Neocomian-Aptian on palynological evidence; it disconformably overlies the Petrel Formation in the west and interfingers with the Marligur Member in the Coburg Peninsula.

The Marligur Member, which crops out poorly, occurs in the subsurface southeast and east of Mountnorris Bay, and is the eastern paralic equivalent of the Darwin Member. It consists of up to 62 m of fine to coarse quartz sandstone with thin pelitic interbeds, and contains spores of late? Neocomian to Aptian age.

The Wangarlu Mudstone Member consists of up to 212 m of mainly micaceous mudstone with glauconitic siltstone, which extends from the Bonaparte Gulf Basin through the south coast of the Cobourg Peninsula to Croker Island (14 km north-northwest of Guialung Point) and Guialung Point. It is Cenomanian in age on the contained molluscs, spores, pollen, and foraminifera.

The highest unit, the Moonkinu Member is up to 400 m thick. It is a fine sublabile sandstone interbedded with siltstone and mudstone, which crops out in the cliff sections of southern Bathurst and Melville Islands and in southern and eastern Mountnorris Bay.

AGE OF COLLECTIONS AND CORRELATION WITH BATHURST/MELVILLE ISLANDS FAUNA

The fossils from Guialung Point (locality 73050109) are believed to be from the Wangarlu Mudstone Member, whilst the remaining three collections have been referred by the field geologists to the Moonkinu Member. A brief glance at the faunal lists from these four collections reveals that they are sufficiently similar to frustrate any attempt at separating them purely on faunal grounds. In both outcrop and hand specimen the lithologies are also difficult to distinguish, although the distinction is clearer with the core material (R. Hughes, formerly BMR, personal communication 1981). The palynological assemblages found in the two members are identical, and cannot be dated any more closely than Cenomanian sensu lato. For the purpose of this paper the four collections are regarded as representing a single assemblage.

The presence of *Turrilites costatus* is sufficient to date the assemblage. In England, *T. costatus* appears high in lower Cenomanian strata and is evident in the lower part of the middle Cenomanian; it reaches its maximum abundance in the lower part of the *rhotomagense* Zone. It also occurs high up in upper Cenomanian strata in north Africa, and had a worldwide distribution in the middle and late Cenomanian (Kennedy, 1971, p. 30).

Of the remaining two ammonites present, *Sciponoceras* ranges from latest Albian to late Turonian in many parts of the world. Although the preservation of my fragmentary specimens does not allow definite identification, they do resemble *S. baculoides* (Mantell, 1822), a Cenomanian form. The presence of another ammonite, *?Borissiakoceras* sp., does not conflict with the proposed Cenomanian age, as members of the same small family are known from strata of Cenomanian to Coniacian age.

Among the gastropods, *?Arrhoges* (*Latiala*) *mountnorrisi* sp. nov. is closely related to the Maastrichtian *A.* (*L.*) *lobata* (Ware, 1926) from Tennessee, Mississippi, and Texas, and the late Campanian *A.* (*L.*) *bailyi* (R. Etheridge Jr, 1904) from South Africa, in most aspects of shell structure (see below). The Architectonicidae is similar to *Architectonica coffea* Sohl from the Campanian Coffee Sands of Mississippi. *Bathraspira brightoni* Abbas, 1973, which two of my specimens greatly resemble, is a late Albian gastropod.

There is, however, little support for the Cenomanian age from the bivalves '*Nuculana*', *Panopea*, and

Thracia, which resemble some Australian Aptian and Albian species and are thought to have been reworked from older strata.

Further support for the Cenomanian age of the Mountnorris molluscs comes from correlation with the Bathurst/Melville Islands fauna. A review of the published lists of previously described fossils from the Bathurst and Melville Islands shows that they consist of one ophiuroid (Skwarko, 1963), one bivalve (Cox, 1964), and 16 ammonite genera and species (Wright, 1963). Neither the ophiuroid nor the bivalve are useful time indicators. Among the abundant ammonites, Wright recognised—apart from a single reworked late Albian *Parengenoceras*, and a Turonian *Collignoniceras* —two Cenomanian assemblages: that of the 'Tapara Bed' (Wright, 1963), which contains seven distinct genera and species (among them *Turrilites costatus* Lamarck, and a *?Borissiakoceras* sp., but unlike my *?Borissiakoceras* sp.) which he ascribed to the late part of the late Cenomanian; and that of the beach boulders without any ammonites in common with the Mountnorris fauna, and of middle Cenomanian age. The rocks that yielded the Mountnorris fauna, despite a somewhat different facies, are regarded as a lateral equivalent of the 'Tapara Bed', and consequently of similar, middle Cenomanian age. A cursory examination of the hitherto undescribed gastropods and bivalves from the south coast of Bathurst Island held in various repositories suggests that the similarity between the two faunas is not limited to merely the single ammonite.

SYSTEMATIC DESCRIPTIONS

BIVALVIA

Family NUCULANIDAE Adams & Adams, 1858

Genus **Nuculana** Link, 1807

Type species: *Arca rostrata* Chemnitz, 1774.

'Nuculana' sp.

(Pl. 2, figs. 1, 2)

Material: Two internal casts of mature left valves; three of immature right valves; and one of an immature left valve; some fragments of dentition and of outside ornament.

Description: Shell 27 mm long and 15 mm high, normally inflated for genus, and of typically posteriorly elongate and rostrate shape. Umbo located one-third shell distance from anterior shell margin. About 15 strong chevron-shaped isodont teeth in front of umbo and about 26 behind. Shell exterior lined with fine concentric riblets.

Remarks: The Mountnorris Bay nuculanid closely resembles some Australian Early Cretaceous species variously described in the past as *Perrisonota etheridgei* Day (MS name), *Yoldia freytagi* Ludbrook, 1966, and *Mesosaccella randsi* (Etheridge Jr, 1892). As the Australian Cretaceous Nuculanidae are shortly to be revised it seems appropriate to temporarily postpone close comparison of my specimens.

Family INOCERAMIDAE Giebel, 1852

Genus **Inoceramus** J. Sowerby, 1814

Type species: *Inoceramus cuvierii* J. Sowerby, 1814.

Inoceramus sp. indet. aff. **concentricus** Parkinson, 1819

(Pl. 1, figs. 9, 10; Pl. 2, fig. 8)

Material: Two large and several smaller fragments of large shells.

Discussion: The specimens are too crushed and incomplete to allow dependable identification. They are similar to *Inoceramus concentricus*, particularly its variety *porrectus* Woods, 1917 from the Late Cretaceous of the South Island of New Zealand.

Inoceramus sp. juv.

(Pl. 1, fig. 18)

Several internal casts of small *Inoceramus* specimens from locality 73050010 are too immature and too poorly preserved to allow reliable comparison at this time.

Family PECTINIDAE Rafinesque, 1815

?Chlamys Group

Genus **?Chlamys** Röding, 1798

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

?Chlamys sp. indet.

(Pl. 2, figs. 6, 7)

Material: An incomplete impression of the external surface of a valve.

Description: Valve ornamented with numerous radial riblets of single order, but not of uniform thickness, somewhat irregularly spaced, narrow and tightly arched in cross-section, and separated from one another by deep narrow interspaces that are U-shaped in cross-section; interspaces mostly wider than riblets.

Discussion: The single incomplete specimen in the collection was found ex-situ between Guialung Point and locality 74 SS 1. Although of unknown shape, its ornament is of the kind usually found in the true chlamids, and sufficiently characteristic to ensure easy future comparison should additional material become available.

Family CARDIIDAE Lamarck, 1809

Subfamily PROTOCARDIINAE Keen, 1951

Genus **Nemocardium** Meek, 1876

Type species: *Cardium semiasperum* Meek, 1876.

Subgenus **Pratulum** Iredale, 1924

Type species: *Cardium thetidis* Hedley, 1902; OD.

Nemocardium (Pratulum) arnhemense sp. nov.

(Pl. 1, figs. 13, 16, 19)

Material: One external impression of the left valve, and three external and one internal impressions of the right valve.

Holotype: CPC 21553 (Pl. 1, figs. 16, 19).

Paratype: CPC 21550 (Pl. 1, fig. 13).

Diagnosis: The diagnostic features of the new species are the combination of weak radial ribs on the anterior, greater part of the shell with stronger radial ribbing on the remainder of the exterior surface of the shell; and the delicate marginal crenulations on the inside of the distal shell margin.

Separation from other species: Cardium rogersi Rennie 1936 from the Early Cretaceous of northern Zululand (Rennie, 1936, pp. 382–383, pl. 49, figs. 3–8) appears to be similarly ornamented, but its hinge line is long and straight, and the posterior shell margin is perpendicular and somewhat invaginated in the middle. These features are absent from the new species.

The Australian (post-Cretaceous) representatives of *Pratulum* are smaller and somewhat more symmetrical than the new species, and tend to have spines on the stronger, posterior riblets.

Description: Shell rounded-quadrate, 22 mm high, 20 mm long, and markedly inflated. Beak slightly in front, clearly defined, incurved, prorsiradiate.

External surface ornamented with fine radial riblets of two orders, and with fairly irregularly and widely spaced weak concentric growth rugae. Simple radial riblets in anterior three-fifths of shell weak and fine; those in remainder of shell somewhat stronger and more prominent.

Delicate marginal crenulations on inside of distal shell margin. In right valve, one anterior lateral tooth and two posterior lateral teeth, and one non-bifid cardinal tooth under beak. Anterior adductor scar well impressed, subcircular; posterior adductor scar narrower and possibly more elongate.

Remarks: There is no umbonal ridge as such, but there is a clear division of the shell's exterior surface based on the strength of ornament. The apparent uniformity in the size of marginal crenulations, and the overall shape of the shell, also point to *Nemocardium* (*Pratulum*).

Family HIATELLIDAE Gray, 1824

Genus **Panopea** Menard, 1807

Type species: *Panopea faujasi* Menard, 1807.

Panopea sp. indet. aff. **aramacensis** (Etheridge Jr, 1892)

(Pl. 1, fig. 14)

Material: An impression of the exterior surface of a right valve.

Description: Shell rather small for genus—33 mm long, 20 mm high—and moderately well inflated. Beak incurved one-third of shell's length in front, and well defined with tightly convex preumbonal carina and more obtuse postumbonal carina. Both carinas approach distal shell margin, modifying its shape. Ribs concentric, fairly robust, broadly convex in cross-section, and separated by narrow V-shaped interspaces in proximal and anterior parts of shell; diffused distally and posteroventrally.

Discussion: The genus *Panopea* is represented by more than 10 species in the Australian Lower Cretaceous strata. Some of these, such as *P. aramacensis* (Etheridge Jr) and *P. maccoyi* Moore, are similar to my specimen. It is thus likely that my specimen is not a genuine Cenomanian species but was washed in from older beds. Because of the lack of adequate material no firm conclusion regarding its identity will be made at this time.

Family THRACIIDAE Stoliczka, 1870

Genus **Thracia** Sowerby, 1823

Type species: *Thracia pubescens* Lamarck.

Thracia (Thracia) sp. indet. aff. **primula** Hudleston, 1890

(Pl. 1, figs. ?17, 20)

Material: An anteriorly and dorsally incomplete mature specimen, and possibly one anterodorsally incomplete immature specimen.

Discussion: The incomplete specimen whose latex cast is illustrated in Plate 1, figure 20 is definitely a *Thracia*, as demonstrated by the prominent posteroventral carina and the fine and uniform concentric striae. The smaller specimen (Pl. 1, fig. 17) may not be a *Thracia*.

In Australia, *Thracia* is found only in Lower Cretaceous strata, where it is represented by two species: *T. wilsoni* Moore, and *T. primula* Hudleston—the latter with the well-developed carina. Although my specimens are too incomplete to allow a convincing comparison, I suspect that they have been reworked from older strata.

GASTROPODA

Family APORRHAIDAE Adams, 1858

Genus **?Arrhoges** Gabb, 1868

Type species: *Chenopus occidentale* Beck, 1847.

Subgenus **?Latiala** Sohl, 1960

Type species: *Anchura lobata* Wade, 1926.

?Arrhoges (Latiala) mountnorrisi sp. nov.

(Pl. 1, figs. 1–3, 5, 6, 8)

Material: About a dozen moulds, all more or less incomplete.

Holotype: CPC 21543 (Pl. 1, figs. 6, 8)

Paratypes: CPC 21538 (Pl. 1, fig. 1); CPC 21539 (Pl. 1, fig. 2); CPC 21540 (Pl. 1, fig. 3); CPC 21542 (Pl. 1, fig. 5).

Diagnosis: The diagnostic feature is the combination of the rather short and robust overall shape with weak spiral shell sculpture, which is also evident in the body whorl in some specimens.

Separation from other species: The new species has a shorter, more robust outer lip and finer concentric ornament on the body whorl than the type species. *A. johnsoni* Stephenson, 1923 from the Upper Cretaceous Snow Hill calcareous member in North Carolina, USA, has more clearly defined and finer axial riblets. *A. turricula* Stephenson, 1923 has a longer and more attenuated wing.

Description: Shell up to 35 mm high; main body about 14 mm wide and 25 mm in overall width; turreted, with spiral angle 35°, ranging up to 39°.

Protoconch not observed. Suture closely adpressed, slightly impressed. Whorls probably eight, broadly convex in lateral profile, ornamented almost entirely with axial ridges except on body whorl. Axials prominent over entire surface of immature specimens (Pl. 1, fig. 2); usually (Pl. 1, figs. 6, 8) but not always (Pl. 1, fig. 5) absent from most of surface of mature specimens; when present, prominent, numerous (22–24), regular, closely spaced, and concave to front, at least proximally. Five spiral striae occasionally preserved on earlier whorls, but better imprinted on body whorl.

Prominent round-crested ridge on line of greatest inflation on distal part of body whorl, and on expanded outer lip, which bends upwards and continues to tip of upturned extension of lip. Ridge reflected on inner surface by narrow canal, also extending to tip (Pl. 1, fig. 1).

Anterior edge of wing somewhat expanded, producing broadly convex (Pl. 1, fig. 1) or irregular (Pl. 1, fig. 8) margin. Outer wall convex.

Discussion: The aporrhaids, which reached their acme of development in the Cretaceous, are in need of revision. At the moment there seems to be no agreement on the generic and subgeneric placings of the multitude of names in use, of which a number are no doubt synonyms. No serious attempt, therefore, is made here at the correct generic placings of the specimens from Mountnorris Bay. However, without doubt these specimens resemble *Arrhoges* (*Latiala*) in the overall shape, broadly expanded wing with thickened outer margin, and axially sculptured body, generally without a distinct spiral ridge. Consequently it is fitting that they should be referred to this subgenus, as suggested by Dr T. Kase (personal communication 1981). However, as described above, the body whorl in the better preserved of my specimens carries spiral threads and a fairly prominent spiral ridge (Pl. 1, fig. 6); in this they resemble less the Maastrichtian species *A.* (*L.*) *lobata* (Wade, 1926) from Tennessee, Mississippi, and Texas and *A.* (*L.*) *bailyi* (R. Etheridge Jr) from the Cretaceous of Zululand (Rennie, 1930), and more the species *Graciliala campbelli* (Stephenson, 1941) from the Maastrichtian Navarro Group of Texas, which, however, has a much more attenuated wing than the new species.

Family ARCHITECTONICIDAE

Genus ?**Architectonica** (Bolten) Röding, 1798

Type species: *Trochus perspectivus* Linné, 1758.

Subgenus ?**Granosolarium** Sacco, 1892

Type species: *Solarium milligranus* Lamarck, 1822.

cf. **Architectonica (Granosolarium) coffea** Sohl, 1964

(Pl. 1, fig. 7)

Material: An almost complete spire mould.

Discussion: The only specimen is small, possibly no larger than 15 mm in diameter, but in addition to the low, broad-angled spire it displays ornament very similar to Sohl's (1964) species from the Upper Cretaceous Coffee Sand of Mississippi. The specimen, however, seems to have a somewhat weaker spiral carina than Sohl's species. It is too poorly preserved to establish whether or not it had a selenizone and heterostrophic protoconch, so no definite comparison can be made with *Conotomaria* Cox, 1959 and *Semisolarium* Cossman, 1915 at this time.

Family PROCERITHIIDAE Cossman, 1905

Genus **Bathraspira** Cossman, 1906

Type species: *Bathraspira tecta* (d'Orbigny, 1842).

Bathraspira sp. nov.? cf. **brightoni** Abbas, 1973

(Pl. 1, fig. 4; Pl. 2, fig. 5)

cf. 1973 *Bathraspira brightoni* Abbas, *British Museum (Natural History) Bulletin (Geology)* 23(2), pp. 129–130, pl. 3, figs. 9, 14.

Material: Two incomplete casts of the rear part of the shell.

Description: Specimen about 11 mm high, 6 mm in diameter, and with spiral angle 38°. Whorls probably six, each with one prominent spiral carina, one weaker spiral carina, and at least one spiral thread—all developed on adapical slope. Abapical carina most prominent; axially striated concave spaces with growth rugae separate it from next distal suture abapically and from thin spiral thread adapically. This narrow thread is followed adapically by another axially striated concave interspace, which is followed in turn by weaker but broad low carina.

Remarks: Both specimens closely resemble *B. brightoni* from the late Albian (Gault Clay) of Folkestone, Kent, and there is little doubt that the two forms are closely related. However, close comparison reveals differences in the detail of development of spiral chords; the most obvious difference is that the contrast between the sizes of the two main carinas is more evident in my specimens, in which the aboral one is much more robust than in *B. brightoni.*

CEPHALOPODA

Family BACULITIDAE Meek, 1876

Genus **Sciponoceras** Hyatt, 1894

Type species: *Hamites baculoides* Mantell, 1822.

Sciponoceras sp.

(Pl. 1, fig. 12)

cf. 1822 *Hamites baculoides* Mantell, THE FOSSILS OF THE SOUTH DOWNS, p. 123, pl. 23, figs. 6, 7.

cf. 1971 *Sciponoceras baculoides* (Mantell); Kennedy, *Special Papers in Palaeontology,* 8, p. 9, pl. 1, figs. 12–18; pl. 2, figs. 1a, b, 2a, b, 3a, b, 4a, b, 5a, b; pl. 3, figs. 1a, b, 2, 8, 11; pl. 4, fig. 14.

Material: Two moulds representing two incomplete specimens.

Discussion: Neither of the specimens shows convincing long, and has compressed cross-section about 7 mm wide at one end and 9 mm at other. Both specimens have low, simple, rather irregularly spaced prorsiradiate riblets limited to venter and ventrolateral parts of shell; these are separated by wider interspaces asymmetrically concave to slightly sigmoidal in profile. Smaller of two specimens probably has one shallow, faint constriction.

Discussion: Neither of my specimens shows convincing constrictions, and their apertures and sutures are not present. The widely distributed *Sciponoceras* has already been reported from Bathurst Island (Wright, 1963), where it is represented by two species: *S. glaessneri,* which has well-developed constrictions but poorly developed ventral ribs, and *Sciponoceras* sp., in which neither ribs nor constrictions are at all well-developed.

Examination of some illustrations of the British representatives of *S. baculoides* (Kennedy, 1971) reveals that some specimens have poorly developed constrictions, and even those present may be spaced at considerable distance from one another.

Family TURRILITIDAE Meek, 1876

Genus **Turrilites** Lamarck, 1801

Type species: *Turrilites costatus* Lamarck, 1801.

Turrilites (Turrilites) costatus Lamarck, 1801

(Pl. 1, fig. 15; ?Pl. 2, figs. 9, 10)

1801 *Turrilites costatus* Lamarck, SYSTEM DES ANIMAUX SANS VERTEBRAES, p. 102.

1857 *Turrilites costatus* Lamarck; Sharpe, *Palaeontographical Society,* 9, p. 66, pl. 27, figs. 1–5, 15, 16.

1963 *Turrilites costatus* Lamarck; Wright, *Palaeontology,* 6(4), 601–602, pl. 81, fig. 4.

Discussion: The previously described specimens of *T. costatus* from the south coast of Bathurst Island (Wright, 1963) appear to be identical with the single mature specimen (Pl. 1, fig. 15). Wright regarded the Bathurst Island *Turrilites* as identical with the type material. Minor morphological differences between the Australian and some European *Turrilites* are seen in the more rib-like (rather than tubercle-like) shape of ribs in the Australian specimens.

Family BINNEYITIDAE Reeside, 1927

Genus ?**Borissiakoceras** Archangelsky, 1916

Type species: *Borissiakoceras mirabilis Archangelsky*, 1916.

?**Borissiakoceras** sp.

(Pl. 1, fig. 11)

Two incomplete lateral moulds and one mould of a fragment of a whorl of small (15 mm diameter) ammonites may belong to a member of the Late Cretaceous family Binneyitidae Reeside, 1927. The species, probably new, is very evolute, and characterised by small umbilicus, flat and apparently unornamented lateral walls, and a flat venter. The suture pattern is not known, precluding definite identification. The specimens are more involute than the Cenomanian-early Turonian type species, and devoid of the ventrolateral ornament that is present in the only other member of the family, the Coniacian *Binneyites* Reeside, 1927.

SCAPHOPODA

Family DENTALIDAE Gray, 1834

Genus **Dentalium** Linné, 1758

Type species: *Dentalium elephantinum;* SD Mountfort 1810.

Dentalium s. str.

Dentalium (Dentalium) sp. nov.?

(Pl. 2, figs. 3, 4)

A single impression of the outside surface of an almost complete specimen of a *Dentalium* is almost 23 mm long, gradually and evenly tapering towards its apex from a maximum diameter of 3 mm to just over 1 mm, and has an arc of 1.8 mm. Its surface is sculptured with about 22 fine longitudinal riblets of irregular width and spacing separated from one another by interspaces two-and-a-half to six times wider than the riblets. The interspaces are apparently smooth.

This specimen differs from *D. sublineatum* Stephenson, 1952, from the Cenomanian Woodbine Formation of Texas, which has finer and more numerous radial threads, and from *D. vaughani* Stephenson, 1941 and *D. navarroi*, from the Maastrichtian Navarro Group of Texas, in which the radial riblets are more regular and more numerous. It is probably a new species.

REFERENCES

ABBAS, H. L., 1973—Some British Cretaceous gastropods belonging to the families Procerithiidae, Cerithiidae and Cerithiopsidae (Cerithiacea). *British Museum (Natural History) Bulletin (Geology)* 23(2), 105-175, 8 plates.

COX, L. R., 1964—New genera and subgenera of Trigoniidae from Australia and Madagascar. *Proceedings of the Malacological Society of London,* 36, 49-52, 1 plate.

HUGHES, R. J., 1978—The geology and mineral occurrences of Bathurst Island, Melville Island, and Cobourg Peninsula, Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 177.

KENNEDY, W. J., 1971—Cenomanian ammonites from southern England. *Special Papers in Palaeontology,* 8, 1-133, 64 plates.

RENNIE, J. V. L., 1930—New Lamellibranchia and Gastropoda from the Upper Cretaceous of Pondoland (with an appendix on some species from the Cretaceous of Zululand). *Annales of the South African Museum,* 28, 159-280, 16 plates.

RENNIE, J. V. L., 1936—Lower Cretaceous Lamellibranchia from northern Zululand. *Annales of the South African Museum,* 31, 277-391, 19 plates.

SKWARKO, S. K., 1963—A new Upper Cretaceous ophiuroid from Australia. *Palaeontology,* 6(3), 579-581, 1 plate.

SKWARKO, S. K., 1966—Cretaceous stratigraphy and palaeontology of the Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 73, 15 plates.

SKWARKO, S. K., 1973—Cretaceous stratigraphy of part of the Wiso Basin, Northern Territory; *in* Palaeontological papers, 1970-71. *Bureau of Mineral Resources, Australia, Bulletin* 140, 85-104, 1 plate.

SOHL, N. F., 1960—Archaeogastropoda, Mesogastropoda and stratigraphy of the Ripley Owl Creek, and Prairie Bluff Formations. *United States Geological Survey, Professional Papers* 331-A, 1-151, 18 plates.

SOHL, N. F., 1964—Gastropods from the Coffee Sand (Upper Cretaceous) of Mississippi. *United States Geological Survey, Professional Papers* 331-C, 345-394, 5 plates.

STEPHENSON, L. W., 1941—The larger invertebrate fossils of the Navarro Group of Texas. *Texas University, Bulletin* 101, 95 plates.

STEPHENSON, L. W., 1952—Larger invertebrate fossils of the Woodbine Formation (Cenomanian) of Texas. *United States Geological Survey, Professional Papers* 242, 1-226, 51 plates.

WRIGHT, C. W., 1963—Cretaceous ammonites from Bathurst Island, northern Australia. *Palaeontology,* 6(4), 597-614, 9 plates.

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PLATE 1

All figures are latex casts at natural size and coated with ammonium chloride, unless stated to the contrary.

Figs.

1–3, 5, 6, 8 **?Arrhoges (Latiala) mountnorrisi** sp. nov.
1, paratype, CPC 21538: apertural view of mature specimen; locality 74 SS 1.
2, paratype, CPC 21539: back view of immature specimen, x2; locality 74 SS 1.
3, paratype, CPC 21540: back view of seemingly mature specimen; locality 74 SS 1.
5, paratype, CPC 21542: back and apertural views of two specimens; locality 74 SS 1.
6, 8, holotype, CPC 21543: back and apertural views of mature incomplete specimen; locality 73050108.

4 **Bathraspira** sp. nov.? cf. **brightoni** Abbas, 1973
CPC 21541: specimen viewed from back, x2; locality 73050108.

7 cf. **Architectonica (Granosolarium) coffea** Sohl, 1964
CPC 21544: ventral view of incomplete specimen, x2, locality 73050108.

9, 10 **Inoceramus** sp. indet. aff. **concentricus** Parkinson, 1819
CPC 21547: 9, proximal part of shell in posterior view; 10, lateral view of incomplete central part of shell; locality 73050109.

11 **?Borissiakoceras** sp.
CPC 21545: lateral view of almost complete cast, x2; locality 73050109.

12 **Sciponoceras** sp.
CPC 21549: oblique-ventral view of latex cast of incomplete shell; locality 73050108.

13, 16, 19 **Nemocardium (Pratulum) arnhemense** sp. nov.
13, paratype, CPC 21550: incomplete external left cast, x2; locality 73050108.
16, 19, holotype, CPC 21553: incomplete external cast and internal mould of right valve, x2; locality 73050108.

14 **Panopea** sp. indet. aff. **aramacensis** (Etheridge Jr, 1892)
CPC 21546: external impression of right valve; locality 73050108.

?17, 20 **Tracia (Thracia)** sp. indet. aff. **primula** Hudleston, 1890
?17, CPC 21554: incomplete left cast; locality 74 SS 1.
20, CPC 21555: anteriorly and dorsally incomplete right cast; locality 74 SS 1.

18 **Inoceramus** sp. juv.
CPC 21559: internal? impression of right valve, x2; locality 73050010.

15 **Turrilites (Turrilites) costatus** Lamarck, 1801
CPC 21552: external impression of incomplete mature specimen; locality 73050108.

CENOMANIAN MOLLUSCA, MOUNTNORRIS BAY

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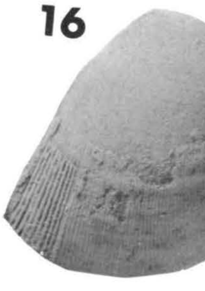

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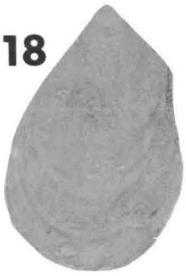

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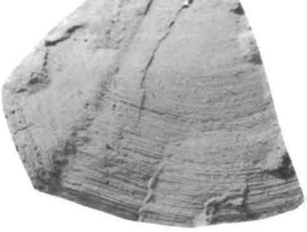

PLATE 2

All specimens are of natural size, coated with ammonium chloride, and photographed in lateral view, unless stated to the contrary.

Figs.

1, 2 **'Nuculana'** sp.
CPC 21557: latex cast of internal impression of left valve, x1 and x4; locality 74 SS 1.

3, 4 **Dentalium (Dentalium)** sp. nov.?
CPC 21590: latex cast of external impression, x1 and x4; locality 73050109.

5 **Bathraspira** sp. nov.? cf. **brightoni** Abbas, 1973
Pl. 1, fig. 4, x7.4.

6, 7 **?Chlamys** sp. indet.
CPC 21551: external impression of incomplete valve, x1 and x4; float specimen from between localities 73050109 and 74 SS 1.

8 **Inoceramus** sp. indet. aff. **concentricus** Parkinson, 1819.
CPC 21558: latex cast of internal impression of incomplete specimen; locality 74 SS 1.

9, 10 **?Turrilites (Turrilites) costatus** Lamarck, 1801
CPC 21556: end-on view of distal end of immature specimen coated with ammonium chloride (9) and uncoated (10), x10; locality 74 SS 1.

CENOMANIAN MOLLUSCA, MOUNTNORRIS BAY

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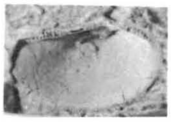

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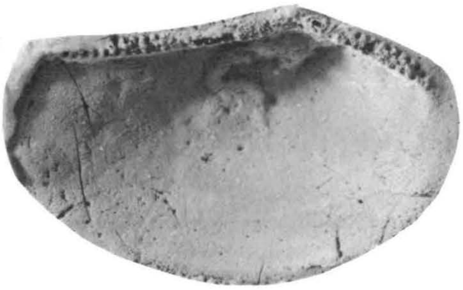

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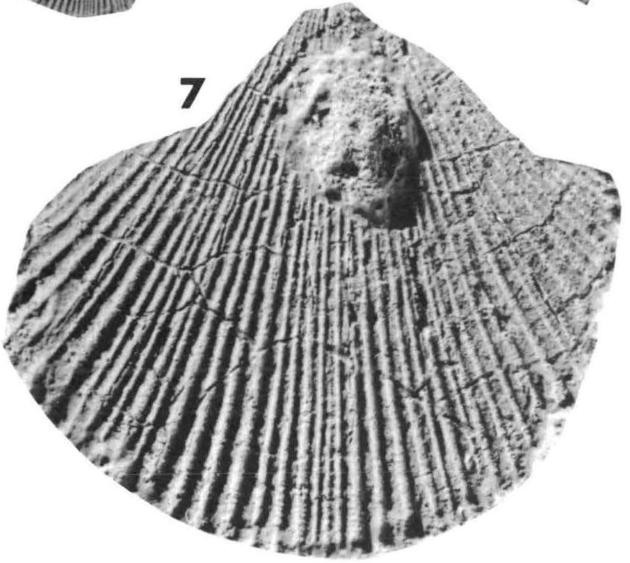

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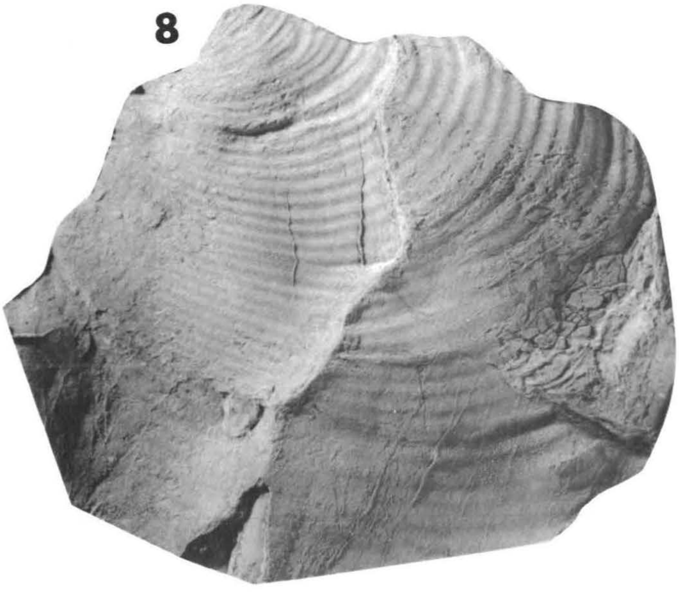

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