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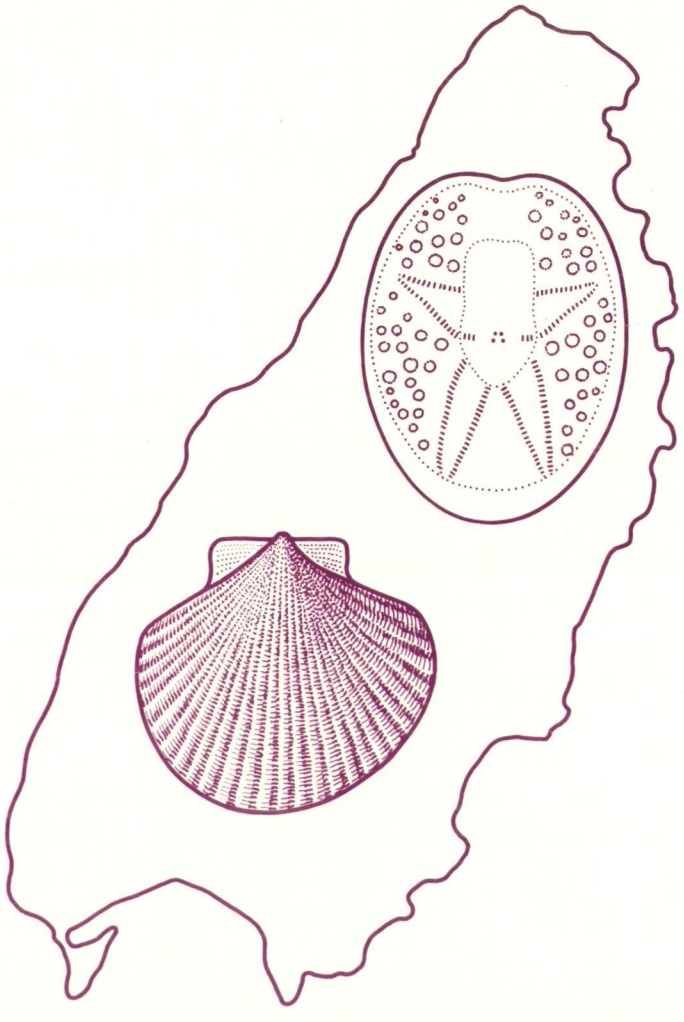
Cenozoic Molluscs and Echinoids of Barrow Island, Western Australia

by

Kenneth J. McNamara and George W. Kendrick



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Cenozoic Molluscs and Echinoids of Barrow Island, Western Australia

Kenneth J. McNamara and George W. Kendrick

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Abstract – A survey of the Cenozoic fossil fauna of Barrow Island, northwest Australia, has yielded a rich fauna of Middle Miocene and Late Pleistocene molluscs, and a rich Middle Miocene echinoid fauna. This paper, in recording 179 species, represents the first documentation of the fossil fauna of Barrow Island. The Miocene limestones reach up to 29 m in thickness in cliff sections exposed on the western side of the island. On the eastern side they are up to 9 m thick and are overlain by Late Pleistocene limestones. Formerly considered to belong to the Trealla Limestone, the Miocene limestones are regarded as a distinct formation, herein termed the "Poivre Formation", on account of their more variable and generally coarser sediment grain size.

The Poivre Formation yielded 270 specimens, comprising 70 species of bivalves and gastropods, 9 species of echinoids, plus indeterminate species of cephalopod, calcareous worm and corals. The Late Pleistocene fauna from an unnamed formation consists of 83 species of bivalves and gastropods, 11 species of corals and a single species of crustacean. Formal descriptions are given of the Miocene bivalves, gastropods and echinoids. New species of naticid gastropod, *Ampullina butleri* sp. nov., toxopneustid echinoid, *Tripneustes pregratilla* sp. nov., clypeasterid echinoid *Clypeaster tumulus* sp. nov. and echinolampadid echinoid *Echinolampas butleri* sp. nov., are described.

The Miocene mollusc and echinoid fauna has little in common with contemporaneous faunas from the Nullarbor Limestone in the Eucla Basin. The echinoid fauna shows more in common with Miocene faunas of Java and India, than it does with Miocene echinoids of southern Australia.The mollusc and echinoid faunas show strong affinities with modern communities.

INTRODUCTION

Barrow Island, situated 55 km off the Pilbara coast of Western Australia at 20°45'S and 115°25'E, is composed predominantly of Miocene limestones. The island is approximately 27 km by 12 km, the long axis running northeast to southwest (Figure 1). It forms the northern-most exposure of a series of anticlines of Miocene and other limestones that outcrop between Shark Bay and Barrow Island, the principal exposure being in the Cape Range. As such, it represents the most northerly surface exposure of Miocene marine deposits in Australia. Barrow Island and its environs are the site of a significant oil and gas field.

The earliest examination of the surface outcrops on Barrow Island was made by McWhae and Parry (1954) in a preliminary geological reconnaissance of the island. They observed the fossiliferous nature of the limestone that comprises most of Barrow Island, noting that: "It is characterised by an assemblage of relatively small foraminifera as well as molluscs and echinoderms." Although noting the variable texture of the limestone, from very fine-grained to coarse-grained, they equated these rocks with the Trealla Limestone, the youngest of the Miocene units to occur in the Cape Range. The age of the limestones was originally determined as Early Miocene by Glaessner, in an appendix to McWhae and Parry's (1954) report. The type section of the fine-grained Trealla Limestone is in the Cape Range. The age of this limestone has since been determined as Middle Miocene (Chaproniere 1975). In addition to the occurrence of Miocene rocks on Barrow Island, small outcrops of an earlier Tertiary unit, were also recorded by McWhae and Parry (1954). These they correlated with the mid-late Eocene Giralia Calcarenite.

Later surveys of the stratigraphy of Barrow Island (Campbell and Willmott 1956; Smith 1962; and Thomas 1975) did little to alter the initial interpretation of the age of the Barrow Island limestones. However, Smith (1962) noted that the Miocene rocks probably overlie the Eocene rocks with a transgressive unconformity. Exposure of the Giralia Calcarenite, as Smith noted, is poor. In

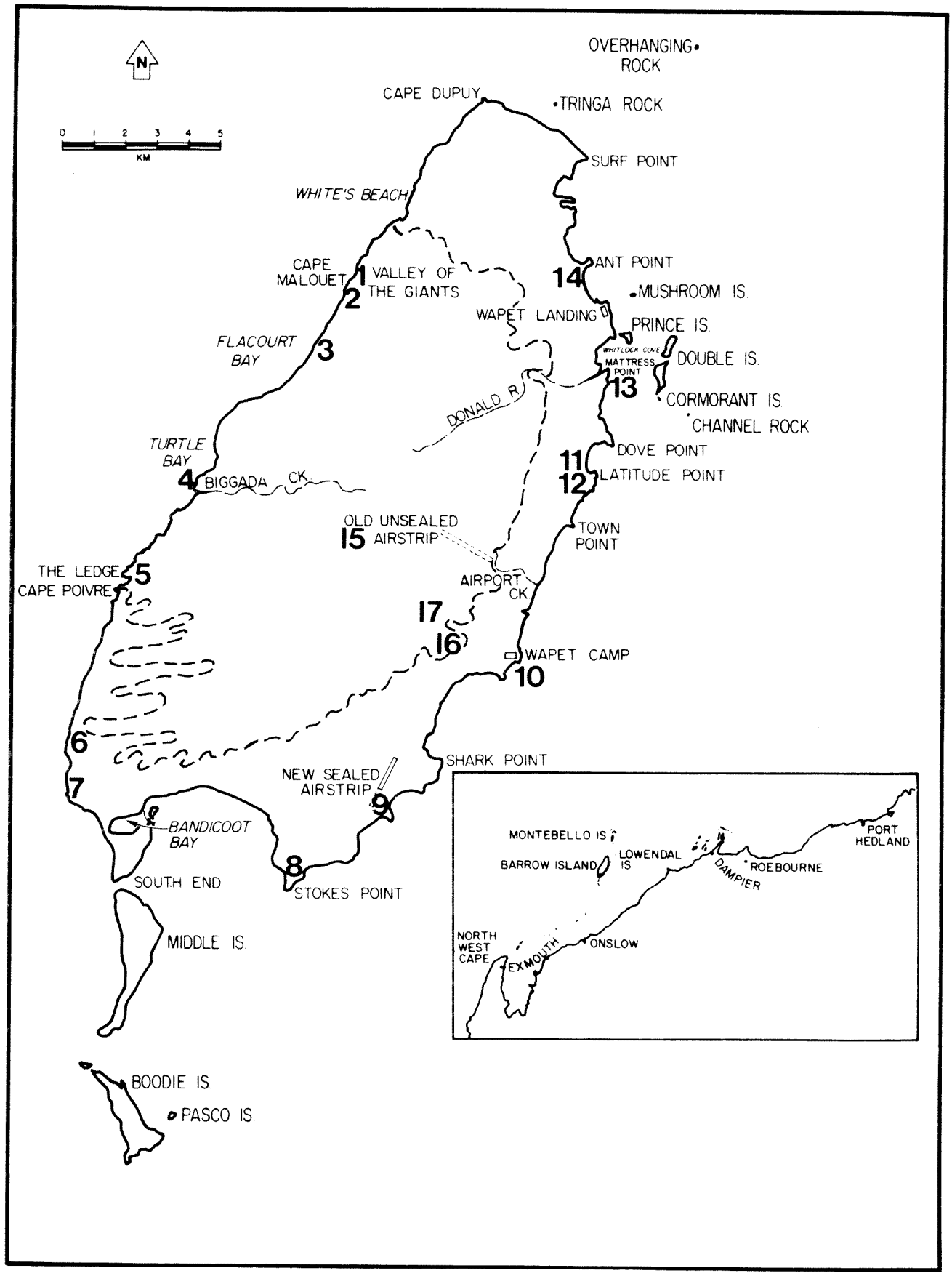

Figure 1 Map of Barrow Island showing location of Miocene collecting localities. Broken line demarcates Pleistocene sediments, that occur predominantly on the eastern side of the island, and the Miocene limestones that outcrop over much of the central part of the island and on the western coast.

addition to the occurrence of Eocene and Miocene strata, Smith (1962) for the first time recorded the presence of quite extensive deposits of superficial Pleistocene sediments on the eastern and south-eastern parts of the island.

No fossils from any of the formations on Barrow Island have been described or figured, neither has a survey been made of the macrofossils. Internal West Australian Petroleum Pty Ltd (WAPET) reports on the foraminifers were made by S. Edgell. A precis of the results is included in this survey. Prior to the fieldwork on which this survey is based, few macrofossil specimens had been collected. The first macrofossils to be obtained from Barrow Island, a small number of echinoids and molluscs, were collected by Mr V. Harris in 1964–5 and others by Mr W.H. Butler in 1975 and deposited in the Western Australian Museum. In 1981 application was made by the authors to WAPET for funding under the auspices of the Barrow Island Research Grant, in order to make collections of Miocene macrofossils. Following the award of a grant, a visit was undertaken to the island between 19 – 26 September, 1981. The two principal groups of marine invertebrates that were collected during the course of this field-work comprise the two major research interests of the authors: echinoids (K.J.Mc.) and molluscs (G.W.K.). The opportunity to visit Barrow Island and collect the faunas therefore enabled us to extend our continuing studies of the Miocene faunas of northwest Australia, which had hitherto been confined to the Cape Range and Gnargoo Range to the south.

The main aims of collecting the fauna were to obtain a comprehensive collection of the Miocene and Pleistocene invertebrate faunas of Barrow Island and to use the information gained from the identification of this material to assist in the analysis of the only tropical Miocene marine macro-invertebrate fauna in Australia, in order to ascertain the faunal relationships of the echinoids and molluscs.

Probably because little collecting had ever been carried out on the island the survey yielded 179 species of marine invertebrates from the Miocene and Pleistocene deposits, all of which are recorded here for the first time. A total of 226 specimens was collected from the Pleistocene sediments, comprising 83 species of molluscs, 11 species of corals, 2 species of echinoids and 1 species of crustacean (Table 2). A total of 270 specimens were collected from the Miocene rocks of Barrow Island, comprising 70 species of bivalves and gastropods, 9 species of echinoids, plus 1 species of calcareous worm, 1 species of cephalopod (*Sepia*) and a number of species of corals. A number of these are undescribed species. Furthermore, some genera and families of molluscs and echinoids were collected which hitherto had not been recorded from the fossil record in Australia. The species of echinoids and molluscs which were collected from the Miocene limestones are listed in Table 1. All registered specimens are housed in the palaeontological collections of the Western Australian Museum (WAM).

This paper represents a preliminary survey of the fossil fauna, and further collecting is required, particularly of the large mollusc fauna, before many of the taxa can be formally described. The smaller echinoid fauna is described to species level where possible, in addition to a general appraisal of the relationships of the fauna. Where sufficient material of undescribed species of both molluscs and echinoids was obtained, these are formally described. The biogeographical significance of the echinoid and molluscs faunas is assessed. Furthermore, a palaeoecological assessment of the echinoid fauna is made.

STRATIGRAPHY

The Miocene limestones of Barrow Island vary greatly in their grain size, both laterally and vertically and are considered to be sufficiently distinct from other Miocene formations to warrant description as a separate formation, herein termed the "Poivre Formation". Vertical lithological changes may be quite pronounced through single exposures of this formation. This is in marked contrast to the Miocene deposits of the Cape Range, where variations in grain size are much less and occur through much greater thicknesses of rock. The greater degree of variability of grain size in the Barrow Island sequence may reflect deposition in very shallow water. In colour the limestones may be either brown, yellow or pink. The limestones are all classified as calcarenites, varying between fine-grained and coarse-grained. The distribution of the echinoids, particularly the infaunal ones, is closely related to the grain size of the sediment. This is discussed in more detail below.

In order to assess the degree of lithological variability, we examined and measured a section near the north end of Flacourt Bay (locality 3). This we propose as the type section of the Poivre Formation. It is named after Cape Poivre, which is on the western coast of the island (Figure 1) The section (Figure 2), measured from top to bottom, is as follows:

2.0 m Pink fine-grained calcarenite, sporadically fossiliferous in patches, with gastropods and bivalves;

1.2 m Pale-brown, rubbly calcarenite containing *Chlamys* and *Clypeaster*;

1.0 m Pink, massive fine-grained calcarenite with *Clypeaster* fragments;

1.8 m	Pale pink/yellow massive fine-grained calcarenite;
1.7 m	Pink, massive fine-grained calcarenite;
1.1 m	Fossiliferous, nodular, mottled pink/yellow calcarenite, containing *Clypeaster* and echinoid spines;
1.6 m	Pink, massive fine-grained calcarenite;
1.5 m	Pink, massive, porcellanous fine-grained calcarenite with worm tubes;
0.2 m	Pink/white mottled fine-grained calcarenite with *Globularia*;
0.6 m	Pale-pink, fine calcarenite with naticid gastropod;
0.25 m	Pink fine-grained calcarenite with fossil fragments;
1.5 m	Yellow, massive fine-grained calcarenite;
1.3 m	Yellow, nodular calcarenite with *Clypeaster* and worm tubes;
1.9 m	Brown-yellow, massive fine-grained calcarenite;
0.5 m	Yellow, nodular calcarenite with cerithiacean gastropod, *Chlamys* and worm tubes;
0.3 m	Yellow-grey, fine calcarenite with coral, *Chlamys*, gastropods and worm tubes;
0.2 m	Pink-grey, massive fine-grained calcarenite;
0.35 m	Brown, strongly recrystallised fine-grained calcarenite;
0.25 m	Yellow, rubbly, nodular calcarenite;
1.4 m	Brown-grey calcarenite with gastropods;
0.5 m	Yellow, massive calcarenite with shell; fragments and layers of cidaroid echinoid spines orientated WSW-ENE;
1.9 m	Grey-yellow, nodular calcarenite; very fossiliferous with naticid gastropod and *Chlamys*;
0.2 m	Yellow, massive calcarenite;
1.4 m	Yellow, nodular calcarenite;
0.7 m	Yellow, massive fine-grained calcarenite;
1.4 m	Yellow, nodular calcarenite – containing many *Echinolampas*. Termed, informally, the "*Echinolampas* bed";
0.9 m	Pink, laminated, sandy calcarenite – containing many *Chlamys*. Termed, informally, the "*Chlamys* bed";
1.0 m	Yellow, nodular calcarenite with a few indeterminate gastropods and echinoids.
28.7 m	Total thickness

Figure 2 Type section, 28.7 m thick, of the Poivre Formation, at the northern end of Flacourt Bay, Barrow Island; locality 3 (see Figure 1).

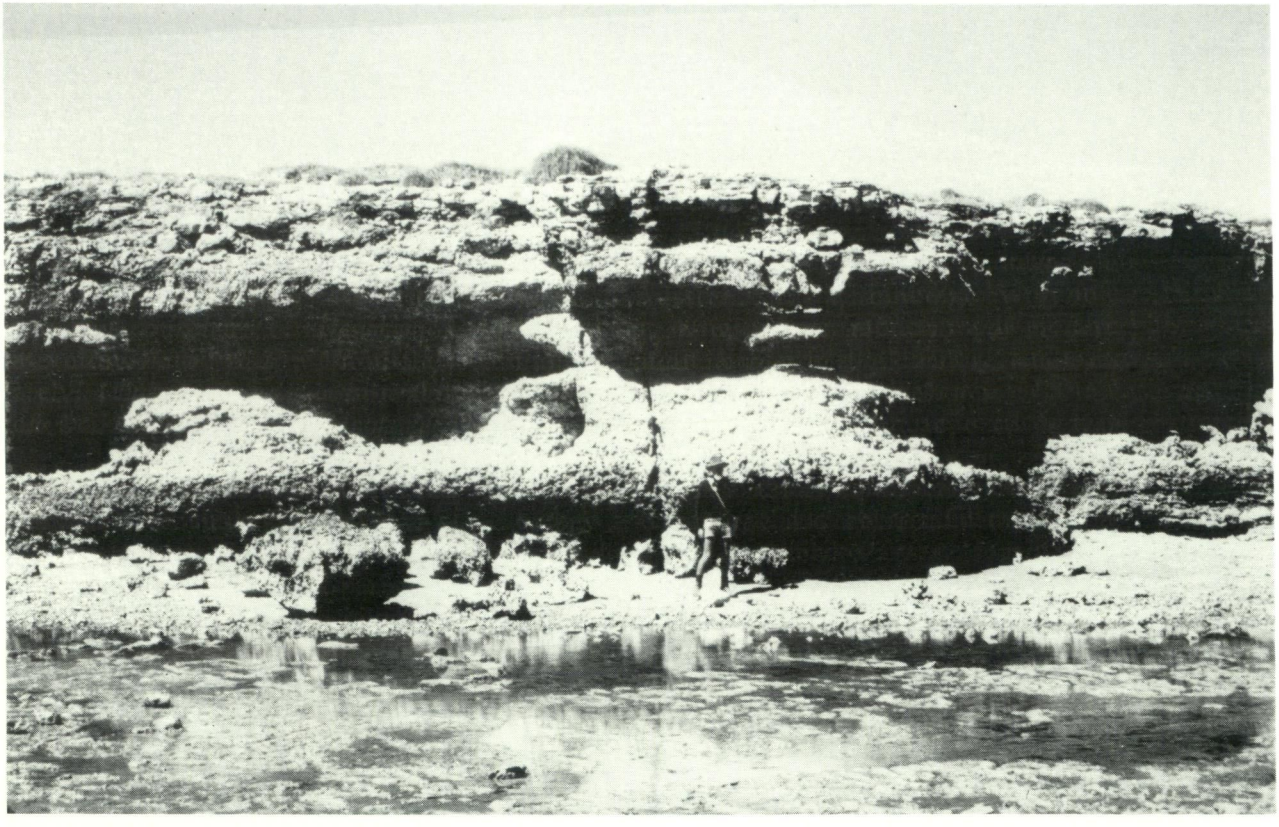

Figure 3 Coastal cliff on eastern side of Barrow Island, north of Stokes Point, Barrow Island, between localities 8 and 9 (see Figure 1).

In general, the sequence can be seen to become more fine-grained up through the section, from predominately a coarse calcarenite to mainly fine-grained calcarenite. As with limestones throughout the island, all are strongly recrystallised. At the very top of the section *Clypeaster* occurs quite commonly in a pink, nodular calcarenite, but generally, the upper 20 m is poorly fossiliferous, compared with the lower 8.7 m. This predominance of fossils in the coarser-grained limestone was observed throughout the island.

Although the Miocene limestones on Barrow Island have always been referred to the Trealla Limestone, lithologically they are quite different. The Trealla Limestone in its type area, the Cape Range, is defined (Condon *et al.* 1955) as a white-cream crystalline limestone, ranging from a very fine-grained calcarenite to a calcilutite. The Miocene of Barrow Island, on the other hand, is pink, yellow or brown and very variable in grain size. The coarser parts are somewhat reminiscent of the Tulki Limestone, which underlies the Trealla Limestone in the Cape Range. There is little doubt, on the basis of the fauna, that the Barrow Island Miocene is younger than the Tulki Limestone, and the same age as the Trealla Limestone. Analysis of the foraminifers in the Barrow Island limestones (Smith 1962, Table 4) shows a close correspondence with those described from the Trealla Limestone in its type area (Chaproniere 1975). Both units are considered to be Middle Miocene in age, on the basis of the foraminifers. Age determinations based on the echinoids support the view of the contemporaneity of the two units.

Lithological units should be based on the nature of the rock type, and not on any age consideration. Thus, although the Barrow Island Miocene is the same age as the Cape Range Trealla Limestone, this should not necessarily be justification for applying the same name to the Barrow Island rocks if their lithologies differ. Consequently, on account of differences in grain size, reflecting differences in environment of deposition, the Miocene limestones of Barrow Island are established as a separate formational unit, the Poivre Formation.

One of the notable observations to emerge from this study of the Cenozoic fossils of Barrow Island was the importance of the macrofossils in distinguishing between the Miocene and Pleistocene deposits. Lithologically the limestones of the two deposits are superficially similar, but recognition of the distinctive Miocene marine invertebrate fauna allowed us to extend the known outcrop of the Miocene.

The principal surface geological map of Barrow Island was prepared by Smith (1962). This map shows the entire eastern side of the island to be overlain by "undifferentiated Quaternary" deposits (Figure 1). However, on the eastern side of the island between Stokes Point (8) in the south and

Figure 4 Outcrop of Poivre Formation at Cape Malouet, Barrow Island; locality 1 (see Figure 1).

Ant Point (14) to the north, the low cliffs are composed almost entirely of Poivre Formation (Figure 3). This was determined from the mollusc and echinoid faunas. In most areas on the island where Pleistocene deposits occur they form a thin capping to the older Miocene rocks. Consequently surface geological maps, such as that herein (Figure 1), do not reflect the presence of Miocene outcrops along the eastern coast of the island. The sections are much thinner than on the western side of the island. For example, the section on the south side of Latitude Point (12) has 2 m of Quaternary sand overlying the following Miocene sequence:

2 m	Pink, massive limestone with abundant *Clypeaster*, echinoid spines, bivalves and gastropods;
3m	White/pink calcarenite with abundant *Clypeaster*, bivalves and gastropods;
4m	Yellow, nodular, very bioturbated limestone with rare *Breynia*, a few *Clypeaster* and occasional patches of gastropods.
9m	Total thickness

Thus coastal exposures of Miocene limestones of the Poivre Formation extend from Cape Malouet (2) to Eagle's Nest (7) on the western side of the island, and from Ant Point to Stokes Point on the east. The northern and southern coasts are covered by Pleistocene deposits and Holocene dunes.

The locality which yielded the most diverse suite of echinoids and molluscs was Cape Malouet (localities 1 and 2). In addition to displaying a variability in sediment grain size, the section at Cape Malouet (Figure 4) illustrates the occurrence of particular echinoids at certain, restricted horizons (Figure 5). The section is as follows, from top to bottom:

5 m	Yellow, nodular limestone with inverted *Clypeaster*;
2 m	Pink, large nodular limestone;
1.5 m	Yellow, sandy, nodular limestone – *Schizaster* at base;
0.2 m	Red, nodular limestone – containing *Clypeaster*;
1 m	Pink, bioclastic limestone with *Clypeaster*;
2 m	Red, nodular, bioclastic limestone – within which a gastropod-rich layer overlies a worm-tube layer that also contains bivalves. These overlie a sparse echinoid fauna, that has yielded *Breynia*, *Clypeaster*, *Schizaster* and *Echinolampas*;
2 m	Brown, nodular limestone – *Schizaster* present near top.
13.7 m	Total thickness

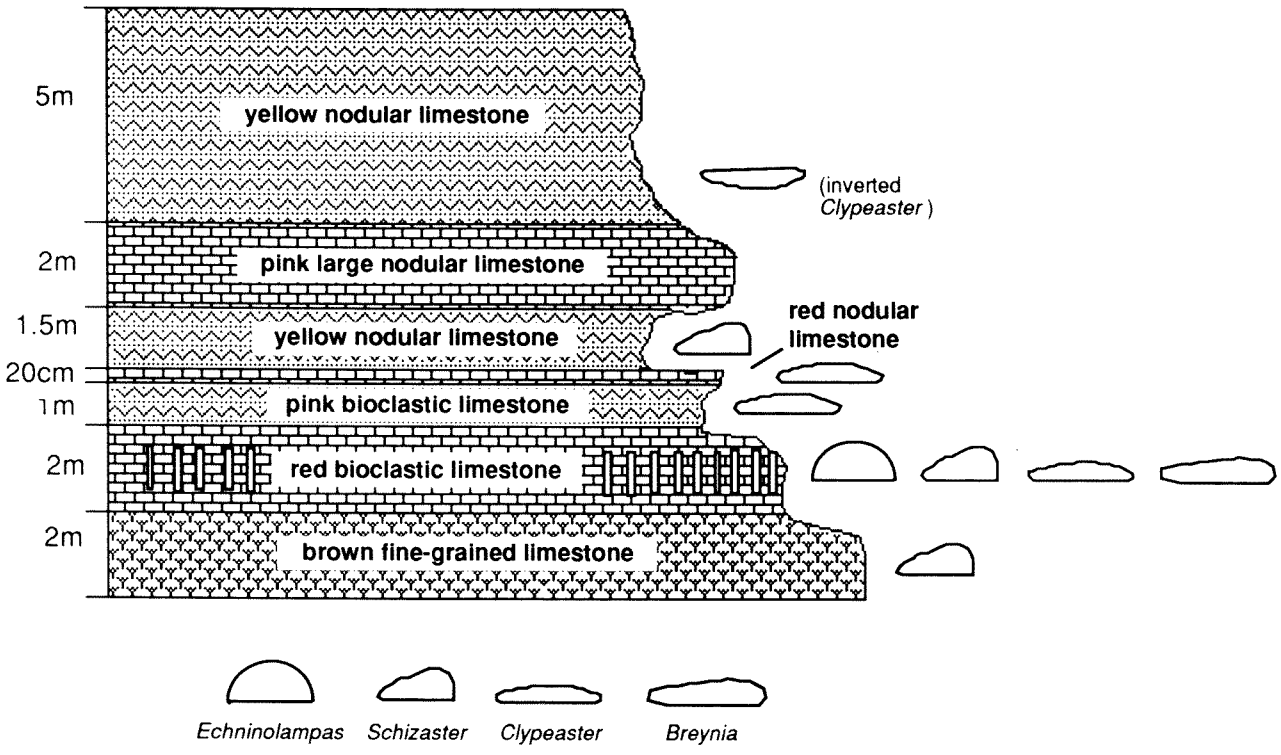

Figure 5 Section through the Poivre Formation at Cape Malouet, Barrow Island; locality 1 (see Figure 1) showing variation in echinoid biofacies with lithology.

The limestones are all calcarenites. The bioclastic limestones are very rich in coarse, fragmented shell material.

LOCALITIES

Miocene fossils were collected from 17 localities. The positions of these localities are shown on Figure 1. The best sources of fossil material were sea cliffs; inland sites yielded limited quantities of poorly preserved specimens. Locality numbers referred to in the text correspond to those on Figure 1 and Tables 1 and 2.

1. Cape Malouet. Poivre Formation. Hard, pink limestone on coastal cliff.
2. Cape Malouet. Poivre Formation. Large boulders on narrow beach at base of coastal cliff, about 0.3 km south of Cape Malouet.
3. Flacourt Bay, north end; coastal cliff. Poivre Formation.
   (a) Yellow-brown, hard, sandy limestone with abundant *Chlamys*.
   (b) Yellow-brown, rubbly limestone overlying *Chlamys* bed.
   (c) *Echinolampas* bed.
   (d) From 2.3 m above *Echinolampas* bed.
4. 0.5 km north of mouth of Biggada Creek, coastal cliff. Poivre Formation. Yellow-brown, strongly re-crystallized limestone.
5. The Ledge, and to 200 m northward. Poivre Formation. Coastal cliff along zone of salt spray.
6. 1 km north of Eagles Nest. Poivre Formation. Coastal cliff with hard, pink limestone; zone of salt spray.
7. Eagles Nest and up to 1 km north. Poivre Formation. Coastal cliff with hard, pink limestone; zone of salt spray.
8. Stokes Point. Poivre Formation. Fine, yellow-brown, rubbly limestone on coastal cliff, 2–4 m above low water mark.
9. Perentie Point II. Poivre Formation. Coastal cliff; yellow-brown, rubbly limestone between two pink limestones.
10. Main WAPET camp. Poivre Formation. Coastal cliff to southeast; thick bed of hard, yellow sandy limestone.
11. Latitude Point. Poivre Formation. Coastal cliff on south side; small lens of white to pink sandy limestone overlying yellow, rubbly limestone.
12. Latitude Point. Poivre Formation. Large, fallen boulders of pink limestone on beach.
13. Mattress Point. Poivre Formation. Coastal cliff at south end; hard, pink limestone about 2 m above low water mark.
14. 0.5 km south of Ant Point. Poivre Formation. Hard, yellow-pink limestone on lower half of coastal cliff.
15. Quarry about 0.4 km southwest from oil well Q58. Age uncertain. From pink, rubbly

limestone overlying friable, yellow-brown limestone.

16. Excavation on eastern side of oil well M64. Age uncertain.
17. Excavation on eastern side of gas injection well M43. Age uncertain.
18. South-eastern corner of island. Late Pleistocene deposits. Bore on WAPET "F" line, depth 9.1 m (30 feet); collected V.H. Harris, 1965.
19. Emergent deposit at east corner. Late Pleistocene deposits. 0.3 km from beach, east of new airport road, 0.1 km north of north end of airstrip; approximately 2.5 m above modern high water mark.
20. Gravel pit south of "Old Shelf Camp"; Late Pleistocene deposits. Between airport and Bandicoot Bay.
21. Gravel pit on west side of oil well B34A. Late Pleistocene deposits. Disturbed shelly-coral material on pit floor, from pale, well-cemented, richly fossiliferous sandy limestone.
22. Scraped area on north side of oil well B35A. Late Pleistocene deposits. Rubble of shelly limestone with abundant coralline material.

PRESERVATION

Exposures of the Poivre Formation examined on Barrow Island show, to an extreme degree, the effects of prolonged subaerial leaching, with the total destruction of primary aragonite and extensive development of secondary calcite cementation. The consequences of this for molluscan fossils, most of which originate as primary aragonite, are invariably severe. Shell fossils are preserved either as secondary calcitic casts of the original shell or, more frequently, as internal moulds. The former are usually very brittle and difficult to extract undamaged from the tough limestone matrix. The latter are of limited taxonomic value and in most cases cannot be identified with confidence beyond family or perhaps genus. The few groups with shells of primary calcite (e.g., Pectinidae, Spondylidae) are not appreciably better preserved than aragonitic forms.

As a general rule, fossils are to be found embedded in hard limestone, in which secondary crystallization of calcite appears to be continuous across the matrix-fossil interface. Such re-crystallization of primary calcite of the echinoid tests has resulted in similar problems of extraction to those encountered for the molluscs. No attempt has been made to employ mechanical means of extraction. The best quality material was located on coastal cliffs, where rapid erosion of the matrix has left a proportion of fossils exposed and relatively well-preserved. The best preserved echinoid specimens, weathered naturally out of sandy limestones, occur on the northwest coast of the island.

MIOCENE FAUNA

The Poivre Formation of Barrow Island formed in very shallow water as a deposit of coarse to fine-grained bioclastic carbonate sand. The formation is characterised by an abundance of molluscs, often large, and locally the presence of large numbers of echinoids. Small corals are present, but nowhere are they dominant elements of the fauna. Large, vertically aligned annelid tubes are a common and characteristic feature of the fossil assemblage. The invertebrate faunas, notably the molluscs, echinoids and foraminifers, provide an indication of the environment of deposition of this limestone.

Molluscs

Molluscs dominate most of the fossiliferous sections examined and the majority represent groups associated in life with soft, sandy substrates. Bivalves are found frequently with the valves articulated; most of these (species of *Tucetona, Codakia, Fimbria, Acrosterigma, Tellina, Semele, Orbicularia*(?), *Ventricolaria, Pitar, Circe, Dosinia*) are filter-feeding, infaunal sand burrowers. A minority are epifaunal in habit, living attached to firm substrates either by byssal threads (*Brachidontes*) or by direct cementation of the shell (*Spondylus, Chama*). In tropical seas species of the two latter groups are commonly found associated with coralline rubble. *Periglypta* is a shallow burrower or nestler among coral and coarse grained substrates generally, whilst the Pectinidae may have adopted the attached-epifaunal and free-swimming habits of their modern counterparts.

The assemblage is notable for the absence of species of the large arcoid bivalve *Anadara*, which is common elsewhere in the Indo-West Pacific Miocene to Recent, often in association with species of the gastropod genus *Vicarya* (identified provisionally from the present material).

The gastropods include a high proportion of epifaunal and shallow-burrowing herbivores, detrital feeders and possible carnivorous grazers, associated with mixed shallow water environments of normal marine salinity, characterized by areas of sand, sea grasses, rock and coral. These include species of the archaeogastropods *Trochus, Thalotia, Angaria, Turbo* and *Phasianella*, the mesogastropods *Xenophora, Cerithidea, Vicarya*(?), *Campanile, Rhinoclavis, Strombus, Rimella, Terebellum* and *Cypraea* and the neogastropod *Pyrene*. Predatory carnivorous gastropods include mesogastropods of

Figure 6 *Sepia* sp., 82.3, Poivre Formation, Ant Point, Barrow Island; locality 14 (see Figure 1); x1.

the Naticidae and Cassidae and neogastropods of the Olividae, Costellariidae, Melongendae, Conidae, Volutidae and Turridae.

The finding of a fossil cuttlefish, of the genus *Sepia* (Figure 6), is further indication that deposition occurred in very shallow water on shoals which, at times, might have been exposed above sea level. Due to their porous nature, cuttlefish "bones" float. In order for one to have been fossilised (and their paucity in the fossil record indicates that this is a rare event) it must have been washed onto a shoal, then quite rapidly covered by sediment as the shoal was inundated by the sea.

Echinoids

The echinoids are dominated by infaunal irregular forms which today inhabit sandy substrates in a neritic environment. Although not a great deal is known about the ecology of many species of living echinoids, it would appear that forms such as *Breynia, Echinolampas, Clypeaster* and *Fibularia* are shallow burrowers in sand (Kier 1975; Thum and Allen 1976; McNamara 1982). *Breynia*, with its array of defensive dorsal spines, burrows such that its dorsal surface lies below the sediment/water interface. Vail (*in* Mooi 1990) has observed that the living *Echinolampas ovata* (which lives around Barrow Island today) has a diurnal

Figure 7 Rich accumulation of cidaroid spines in the type section of the Poivre Formation northern end of Flacourt Bay, Barrow Island; 8 m above base; showing alignment by current activity, in a WSW – ENE direction.

Table 1 Fossil invertebrates from the Poivre Formation of Barrow Island. Locality numbers correspond to those in text.

	Locality Numbers																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	unspecified
Bivalves																		
1. *Glycymeris (Tucetona)* sp.	+			+							+							
2. *Brachidontes* (?) sp.									+									
3. *Amusium* sp.														+				
4. *Semipallium (Semipallium)* sp.													+					
5. *Chlamys (Annachlamys)* aff. *murrayana* (Tate)		+																
6. *Spondylus* sp.		+																
7. *Codakia* (?) sp.	+										+		+					
8. *Fimbria* aff. *soverbii* (Reeve)	+																	
9. *Chama* sp.								+										
10. carditid gen. et sp. indet.											+							
11. *Acrosterigma* sp.	+		+	+							+							
12. *Tellina* s.1. sp. A	+																	
13. *Tellina* s.1. sp. B							+								+		+	
14. *Tellina* s.1. sp. C							+											
15. *Semele* (?) sp.	+																	
16. *Orbicularia* (?) sp.	+		+												+	+		
17. *Periglypta* (?) sp.	+											+						
18. *Ventricolaria* (?) sp.	+		+								+							
19. *Pitar* (?) sp.											+							
20. *Circe* (?) sp.		+																
21. *Dosinia (Austrodosinia?)* sp.											+							
Gastropods																		
22. *Trochus (Trochus)* cf. *maculatus* Linnaeus	+																	
23. *Trochus* sp.						+												
24. *Thalotia* sp.		+																
25. *Angaria* cf. *tyria* (Reeve)											+							
26. *Turbo (Marmarostoma)* sp.	+									+	+				+			
27. *Phasianella* sp.										+								
28. rissoid gen. et sp. indet.										+								
29. vitrinellid gen. et sp. indet.								+			+							
30. *Cerithidea* (?) sp.								+									+	
31. *Vicarya* (?) sp.					+													
32. potamidid gen. et sp. indet.				+														
33. *Cerithium* (?) sp.											+							
34. *Rhinoclavis (Rhinoclavis)* cf. *fasciata* (Bruguière)	+	+																
35. *Rhinoclavis (Rhinoclavis)* sp.	+																	
36. *Rhinoclavis (Proclava)* sp.											+							
37. *Semivertagus* sp.	+									+								
38. cerithiid gen. et sp. indet. sp. A	+										+							
39. cerithiid gen. et sp. indet. sp. B	+																	
40. *Campanile* sp.					+			+	+	+	+				+			+
41. *Xenophora (Xenophora)* sp.			+					+										
42. *Strombus (Tricornis)* aff. *maximus* Martin							+											
43. *Strombus (Trichornis)* sp. A							+	+		+	+	+		+				
44. *Strombus (Tricornis)* sp. B										+								
45. *Strombus (Lentigo)* sp.	+	+	+															
46. *Strombus (Lentigo?)* sp.			+															
47. *Strombus* s.1. sp.								+										
48. *Rimella* sp.											+							

Table 1 (continued)

	Locality Numbers																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	unspecified
49. *Terebellum terebellum* (Linnaeus)				+	+			+										
50. *Zoila*? sp.												+						
51. *Cypraea* sp. A	+																	
52. *Cypraea* sp. B															+			
53. *Cypraea* sp. C	+																	
54. *Cypraea* sp. D					+			+							+			
55. *Cypraea* sp. E	+																	
56. *Natica* sp.					+	+				+								
57. *Mamilla* cf. *melanostoma* (Gmelin)					+			+										
58. *Ampullina butleri* sp. nov.	+	+			+			+									?	
59. naticid gen. et sp. indet.	+																	
60. cassid gen. et sp. indet.								+							+			
61. *Pyrene* sp.										+	+							
62. *Melongena* sp.	+																	
63. olivid gen. et sp. indet.	+									+								
64. *Vexillum* (*Costellaria*) sp.										+								
65. *Lyria* (s.l.) sp.											+							
66. *Conus* sp. A	+																	
67. *Conus* sp. B											+							
68. *Conus* sp. C											+							
69. *Conus* sp. D								+										
70. turrid gen. et sp. indet.	+																	
Echinoids																		
72. *Breynia* aff. *carinata* d'Archiac and Haime	+						+											
73. *Schizaster* (*Schizaster*) aff. *compactus* Koehler	+				+													+
74. *Echinolampas tumulus* sp. nov.	+	+	+		+	+			+									
75. *Clypeaster butleri* sp. nov.	+		+		+			+			+							
76. *Fibularia* sp.					+													
77. *Tripneustes pregratilla* sp.nov.					+													
78. *Eucidaris* sp.							+											
79. *Phyllacanthus* cf. *clarkeii* Chapman and Cudmore							+											
80. *Goniocidaris* cf. *murrayensis* Chapman and Cudmore					+													
Totals of taxa by localities	30	4	5+1	10	14	2	9	16	1	12	20	3	1	3	7	1	2+1?	3

activity, burrowing into the sand, with half its test exposed at night, but burrowing completely during the day. *Clypeaster* is likewise known to be a very shallow burrower, while *Fibularia* nestles between large sand grains in very shallow water. *Schizaster* s.s. inhabits fine sand to mud, but burrows deeper than the other genera (Kier and Grant 1965; Chesher 1966).

All these genera are shallow water forms. Both *Breynia* and *Echinolampas* live in the intertidal zone. *Tripneustes*, an epifaunal echinoid, which occurs mainly as broken fragments in the Poivre Formation, is an intertidal to subtidal inhabitant.

The paucity of epifaunal echinoids is probably a function of preservation. Of the three recorded genera of cidaroids (*Eucidaris*, *Phyllacanthus* and *Goniocidaris*) all are known only from the presence of stout spines. Some bedding planes contain rich accumulations, sometimes current-aligned (Figure 7). As Kier (1977) has noted, the fossil record of epifaunal regular echinoids is poor, as they break apart rapidly after death. Infaunal, irregular echinoids are far more likely to be preserved, as they are less liable to be affected by current activity. All of the echinoid genera recorded in the Poivre Formation live in the area today.

Foraminifers

The foraminiferal community that occurs in the Middle Miocene Poivre Formation on Barrow Island (Table 2) equates with the *Austrotrillina howchini-Flosculinella bontangensis* association of Chaproniere (1975). In addition to these species, the association is dominated by *Marginopora vertebralis*. This association occurs in the upper Trealla Limestone in Cape Range. In both localities miliolines predominate. The presence of alveolinids, such as *Borelis* and *Flosculinella* indicates accumulation in high energy conditions within the shallower parts of the euphotic zone (Chaproniere 1975). The occurrence of *Marginopora vertebralis, Sorites* spp. and *Peneroplis* spp., all encrusting and attached forms, suggests, as on Cape Range, that sea-grass communities were present in the vicinity. *Marginopora vertebralis* has been recorded living either attached to solid substrates, or living freely on unconsolidated reef detritus (Ross 1972). *Amphistegina* is adapted to high energy conditions in normal oceanic salinities. *Rotalia*, which also occurs in this association on Barrow Island, is restricted to shallow high energy environment, between 0 and 40 m. *Elphidium* is another genus that is known to be associated with sea grasses. Thus the foraminiferal assemblage in the Poivre Formation on Barrow Island indicates deposition of the sediment in depths less than 30 m, metahaline salinities and high-energy conditions.

Conclusion

Although far from being a complete representation of the original fauna, the material obtained in this survey is indicative of a high level of trophic diversity during the Middle Miocene, such as would be expected to occur on a shallow bank or shoal of the inner to middle shelf, with well circulated water of normal marine salinity. The substrate was predominantly sandy, and probably included areas of sea grass and hard ground, probably coralline. Sea temperatures were probably comparable with those prevailing at present in the area.

RELATIONSHIPS OF THE MIOCENE FAUNA

Despite the limited and qualified nature of many of the identifications presented below (see Systematic Palaeontology), it is clear that the molluscs and echinoids of the Poivre Formation of Barrow Island have little in common with those of the coeval Nullarbor Limestone of the Eucla Basin, listed and figured by Ludbrook (*in* Lowry 1970), and even less with the more fully documented Miocene faunas of southeastern Australia (Ludbrook 1973; Darragh 1985). The only species unquestionably common to both the Poivre Formation and Nullarbor Limestone as indicated from the present study is *Terebellum terebellum* (Linnaeus). Other possible common species are *Campanile* sp. and *Conus* sp. A, both subject to confirmation. Moulds of a hamineid gastropod (WAM 81.1535) from the Trealla Limestone of the Gnargoo Range are identical with a specimen from the Nullarbor Limestone in the collections of the Geological Survey of Western Australia and listed by Ludbrook (*in* Lowry 1970, p. 97) as "cf. *Cylichnella callosa* Tate and Cossmann". This species however has not been recorded from Barrow Island. Similarly, the echinoid fauna, although containing cosmopolitan and long-ranging elements such as *Schizaster* and *Echinolampas*, comprises a number of distinct elements hitherto not recorded from the Miocene of Australia. This includes both the genera *Breynia* and *Tripneustes*.

From the foregoing, it may be concluded that, by Middle Miocene time, the mollusc and echinoid faunas of the Pilbara coast (and perhaps all of northern Australia) had become differentiated to a substantial degree from those of southern Australia. This distinction became even more accentuated in the Pliocene, when elements of the southern Australian Miocene echinoid fauna, such as *Echinolampas* and *Schizaster* became locally extinct in the south, but live today off the north-west Australian coast.

From studies of sedimentary environments and foraminiferal assemblages in the Tertiary of southern Australia, Crespin (1950) recognized a "Bass Strait Province" extending from Gippsland – northern Tasmania to southeastern South Australia, and an "Austral-Indo-Pacific Province" extending westward from the aforementioned to North West Cape. Barrow Island thus lies a short distance outside the boundaries of the "Austral-Indo-Pacific", as defined. However, because the Trealla Limestone lies entirely southward from North West Cape and within that Province, the Poivre Formation, with its essentially similar fauna, could be included in the Province. Such an interpretation, however, may well be an oversimplification of the true picture, for the echinoid fauna suggests a strong differentiation between those from north-west Australia and those from the southern part of the continent. While it has been argued (Carter and McKinney 1992) that apparent biogeographical disparities may often be largely influenced by facies differences (their 'facies mismatching'), in the case of the southern Australian and northwest Australian sequences, facies mismatching is not a factor, as both assemblages are preserved in calcarenites of a similar range of grain sizes.

The echinoid fauna of Barrow Island certainly has far more in common with the echinoid fauna of

the Miocene deposits of India (Duncan and Sladen 1882–86), than it does with the rich Miocene faunas of southern Australia. Both *Breynia* and *Tripneustes*, which are common elements of the modern north-west Australian fauna, are common in the Barrow Island Miocene and in Miocene rocks of the Indian sub-continent. However, they are both absent from the Miocene strata of southern Australia. The occurrence of these genera in the Miocene of Java (Jeannet and Martin 1937) further establishes the tropical nature of the echinoid fauna and a closer relationship with northern, rather than southern, faunas. Similarly, even though *Echinolampas* and *Schizaster* are common to the northern and southern Australian regions, they are represented by different species.

Noteworthy in the mollusc material collected is a species of the Tethyan-relict genus *Campanile*, located significantly in an intermediate situation between previous Miocene records from Java and southern Australia. Records of the extinct genera *Vicarya* and *Ampullina* strengthen links with the Miocene faunas of the Indo-West Pacific area. A conspicuous absence from the study material is any representation of the genus *Anadara*, which is generally prominent in Miocene faunal lists from tropical areas north of Australia.

At this point, the preliminary character of the present study should be emphasized. Without the foundation of an exhaustive taxonomic analysis of the fauna, which awaits further collecting from other areas, any conclusions drawn are likely to be incomplete and of a qualified nature. It is therefore desirable that the study of the Miocene molluscs and echinoids continues, both at Barrow Island and on the mainland. This will entail, necessarily, comparative studies of Neogene faunas of the wider Indo-West Pacific Region, in particular with those of the Indo-Malaysian Archipelago, southern India and the southwest Pacific Islands. Such a study has potential for a major contribution to the Neogene palaeobiogeography of the Australasian Region. The collections made from Barrow Island provide a very important data base for these continuing studies.

ECHINOID PALAEOECOLOGY

An analysis of the relationships of the echinoid fauna of the Poivre Formation to the sediment grain size can only be undertaken in conjunction with reference to the Early-Middle Miocene of the Cape Range and the Gnargoo Range. These are currently being studied in detail by one of us (K.J.Mc.). As noted above, the Barrow Island Poivre Formation equates chronostratigraphically with the Trealla Limestone of the Cape Range and the Gnargoo Range. In terms of the echinoid fauna, the Cape Range Trealla Limestone is very poorly fossiliferous, only one specimen of *Breynia* aff. *carinata* having been collected. However, the echinoid fauna of the Gnargoo Range is far richer and shows many similarities to the echinoid fauna of the Poivre Formation on Barrow Island, but some important differences occur. These can be attributed to differences in the nature of the sediment which the echinoids inhabited in the two regions.

Numerically, the most abundant echinoids in the Gnargoo Range Trealla Limestone are *Breynia* and *Schizaster*. The only other echinoids which have been collected from there are *Clypeaster*, *Sismondia*, *Schizechinus* and *Echinolampas*, all of which occur very rarely. In the Poivre Formation of Barrow Island, however, *Breynia* is one of the less common elements, as is *Schizaster*. *Echinolampas*, on the contrary, occurs commonly on Barrow Island, as does *Clypeaster*, which is known from the Gnargoo Range from just a single specimen. *Sismondia* has not been found at Barrow Island.

Today, living species of *Echinolampas* and *Clypeaster* are largely confined to moderate to coarse-grained sand, in shallow water, although Nebelsick (1992) has recorded *Clypeaster* even in muds. However, this genus predominates in sand facies. *Breynia* and *Schizaster* are able to inhabit finer grained sands than either *Echinolampas* or *Clypeaster*, and probably are able to inhabit deeper water.

In his study of living echinoids in the northern Bay of Safaga in the Red Sea, Nebelsick (1992) identified a 'seagrass' echinoid community, dominated by *Tripneustes* and *Clypeaster*. The occurrence of these two genera as dominant members of the echinoid community at The Ledge in particular, is probably reflective of a seagrass community in the region during the Middle Miocene. This supports the interpretation of the foraminiferal assemblage, as a part of a seagrass community.

The occurrence of *Eucidaris*, *Phyllacanthus* and *Goniocidaris* in the Poivre Formation is comparable to the presence of *Eucidaris*, *Phyllacanthus* and *Prionocidaris* in the predominantly coarse calcarenites in the Bay of Safaga today (Nebelsick 1992).

When compared with the Tulki Limestone of the Cape Range, which underlies the Trealla Limestone, confirmation of the strong control of sediment type on echinoid distribution is found. The echinoid faunas of the Tulki Limestone and the Poivre Formation of Barrow Island, have more in common with each other at the generic level than do the echinoids of the Poivre Formation with those of the coeval Trealla Limestone of the Gnargoo Range, even though the Poivre Formation is younger than the Tulki Limestone. In the Tulki Limestone the most common echinoids are

Table 2 Mollusc, arthropod and coral species from Pleistocene localities on Barrow Island.

		Localities				
		18	19	20	21	22
	Bivalves					
1.	*Arca ventricosa* Lamarck				+	
2.	*Barbatia (Barbatia) amygdalumtostum* (Roding)			+		
3.	*Barbatia (Barbatia)* cf. *helblingi* (Bruguière)				+	
4.	*Brachidontes ustulatus* (Lamarck)		+		+	
5.	*Modiolus philippinarum* Hanley					+
6.	*Chlamys (Chlamys)* cf. *australis* (Sowerby)					+
7.	*Chlamys (Annachlamys) leopardus* (Reeve)					+
8.	*Saccostrea cuccullata* (Born)			+	+	
9.	*Epicodakia bella* (Conrad)				+	
10.	*Divaricella ornata* (Reeve)	+	+	+		
11.	lucinid gen. et sp.indet.				+	
12.	*Chama* sp.					+
13.	*Megacardita turgida* (Lamarck)			+	+	+
14.	*Cardites* sp.			+		
15.	*Acrosterigma dupuchense* (Reeve)		+	+	+	+
16.	*Fulvia aperta* (Bruguière)					+
17.	*Fragum (Fragum) unedo* (Linnaeus)	+	+	+	+	+
18.	*Fragum (Fragum) carinatum* Lynge)		+	+	+	
19.	*Hemidonax donaciformis australiensis* (Reeve)		+			
20.	*Mactra (Mactra) abbreviata* Lamarck					+
21.	*Atactodea striata* (Linnaeus)		+		+	
22.	*Tellina (Tellinella) staurella* Lamarck				+	
23.	*Tellina (Pharaonella) perna* Spengler				+	
24.	*Dosinia* sp.				+	+
25.	*Gafrarium intermedium* (Reeve)			+		
26.	*Circe scripta* (Linnaeus)		+			
27.	*Circe lenticularis* Deshayes			+	+	+
28.	*Gouldia (Gouldia)* sp.		+	+	+	
29.	*Callista impar* (Lamarck)		+	+	+	
30.	*Tapes (Ruditapes) variegatus* Sowerby				+	
31.	*Placamen berrii* (Gray)		+		+	
32.	*Placamen* sp.				+	+
33.	*Glycydonta* sp.				+	
34.	*Brechites (Brechites) australis* (Chenu)				+	+
	Scaphopods					
35.	*Laevidentalium* sp.		+	+		
	Gastropods					
36.	*Diodora jukesi* (Reeve)					+
37.	*Acmaea saccharina* (Linnaeus)		+			
38.	acmaeid gen. et sp. indet.		+			
39.	*Tectus pyramis* (Born)	+	+		+	+
40.	*Tectus fenestratus* (Gmelin)		+	+	+	+
41.	*Euchelus (Euchelus) atratus* (Gmelin)				+	
42.	*Hybochelus* cf.*cancellatus* (Krauss)	+				
43.	*Monodonta (Monodonta) labio* (Linnaeus)		+			
44.	*Thalotia (Prothalotia)* cf. *flindersi* (Fischer)		+			
45.	*Thalotia (Prothalotia)* sp.				+	
46.	*Angaria tyria* (Reeve)					+
47.	*Turbo (Marmarostoma) haynesi* Preston			+	+	+
48.	*Astralium pileolum* (Reeve)			+		
49.	*Liotina* cf. *peronii* (Kiener)		+			
50.	*Phasianella* (?) sp.	+				
51.	*Nerita* sp.		+			
52.	*Littorina (Littorinopsis) scabra* Linnaeus				+	
53.	*Cerithium tenellum* Sowerby		+			
54.	*Cerithium corallium* Kiener		+			

Table 2 (continued)

		Localities				
		18	19	20	21	22
55.	*Rhinoclavis aspera* (Linnaeus)				+	+
56.	*Rhinoclavis fasciata* (Bruguiere)				+	+
57.	*Semivertagus nesioticum* Pilsbry and Vanatta			+		
58.	*Clypeomorus* sp.		+			
59.	*Clypeomorus bifasciata* (Sowerby)		+			
60.	*Terebellum terebellum* (Linnaeus)					+
61.	*Cypraea annulus* Linnaeus	+				
62.	*Cypraea eglantina* Duclos					+
63.	*Cypraea errones* Linnaeus				+	
64.	*Cypraea histrio* Gmelin					+
65.	*Tonna* or *Malea* sp.				+	
66.	*Cymatium* (*Septa*) *pilearis* (Linnaeus)					+
67.	*Cymatium* (*Septa*) *gemmata* (Reeve)				+	
68.	*Thais* (?) sp.			+		
69.	*Drupa* sp.		+			
70.	*Cantharus* (*Pollia*) *undosus* (Linnaeus)		+			
71.	*Pyrene* sp. A		+			
72.	*Pyrene* sp. B		+			
73.	*Nassarius livescens* (Philippi)		+			
74.	*Syrinx aruanus* (Linnaeus)		+			
75.	*Vexillum* (*Vexillum*) cf. *vulpecula* (Linnaeus)		+			
76.	*Pterygia* sp.			+		
77.	*Cymbiola nivosa oblita* (Smith)	+			+	+
78.	*Amoria grayi* Ludbrook		+		+	+
79.	*Melo amphora* (Solander)					+
80.	*Conus* sp.		+			
81.	*Bulla* sp.			+	+	+
82.	*Atys* sp.		+			
83.	*Adamnestia* cf. *arachis* (Quoy and Gaimard)				+	
Totals of mollusc species, by localities		7	34	19	39	27
Crustacean						
1.	*Ubogebia* (*Calliadne*) *hexaceras* Ortmann				+	
Corals						
1.	*Galaxea astreata*			+	+	+
2.	*Galaxea fascicularis*					+
3.	*Platygira*? sp.					+
4.	*Acropora* sp. A	+				+
5.	*Acropora* sp. B					+
6.	*Acropora* sp. C					+
7.	*Lobophyllia* sp.					+
8.	*Favites* sp.			+		
9.	*Goniastrea* sp.		+			
10.	*Plesiastrea* sp.			+		
11.	*Cyphastrea* sp.			+		

Echinolampas westralensis (Crespin) and an undescribed species of *Clypeaster*. These two genera are the most common echinoids in the Barrow Island Poivre Formation. The Tulki Limestone, like the Poivre Formation, is predominantly a coarse, bioclastic limestone, hence the predominance of the two genera, both of which are characteristically shallow water genera. The specific difference between the *Echinolampas* from the Tulki and Trealla Limestone, and the occurrence of the same species of *Echinolampas* on Barrow Island as in the Gnargoo Range, confirms the temporal correlation of these two sequences. This is so, even though lithologically some of the coarser parts of the Barrow Island limestones are lithologically more similar to those of the Tulki Limestone. Clearly, an understanding of the degree of lithological control on echinoid distribution is an important

prerequisite to a detailed biostratigraphical analysis of the Miocene limestones of northwest Australia.

At a more detailed level, echinoid distribution within the Poivre Formation on Barrow Island appears to show a relationship to sediment grain size. For instance, at Cape Malouet *Schizaster* was only collected from brown, nodular limestone, while *Breynia, Clypeaster* and *Echinolampas* were collected from red, nodular limestone. To the south, at Flacourt Bay, specimens of *Echinolampas* were very common in a yellow, nodular, calcarenite. Rarely, *Fibularia* and *Clypeaster* also occurred in this bed (termed the "*Echinolampas* bed").

The distribution of *Echinolampas* shows how even at the interpopulation level within a single species, local environmental conditions are likely to have strongly influenced the distribution of particular age classes. At Flacourt Bay, all specimens of *Echinolampas* which were collected are small, varying in test length between 20 and 40 mm. To the north, at Cape Malouet, the few specimens collected are a little larger, between 40 and 50 mm test length. A "nest" of *Echinolampas* collected from locality 7, 1 km north of Eagle's Nest, are all large specimens, ranging between 80 and 90 mm test length. The occurrence of these specimens in life position, apex uppermost, suggests that they died and were fossilised in life position. The small specimens from Flacourt Bay are preserved in a brown, relatively coarse calcarenite, whereas the larger specimens from Eagle's Nest occur in a pink, finer-grained calcarenite. The occurrence of particular size classes at different localities suggests strong environmental control. Whether environmental factors limit size or whether they represent different age classes is not known. Néraudeau (1991) has recorded a similar phenomenon in the Cenomanian spatangoid *Mecaster*. Clustering of different size classes in this case was related to sediment grain size and levels of organic material in the sediment.

In general, large populations of irregular echinoids such as these, preserved in the sediment which they inhabited, provide a greater degree of information than can be obtained from Recent matyrial in museum collections. More often than not, information on sediment type inhabited by the echinoid is absent from data associated with collections of living material. The presence of *Tripneustes* only as broken fragments is a further indication of the high energy conditions under which these sediments accumulated.

PLEISTOCENE MARINE FAUNA

Emergent marine deposits containing an abundance of fossil molluscs and corals have been located in an area of low topography at the southern and south-eastern part of Barrow Island (Figure 1). From collections made from this area, 83 mollusc species have been recognized (Table 2). Positive identifications are available for 52 of these. It could be expected that any further collecting in the area is likely to increase the number of species on record. Although manifestly incomplete, compared with other Pleistocene assemblages in Western Australia, the assemblage, with few exceptions, shows strong affinity with modern mollusc communities of the inshore shallows around the eastern and southern shores of Barrow Island. The environment of deposition was characterized by a mosaic substratum of sand, coral and seagrass, under conditions of moderate to low wave energy and good tidal circulation; water depth was not likely to have exceeded 5 m.

Molluscan families with the strongest representation in the study material are the Veneridae (10 species), Trochidae (8 species), Cerithiidae (7 species), Cardiidae and Cypraeidae (4 species each); an additional 34 families are represented by 50 species. Worthy of note is the absence from the collections of any representation from such major tropical families as the Strombidae, Naticidae, Mitridae, Olividae, Turridae, Terebridae and Pyramidellidae, and the limited representation of Tellinidae, Neritidae, Muricidae, Buccinidae and Conidae. The absence of species of the mangrove-associated Arcidae and Potamididae was unexpected and may be the result of inadequate sampling, particularly in proximity of the palaeo-shoreline.

It has not been possible as yet to determine with certainty whether the various collection sites represent one or several depositional events, but for the purpose of this survey, no differentiation between them will be made. The identities of the fossils, their preservation, and the occurrence of all sites within a few metres of modern mean sea level, appear to be consistent overall with a Late Pleistocene, or "Last Interglacial" age. In their physical relationship to the modern littoral and to pre-existing landforms (Tertiary limestone uplands), the Barrow Island Pleistocene beds compare closely with the Tantabiddi Member of the Bundera Calcarenite of the Cape Range area, for which a Late Pleistocene age is reported from uranium-series age determinations (van de Graaff *et al.* 1976; Veeh *et al.* 1979; Kendrick *et al.* 1991). A second likely correlate is the Dampier Limestone of Shark Bay, a mollusc assemblage from which has been described recently by Kendrick (1990).

Three mollusc species from the Barrow Island Pleistocene beds warrant particular comment:

(i) *Fragum (Fragum) carinatum* (Lynge). This small but distinctive species, though rarely common, has an extensive range in the younger

Quaternary of the Carnarvon and Perth Basins, extending as far south as the hinterland of Geographe Bay, but is unknown from any Holocene or modern source in Western Australia (Kendrick 1990: 37, fig. 2). Extant populations occur in the South China Sea and adjacent areas of the South-West Pacific (Lynge 1909). In Western Australia, all available evidence suggests that *F. carinatum* is restricted to the Middle and Late Pleistocene.

(ii) *Gouldia (Gouldia)* sp. The present material, of undetermined and possibly undescribed species, appears to provide the first record of the genus from Western Australia.

(iii) *Rhinoclavis (Rhinoclavis) aspera* (Linnaeus). This common, wide-ranging Indo-West Pacific species has been recorded hitherto from the Recent of the northernmost parts of the Australian coast but never previously from as far south as Barrow Island (Wells and Bryce 1985: 56, pl. 12, fig. 142). The present record indicates a substantial contraction of range to the north by the species, since the Late Pleistocene.

SYSTEMATIC PALAEONTOLOGY

Class Bivalvia Linnaeus

Family Glycymeridae Newton

Glycymeris (Tucetona) sp.

Figure 8A

Material

WAM 82.468 (1), 82.525 (2), 82.555 (3). One pair and five single valves, all incomplete.

Distribution

Barrow Island, localities 1, 4, 11. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone. Middle Miocene.

Description

A medium-sized, sub-orbicular (juvenile) to sub-trigonal (mature) species of *Tucetona*, bearing 18–23 strong, spaced, lightly beaded costae and thin, transverse growth lamellae; umbones submedian, moderately inflated and projecting a little above the short auriculate dorsal margin; dorsal areas weakly defined; cardinal area narrow. Hinge short, strongly arched, 11 anterior and 11 posterior teeth, the posterior series the longer; ventral margin strongly crenulate internally. Height 36.6, length 36.3, inflation (estimated, both valves) 25 mm.

Remarks

Internal characters given above have been taken from material (WAM 81.1523, 81.1601, 82.525, 83.2539, 83.2656) collected from the Trealla Limestone of the Gnargoo Range. The species is distinct from any recorded hitherto from the Tertiary of (southern) Australia (Ludbrook 1965). It resembles the figures of a modern specimen of *Tucetona* from 74 km (46 miles) WSW of Cape Jaubert and identified as *"Pectunculus" vitreus* Lamarck by Odnher (1917, pl. 1, figs 12, 13). Another similar and possibly related species is *Glycymeris* sp. B of Popenoe and Kleinpell (1978, pl. 13, fig. 170) from the Late Pliocene Vigo Formation of Luzon.

Family Mytilidae Rafinesque

Brachidontes (?) sp.

Material

WAM 82.507 (1). One RV, showing the exterior.

Distribution

Barrow Island, locality 10. Poivre Formation, Middle Miocene.

Description

A small finely-ribbed mytilid resembling a species of *Brachidontes*, with a well-defined antero-postero angulation and a strong postero-dorsal flair; dorsal sculpture of fine, bifurcating, beaded costae; ventral sculpture of very fine, crowded riblets. Internal characters unknown. Height about 10.0, length about 28.0 mm.

Remarks

Lacking details of the umbonal cavity and margin, the generic position of the species is uncertain. Shells of the genus *Septifer* Récluz are similar externally to those of *Brachidontes* but have the anterior adductor scar on a strong internal septum located near the umbones, an area not visible on the present specimen.

Family Pectinidae Rafinesque

Amusium sp.

Material

WAM 82.574 (1). One articulated pair, fragmentary.

Distribution

Barrow Island, locality 15. Poivre Formation, Middle Miocene.

Description

A poorly preserved pectinacean bivalve with paired internal costae, consistent with a species of the genus *Amusium* Roeding. Height about 55, length about 53, inflation (both valves) 16 mm.

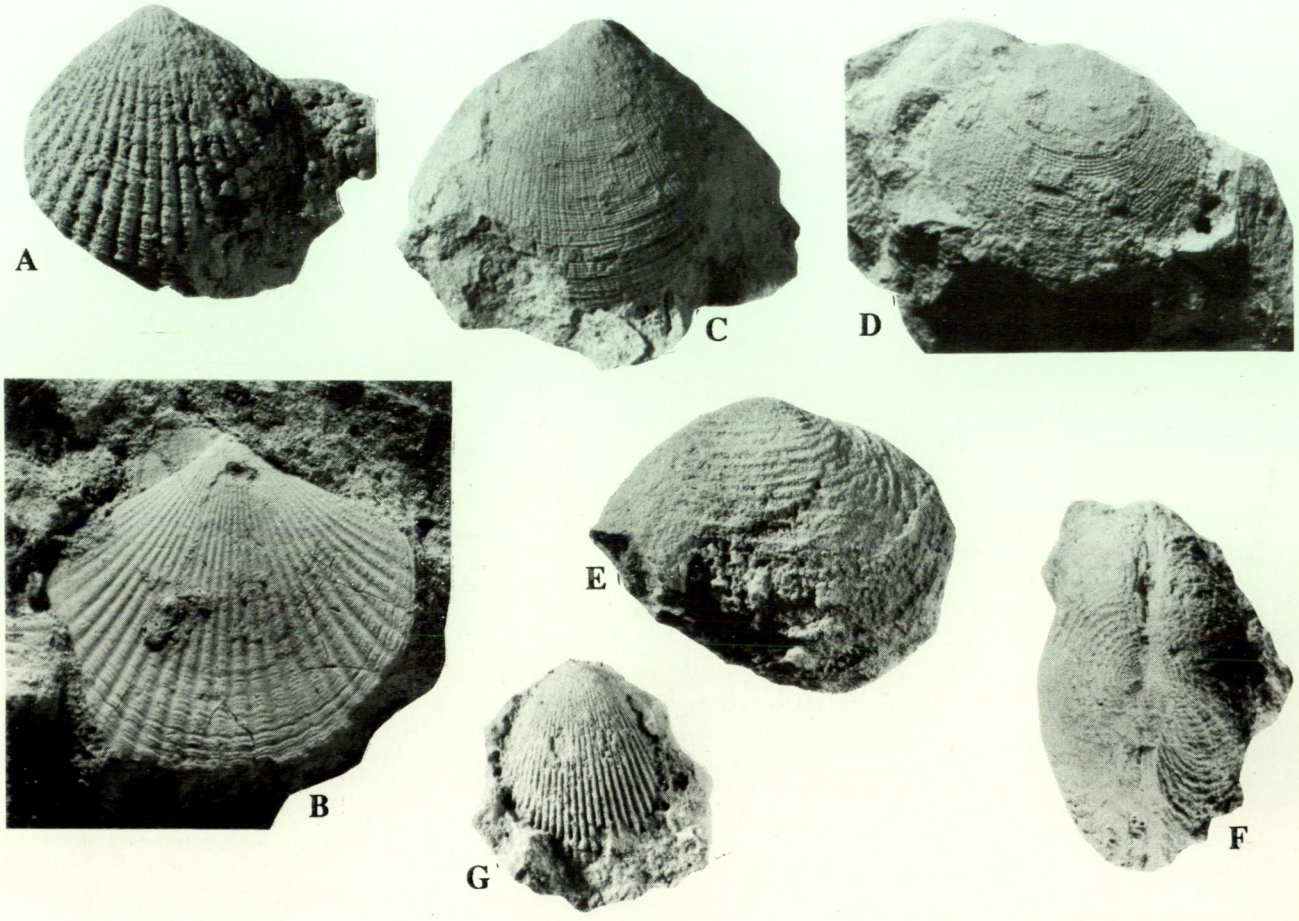

Figure 8 Bivalves from the Poivre Formation, Middle Miocene, Barrow Island: A, *Glycymeris (Tucetona)* sp., 82.468; B, *Chlamys (Annachlamys)* cf. *murrayana* (Tate), 82.551a; C, D,*Codakia* (?) sp., 82.528a, b; E,F, *Fimbria* aff. *soverbii* (Reeve), 82.680; G, *Acrosterigma* sp., 82.502. All x1.

Remarks

Specific determination would require the collection of better-preserved material. The genus ranges from the Lower Miocene to Recent in tropical and subtropical seas.

Semipallium (Semipallium) sp.

Material

WAM 82.505 (1). One valve.

Distribution

Barrow Island, locality 14. Poivre Formation, Middle Miocene.

Description

A small, poorly preserved *Semipallium* (s.s.), bilaterally compressed, with nine costae, narrower than the interspaces and bearing multiple riblets; apical angle and auricles indeterminable. Height about 46, length about 41 mm.

Remarks

The specimen comprises the internal mould of a single valve, probably a left, with remnants of the shell retained around the presumed postero-ventral margin. It bears a general resemblance to the extant Indo-West Pacific species *S. (S.) luculentum* (Reeve) but specific determination would require access to better material. The genus and subgenus range from Miocene to Recent.

Chlamys (Annachlamys) aff. *murrayana* (Tate)

Figure 8B

Material

WAM 82.551 (2). Probably a LV and a RV, exteriors only.

Distribution

Barrow Island, locality 3a. Poivre Formation, Middle Miocene.

Description

A medium-sized, bilaterally compressed species of Annachlamys, a little longer than high, with 26–31 low, rounded costae, initially narrower than the interspaces but reversing this with growth; apical angle 120°; disc and auricles with weak, transverse growth striae. Internal characters unknown. Height about 45, length about 49 mm.

Remarks

The species is related to the southern Australian Miocene species C. *(A.) murrayana* (Tate), differing in its narrower and more numerous costae and slightly greater apical angle. In Tate's species, the auricles are weakly radially ribbed but this is not apparent in the present material.

The extant C. *(A.) leopardus* (Reeve) represents the subgenus in modern seas of northern Australia. It differs from the Barrow Island species in its fewer, more prominent costae with wider interspaces, and radially ribbed auricles. The subgenus occurs from Miocene to Recent in "Eurasia (Tethyan) – Australia" according to Hertlein (*in* Moore 1969).

Family Spondylidae Gray

Spondylus sp.

Material

WAM 82.552 (5). Two pairs and three fragmentary single valves.

Distribution

Barrow Island, locality 3a. Poivre Formation. Also, Gnargoo Range, Lyndon River District. Trealla Limestone. Middle Miocene.

Description

The limited available material indicates a small, strongly inequivalved species of *Spondylus*, the upper LV less inflated than the RV, which projects well beyond the hinge margin; attachment area of the RV small and well defined; umbones strongly divergent, opisthogyrate; sculpture of both valves similar, comprising radial costae of two orders, the larger numbering about 21, and bearing spaced, erect spines; fine radial threads are visible along the intercostal spaces. Hinge and other internal characters unknown. Height about 49, length about 48 mm.

Remarks

The material is poorly preserved and the above description incorporates details from specimens (WAM 81.1602, 81.1603, 81.1524), considered to be conspecific, from the Trealla Limestone of the Gnargoo Range. The present species differs from the long-ranging southern Australian Tertiary species *S. gaderopoides* McCoy in its smaller size and more erect and more numerous costal spines. From the Miocene *S. pseudoradula* McCoy, it differs in having more numerous costae, bearing more and stronger, erect spines. The affinities of the present species remain to be clarified but are expected to lie with coral-associated species of the Indo-West Pacific region.

Family Lucinidae Fleming

Codakia (?) sp.

Figures 8C,D

Material

WAM 82.475 (1), 82.528 (2), 82.547 (1). Two pairs and two single valves.

Distribution

Barrow Island, localities 1, 11, 13. Poivre Formation, Middle Miocene.

Description

A medium-sized, suborbicular, robust bivalve of lucinoid form, compressed in the juvenile and becoming moderately inflated with growth; umbones damaged in all available specimens but probably prosogyrate; no obvious escutcheon; lunule obscured; sculpture of numerous, fine, close radial costellae with linear interspaces, crossed by very fine, close growth lamellae, forming a finely imbricated surface. Internal characters unknown. Height about 40, length about 40, inflation (1 valve) about 5 mm.

Remarks

In the absence of material from which the internal characters can be observed, the species is referred provisionally to the genus *Codakia* Scopoli. The sculpture is notably finer than that of extant species of *Codakia* from northern Australia.

Family Fimbriidae

Fimbria aff. *soverbii* (Reeve, 1842)

Figures 8E,F

Material

WAM 82.680 (1). An articulated pair.

Distribution

Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description

A small (probable immature specimen), inflated, transversely produced species of Fimbria with low, prosogyrate umbones and incurved beaks; sculpture of thin, spaced erect, transverse lamellae and fine, close radials; radials stronger around the umbones, forming a cancellate sculpture; escutcheon well developed; lunule obscured. Internal characters unknown. Height about 40, length about 50, inflation (both valves) 28 mm.

Remarks

The species resembles the extant Indo-West

Pacific *Fimbria soverbii* (Reeve), differing in the umbonal sculpture, which in Reeve's species comprises fine, erect, transverse lamellae and weak, interstitial radials. The fossil species shows a well-developed cancellate sculpture in this area, somewhat recalling that in *F. fimbriata* (Linnaeus), the type species of the genus.

F. soverbii has been recorded from the Late Pleistocene Dampier Limestone of Shark Bay, Western Australia by Kendrick (1990: 36).

Family Chamidae Blainville

Chama sp.

Material

WAM 82.582 (1). A fragmentary LV.

Distribution

Barrow Island, locality 8. Poivre Formation, Middle Miocene.

Description

A small, fragmentary LV (lower) of a species of *Chama*, with a prominent elevated umbone and incurved beak; a single, large, transverse cardinal tooth is located posterior to the beak; sculpture of irregular, transverse lamellae. Height about 23, length about 19, inflation 12 mm.

Remarks

The valves of *Chama* species are markedly discrepant and the single specimen in the present material is inadequate for specific determination. The genus occurs throughout the Cainozoic in tropical and temperate seas.

Family Carditidae Fleming

Carditid gen. et sp. indet.

Material

WAM 82.526 (1). A fragmentary LV.

Distribution

Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description

The sole available specimen comprises the dorsal portion of a small, thick-shelled, strongly inflated carditid with a prosogyrate beak and about 19 narrow beaded costae, which become narrower and more crowded posteriorly. Height (estimated) about 21, length about 21, inflation (one valve) about 9 mm.

Remarks

The specimen may represent a species of the genus *Glans* Megerle, but generic confirmation would require access to better material.

Family Cardiidae Lamarck

Acrosterigma sp.

Figure 8G

Material

WAM 82.470 (2), 82.502 (1), 82.527 (1), 82.556 (3). One pair and six fragmentary single valves.

Distribution

Barrow Island, localities 1, 4, 5, 11. Poivre Formation, Middle Miocene.

Description

A small, obliquely ovate species of *Acrosterigma*, shell higher than wide, inflated, with prosogyrate umbones and bearing up to about 40 close, radial costae, wider than the interspaces and of four forms; the anterior 15 (or so) strongly beaded; the next 12 smooth initially and becoming beaded with growth; the next 6 smooth initially and becoming transversely scaled along the sides and crests; the posterior ribs with very small, spaced scales on the flattened crests. On three specimens from locality 4, the median costae are alternately wide and narrow. Internal characters unknown. Height about 31, length about 27, inflation (one valve) about 12 mm.

Remarks

The affinities of this species appear to lie with the group of small-shelled Indo-West Pacific *Acrosterigma* exemplified by the extant *A. maculosum* (Wood). A related species may be *'Cardium' quilonense* Dey from the Miocene Quilon Beds of Kerala (Dey 1962). A second, small but more finely-ribbed species of *Acrosterigma* occurs in the Trealla Limestone of the Gnargoo Range, Lyndon River district (WAM 81.1604, 81.1605).

Modern species of this genus and the closely related *Trachycardium* Mörch in the Indo-Southwest Pacific are discussed by Wilson and Stevenson (1977) and Voskuil and Onverwagt (1991).

Family Tellinidae de Blainville

Tellina (s.l.) sp.A

Material

WAM 82.471 (1). A fragment of a LV.

Distribution

Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description

Part of the LV of a medium sized species of *Tellina* with a weak posterior flexure; postero-dorsal margin almost straight (very slightly convex); posterior extremity broken but probably subacuminate; umbone broad, flattened; beak acute, prosogyrate, incurved; lunule well-defined; escutcheon long, narrow; posterior lateral tooth present, remote from the beak; cardinals obscured; sculpture of fine, close, transverse and radial costae, beaded at the intersections. Height about 37, length estimated at about 45, inflation (one valve) about 10 mm.

Remarks

The tellinine affinity of the species is confirmed by the weak posterior flexure and form of the interior of the postero-dorsal margin, including the lateral tooth. Subgeneric and specific determination would require the collection of further material.

Tellina (s.l.) sp. B

Figures 9A–C

Material

WAM 82.569 (1), 82.576 (1), 82.600 (1). Three internal moulds.

Distribution

Barrow Island, localities 7, 15, 17. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description

Internal moulds of tellinid form, bilaterally compressed, transversely ovate; posteriorly rostrate and flexed to the right; anteriorly rounded and flexed slightly to the left; valves discrepant, the LV more convex; rostral area of the LV bears an internal rib, that of the RV bears a corresponding internal groove; both rib and groove located well-posteriorly; umbones small, submedian, slightly opisthogyrate, projecting a little; pallial sinus of medium size, rounded, rather high. Hinge and external characters unknown. Height about 45, length about 55, inflation (both valves) about 20 mm.

Remarks

The material is of similar size and proportions to the extant, Indo-West Pacific species *Tellina (Tellinella) virgata* Linnaeus, but precise determination would require knowledge of the hinge and external characters. A similar, well-preserved and apparently conspecific internal mould from the Trealla Limestone of the Gnargoo Range (WAM 81.1525) is figured. A fossil species proportioned similarly to the present species is *Tellina (Tellinella) retifera* Martin from the Miocene of Java (Martin 1917: 275, tab. v, fig. 138).

Tellina (s.l.) sp. C

Material

WAM 82.570 (1). An internal mould.

Distribution

Barrow Island, locality 7. Poivre Formation, Middle Miocene.

Description

A large bilaterally compressed internal mould of tellinid form, transversely ovate, weakly flexed to the right posteriorly; umbones median, slightly prosogyrate and low; inflation of the valves about equal; anterior and posterior margins rounded; pallial sinus high, ascending; pallial line on the LV well distanced from the margin. External characters unknown. Height 43, length 64, inflation (both valves) 21 mm.

Remarks

The material is consistent with a species of *Tellina* similar to the wide-ranging Indo-West Pacific *Tellina (Scutarcopagia) scobinata* Linnaeus, though differing a little from that species in the configuration of the pallial sinus. In proportions, the specimen is comparable with species of other tellinid groups such as *Pseudarcopagia* Bertin, but positive determination would require access to further material with external characters.

Family Semelidae Stoliczka

Semele (?) sp.

Figure 9D

Material

WAM 82.469 (5). Five articulated pairs.

Distribution

Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description

A large, moderately inflated tellinoidean bivalve resembling a species of *Semele*, with a weak posterior flexure, a well-defined postero-dorsal shoulder; beaks slightly projecting, prosogyrate; lunule well-defined; antero-dorsal margin straight; postero-dorsal margin shorter, slightly convex; posterior margin truncate; other margins evenly rounded; sculpture worn but probably of irregular, fine, close, transverse lamellae. Internal characters

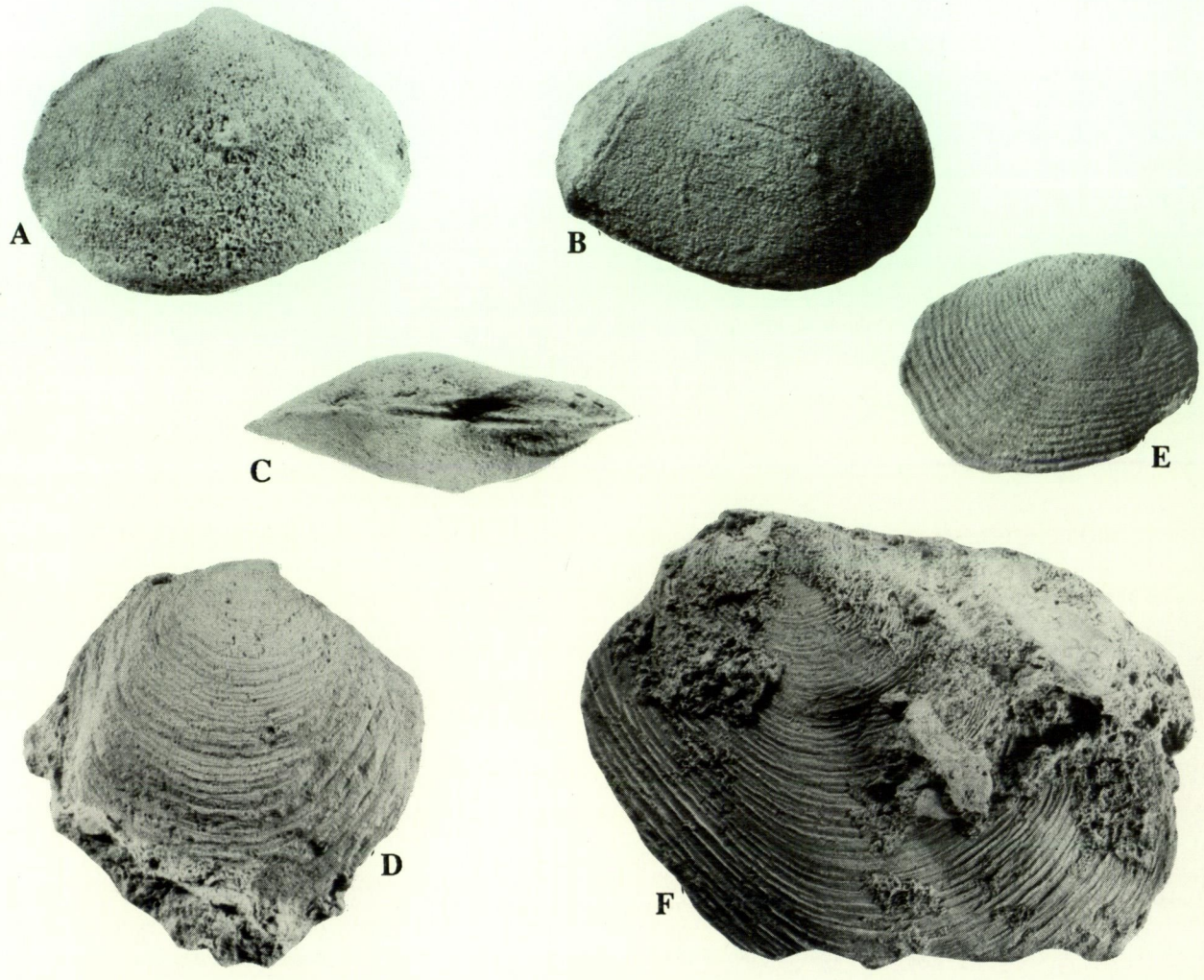

Figure 9 Bivalves from the Middle Miocene of the Gnargoo Range and Barrow Island, W.A.: A–C, *Tellina* (s.l.) sp.B, 81.1525, Trealla Limestone, Gnargoo Range, Lyndon River district; D, *Semele* (?) sp., 82.469a, Poivre Formation, Barrow Island; E–G, *Orbicularia* (?) sp., E, 65.739, Poivre Formation, Barrow Island; F, 82.472a, Trealla Limestone, Gnargoo Range, Lyndon River district; G, 81.1606, Trealla Limestone, Gnargoo Range, Lyndon River district. All x1.

unknown. Height about 73, length about 73, inflation about 20 mm.

Remarks

Confirmation of the identify of the species would require knowledge of the hinge and other internal characters, none of which is visible on the present material. Externally, the specimens resemble unidentified specimens of *Semele* (e.g. WAM 2168.68, 1020.70) in the WAM collection of modern molluscs from Woody Island and Yeppoon, Queensland, respectively.

Family Psammobiidae Fleming

Orbicularia (?) sp.

Figures 9E–F

Material

WAM 65.739 (1), 75.960 (2), 82.472 (6), 82.503 (1), 82.575 (2), 82.583 (1). Ten pairs and 2 single valves.

Distribution

Barrow Island, localities 1, 5, 8, 15. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description

A large, bilaterally compressed, inequilateral bivalve of tellinoidean form, anteriorly produced, posteriorly abbreviated; postero-dorsal area weakly offset but without obvious flexure or rostration; RV slightly more inflated than the LV; umbones broad, flattened; beaks opisthogyrate and projecting a little at about the posterior third; sculpture similar on each valve, of fine close irregular, anastomosing transverse costae; radial sculpture absent; pallial sinus large, rounded, high. The internal mould of the RV shows a radial fold extending from below the beak toward the antero-

ventral margin. Height about 85, length about 115, inflation (both valves) about 35 mm.

Remarks

In its proportions and sculpture, this distinctive species resembles a large *Orbicularia* (see Keen *in* Moore 1969: N632, fig. E116, 8a). Positive determination would require knowledge of the hinge and other internal characters. The genus is recorded hitherto only from the Recent of the Indo-SW Pacific (Keen *in* Moore 1969: N633).

Family Veneridae Rafinesque

Periglypta (?) sp.

Material

WAM 82.473 (1). An incomplete RV.

Distribution

Barrow Island, localities 1. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description

A medium-sized venerine bivalve resembling a species of *Periglypta*, ovate, inflated and sculptured with spaced, thin, erect, transverse lamellae and low, crowded radial costellae in the interspaces; dorsal margin roundly arched, other margins missing. Posterior and median cardinal teeth large, bifid; anterior cardinal missing; lunule and escutcheon obscured. Height about 55, length about 63, inflation (one valve) about 28 mm.

Remarks

In the available characters, the material resembles the extant Indo-West Pacific species *Periglypta puerpera* (Linnaeus), the type species of *Periglypta* Jukes-Brown. Generic confirmation would require knowledge of the hinge, escutcheon and pallial configuration (Darragh 1965). A second and probably related species is that recorded as "*Venus (Chione) listeri* Gray" in Martin (1917: 272, tab. v, figs 130, 131) from the Miocene of Java. The identity of Martin's species is uncertain; *P. listeri* is said to be a modern Caribbean species by Abbott (1974).

A species of *Periglypta*, unidentified and possibly undescribed, which also resembles the present species, occurs in the Late Eocene Merlinleigh Sandstone of the Carnarvon Basin (WAM 79.2860).

Ventricolaria (?) sp.

Figure 10A

Material

WAM 82.474 (2), 82.529 (1). One pair, one LV, one RV.

Distribution

Barrow Island, localities 1, 5, 11. Poivre Formation, Middle Miocene.

Description

A medium-sized bivalve of venerine form, suborbicular, inflated; umbones prominent, prosogyrate; beaks incurved; lunule depressed; sculpture of low, close, narrow, transverse costae, which become recurved dorsally with growth; intercostal spaces apparently smooth. Internal characters unknown. Height about 40, length about 45, inflation (one valve) about 10 mm.

Remarks

In the absence of internal characters, the generic determination remains provisional.

Pitar (?) sp.

Material

WAM 82.531 (1). An incomplete RV.

Distribution

Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description

A small bivalve, probably juvenile, of pitarine form, transversely ovate, inflated; umbone prominent, prosogyrate; beak incurved; lunule shallow, poorly defined; escutcheon narrow, elongate; exterior apparently smooth. Internal characters unknown. Height about 10, length about 15, inflation (one valve) about 4 mm.

Remarks

Generic confirmation would require the collection of better preserved material.

Circe (?) sp.

Material

WAM 82.557 (1). An articulated pair.

Distribution

Barrow Island, locality 4. Poivre Formation, Middle Miocene.

Description

A medium sized, suborbicular, moderately inflated bivalve resembling a species of *Circe*, with projecting, submedian umbones and slightly prosogyrate beaks; lunule and escutcheon small, weakly defined; sculpture of low, irregularly

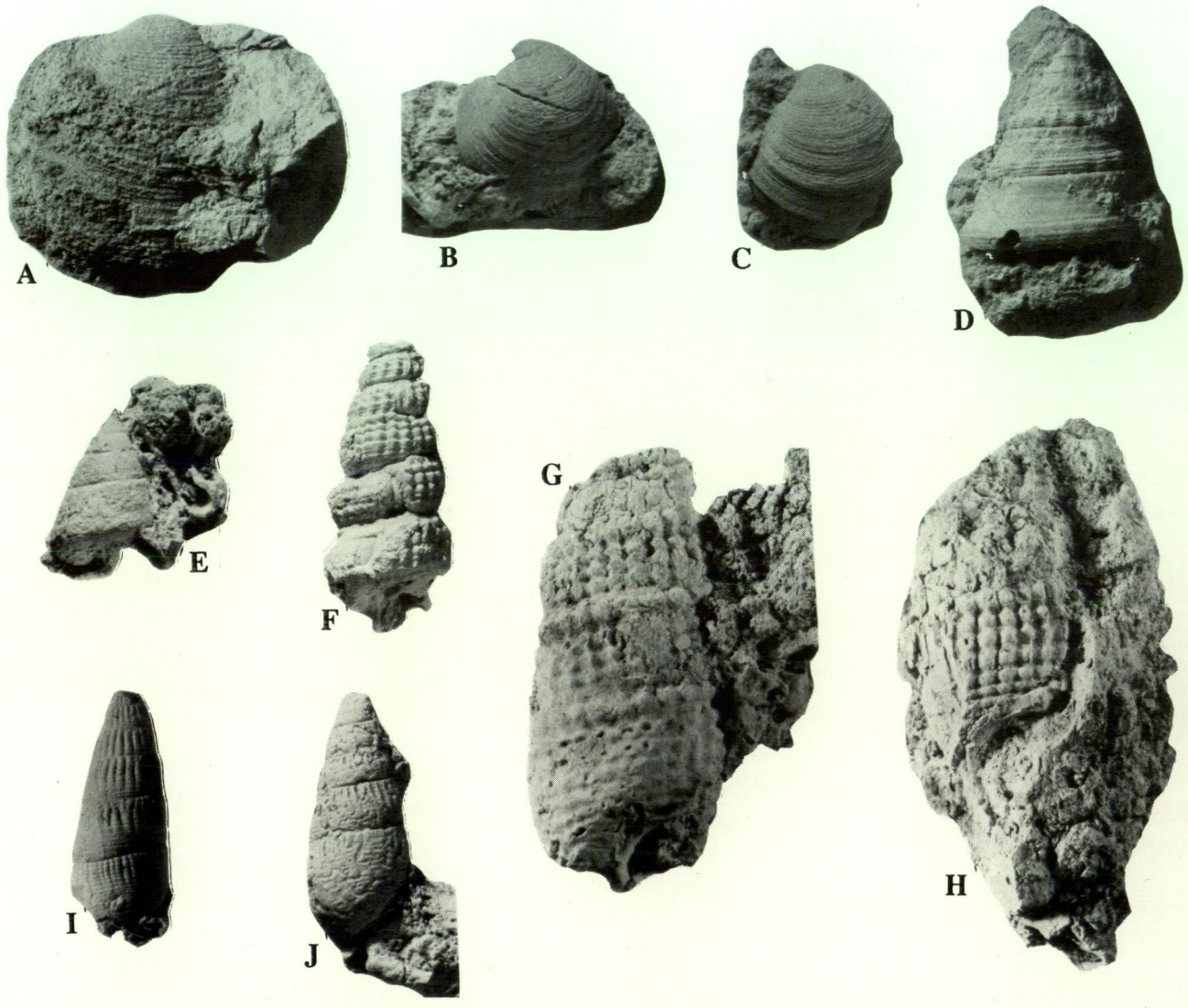

Figure 10 Bivalves and gastropods from the Poivre Formation, Middle Miocene, Barrow Island, W.A.: A, *Ventricolaria* (?) sp., 82.474a, x1; B,C, *Dosinia (Austrodosinia)* (?) sp, 82.530a, x1; D, *Trochus (Trochus)* cf. *maculatus* Linnaeus, 82.476, x1; E, *Thalotia* sp., 82.498a, x1.5; F, *Cerithidea* (?) sp., 82.601a, x1; G,H, potamidid gen. et sp. indet., 82.558a,d, x1; I,J, *Rhinoclavis (Rhinoclavis)* cf. *fasciata* (Brugière), 82.499, x1.

transverse costae (poorly preserved). Internal characters unknown. Height about 22, length 22, inflation (both valves) 11 mm.

Remarks

In size, shape and as far as can be seen, sculpture, the species resembles the extant Indo-West Pacific *Circe sulcata* Gray. Generic confirmation would depend on knowledge of the internal characters.

***Dosinia (Austrodosinia* ?) sp.**

Figures 10B,C

Material

WAM 82.530 (2). Two incomplete LVs.

Distribution

Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description

A small, suborbicular and inflated species of *Dosinia* with elevated, strongly prosogyrate umbones and incurved beaks; lunule short, deep; escutcheon long, well-defined by an angulation; sculpture of fine, crowded, low transverse riblets; no radial sculpture visible; ventral margin not crenulate. Other internal characters unknown. Height 17.5, length about 17, inflation (one valve) 5.5 mm.

Remarks

The two specimens to hand are small and

possibly immature. Tentative assignment to the subgenus *Austrodosinia* is based on the angular margin of the escutcheon; confirmation, would depend on knowledge of the internal characters. The present species is not unlike a species of *Dosinia* in the Late Eocene Merlinleigh Sandstone of the Carnarvon Basin, but differs in its more elevated umbones.

Class Gastropoda Cuvier

Family Trochidae Rafinesque

Trochus (Trochus) cf. *maculatus* Linnaeus, 1758

Figure 10D

Material

WAM 82.476 (1). One incomplete shell.

Distribution

Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description

A medium-sized species of *Trochus* s.s. with a strong, composite, spiral rib above the suture; whorls somewhat plicate toward the apex; periphery bluntly rounded; spiral sculpture becomes obsolete abapically; growth striae fine, strongly prosocline; spire angle about 45°. Apical, apertural and basal characters unknown. Height about 37, maximum diameter about 32 mm.

Remarks

In shape and sculpture, the single available specimen resembles the extant, Indo-West Pacific species *T. (T.) maculatus* Linnaeus. *T. maculatus* occurs in the Pliocene of Java and Guam (Ladd 1966) and a related form is recorded from the Miocene of Japan (Itiogawa *et al.* 1981). Positive determination of the present species would require the collection of further material.

Trochus (s.l.) sp.

Material

WAM 82.565 (2). Two incomplete shells.

Distribution

Barrow Island, locality 6. Poivre Formation, Middle Miocene.

Description

A medium-large species of *Trochus* with an elevated, slightly concave spire; base of each whorl defined by a projecting carination, which is weakly plicate toward the apex, rounded and slightly expanded on the last whorl; whorls individually concave, the last with a shallow spiral depression at the adapical third; apical angle about 45°; base apparently umbilicate. Whorls more or less smooth apart from strongly prosocline growth striae. Apertural characters unknown. Height about 52, maximum diameter about 39 mm.

Remarks

This is a distinctly weakly sculptured species, referred tentatively to *Trochus* from the apparent presence of an umbilicus on one of the two specimens.

Thalotia sp.

Figure 10E

Material

WAM 82.498 (2). Two incomplete shells.

Distribution

Barrow Island, locality 2. Poivre Formation, Middle Miocene.

Description

A medium-sized species of *Thalotia* with stepped whorls and well impressed, linear sutures; sculpture of fine, close spiral threads on the spire and base; apertural characters unknown. Height 15, maximum diameter 11 mm.

Remarks

Without details of the columella, it is not possible to assign the species to a subgenus.

Family Turbinidae Rafinesque

Angaria cf. *tyria* (Reeve, 1842)

Material

WAM 65.742 (1), 82.532 (1). An internal mould and an incomplete juvenile shell.

Distribution

Barrow Island, locality 11 (65.742 from "Barrow Island surface"). Poivre Formation, Middle Miocene.

Description

A species of *Angaria* with a sculpture of low, spaced, spiral ribs bearing low, transverse scales; sutural ramp with about three spaced spirals; peripheral shoulder offset by an enlarged composite spiral rib, below which a further six spirals are visible; others not preserved. Basal characters unknown. Height 39, maximum diameter 55 mm.

Remarks

In form and sculpture, the species resembles the extant Western Australian *Angaria tyria* (Reeve) (Wells and Bryce 1985: 40, pl.6, fig.59). *A. tyria* is recorded from the Roe Calcarenite of the Eucla Basin by Ludbrook (1978). Evidence favouring a Pliocene age for that formation is presented by Kendrick *et al.* 1991: 424).

The genus *Angaria* is referred to the Turbinidae following Marshall (1979) and Hickman and McLean (1990).

Turbo (Marmarostoma) sp.

Material

WAM 82.477 (1), 82.478 (1), 82.479 (1), 82.508 (1), 82.533 (1), 82.577 (2). One juvenile shell, four internal moulds, two opercula.

Distribution

Barrow Island, localities 1, 10, 11, 15. Poivre Formation, Middle Miocene.

Description

A medium-sized species of *T. (Marmarostoma)* with convexly rounded whorls and moderately elevated spire; sculpture of spirtal threads, those at the shoulder and immediately above it being stronger than the others. Internal side of operculum flat, exterior convex and possibly pustulose. Height about 75, maximum diameter about 65 mm.

Remarks

The available material, comprising a shell, internal moulds and opercula, is referred provisionally to one species, but confirmation is required from other better preserved specimens.

Phasianella sp.

Material

WAM 82.510 (1), 82.535 (1). Two shells.

Distribution

Barrow Island, localities 10, 11. Poivre Formation, Middle Miocene.

Description

A small (juvenile?) species of *Phasianella* with rounded whorls and elevated spire. Height 8, maximum diameter 3.7 mm.

Remarks

The genus is assigned to the Turbinidae, following Hickman and McLean (1990).

Family Rissoidae Gray

Rissoid gen. et sp. indet.

Material

WAM 82.512. One shell.

Distribution

Barrow Island, locality 10. Poivre Formation, Middle Miocene.

Description

A small, incomplete shell of "rissoid" form with an elevated spire, incised sutures and cancellate sculpture. Apertural and other characters unknown. Height about 5, maximum diameter about 3 mm.

Remarks

The familial assignment is tentative and requires confirmation.

Family Tornidae Sacco

Tornid gen. et sp. indet.

Material

WAM 82.534 (1), 82.584 (1). Two shells

Distribution

Barrow Island, localities 8, 11. Poivre Formation, Middle Miocene.

Description

A small discoidal shell with rapidly-enlarging whorls, resembling a species of *Vitrinella*; spire low, whorls smooth, sutures impressed. Basal and apertural features unknown. Height 5.0, maximum diameter 9.6 mm.

Remarks

Generic determination of the species would require the collection of further material.

Family Potamididae H. and A. Adams

Cerithidea (?) sp.

Figure 10F

Material

WAM 82.586 (1), 82.601 (2). Three incomplete shells.

Distribution

Barrow Island, localities 8, 17. Poivre Formation, Middle Miocene.

Description

A medium-sized species of cerithioidean gastropod, with numerous, convexly-rounded whorls and impressed sutures; sculpture of strong, close, axial costae cut by about four spiral grooves on each spire whorl, producing a strongly cancellate surface; varixed at growth pauses; aperture rounded. Other characters unknown. Height (estimated) 58, maximum diameter about 20 mm.

Remarks

The strongly cancellate sculpture and rounded whorls suggest a species of *Cerithidea* related to *C. obtusa* (Lamarck), which ranges from Miocene to Recent in the Indo-West Pacific region (Ladd 1972). The fossil species is more strongly sculptured than Lamarck's species; further material is required for positive determination. In modern seas, the species of *Cerithidea* are associated usually with inshore mangrove environments.

Vicarya (?) sp.

Material

WAM 75.965 (1). One incomplete shell.

Distribution

Barrow Island, locality 5. Poivre Formation, Middle Miocene. An internal mould (WAM 81.1529) devoid of external characters but with a tapered, concave outline to the spire, from the Trealla Limestone of the Gnargoo Range, Lyndon River district, may be conspecific with the present species.

Description

Part of the spire of a medium-sized, subulate, cerithioidean shell with a tapered, concave spire and numerous, flattened, turreted whorls and lightly impressed sutures; sculpture of apical whorls unknown; at diameters of 7–9 mm, the sculpture comprises four spiral ribs, of which those above and below the sutures are nodulose and more prominent than the others; between the two median ribs is a wider space bearing close, microscopic spiral threads; at diameters 9–15 mm, the adapical and abapical ribs become relatively enlarged and more nodulose, the former developing short, stout, projecting spines, about 12 to each whorl. Aperture unknown. Height 60+, maximum diameter 20 mm (fragment).

Remarks

The single specimen to hand is damaged somewhat and is assigned to the genus *Vicarya* Archiac and Haime subject to confirmation from better material. The main evidence in support of this conclusion is the clear presence of distinct, spinose projections from the adapical rib of the developed whorls. The genus is widespread in Miocene faunas of the Indo-West Pacific region (e.g. Kanno *et al.* 1980), but has no known living representative. It appears to be unrecorded hitherto from Australia.

Potamidid gen. et sp. indet.

Figures 10G, H

Material

WAM 82.558 (4). Four incomplete shells.

Distribution

Barrow Island, locality 4. Poivre Formation, Middle Miocene.

Description

A large cerithioidean gastropod with moderately to slightly inflated whorls, sculptured with strong spiral chords, eight on the last whorl and four on the penultimate whorl; spirals crossed by close, strong axials producing a strongly beaded surface which persists to the last whorl; the subsutural spiral is wider than the others and bears low spines directed adapically; whorls weakly and irregularly varicose; aperture higher than wide with an external varix and a short, thick, parietal denticle. Other characters unknown. Height (estimated) about 90, maximum diameter about 30 mm.

Remarks

This large and distinctive species is referred to the Potamididae on account of its heavy, granose sculpture, which recalls that of some species of the genus *Terebralia* Swainson. It appears however to lack the columellar plait of that genus, but the incomplete nature of the material makes for some uncertainty in that regard.

Family Cerithiidae Férussac

Cerithium (?) sp.

Material

WAM 82.538 (1). One fragmentary shell.

Distribution

Barrow Island, locality 11. Poivre Formation. Also, ?Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description

Part of the spire (three whorls) of a medium sized cerithiid gastropod with about ten strong,

rounded, axial plicae on each whorl; plicae interrupted below the suture and randomly aligned from whorl to whorl; secondary sculpture of numerous fine, spiral threads; suture linear, impressed, undulating around the plicae. Height unknown, maximum diameter 14 mm.

Remarks

The distinctive sculpture suggests an affinity with the genus *Cerithium* Bruguière, but confirmation would require the collection of further material. This or a very similar species occurs in the Trealla Limestone of the Gnargoo Range.

Rhinoclavis (Rhinoclavis) cf. *fasciata* (Bruguière, 1792)

Figures 10I, J

Material

WAM 82.481 (2),82.499 (1). Three incomplete shells.

Distribution

Barrow Island, localities 1, 2. Poivre Formation, Middle Miocene.

Description

A medium sized *Rhinoclavis* s.s. with slightly convex, turreted whorls and linear, impressed sutures; sculpture of close axials, becoming obsolete on the last whorl; crossed by fine spiral threads; columella short, anterior canal recurved; whorls weakly varicose. Height about 44, maximum diameter about 16 mm.

Remarks

In its subdued sculpture and proportions the present species resembles closely the extant and variable *R. (R.) fasciata* (Bruguière), differing however in the shorter columella. Because of adherent matrix, no details from within the aperture can be seen. *R. (R.) fasciata* is recorded (as *R. procera* (Kiener)), from Miocene and younger beds on Guam, Saipan and Viti Levu by Ladd (1972); it is common in the Pleistocene beds of Barrow Island and in modern faunas of adjacent waters.

Rhinoclavis (Rhinoclavis) sp.

Figures 11A, B

Material

WAM 82.480 (4). Four fragmentary shells.

Distribution

Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description

A medium-sized species of *Rhinoclavis* (s.s.) with turreted slightly inflated whorls; sculpture of the spire whorls predominantly axial, strong, becoming obsolete on the last whorl; there is one strong spiral rib below the suture and three weaker spirals on the spire whorls; about eight spirals on the last whorl, extending over the base; whorls weakly varicosed; anterior canal recurved, short, close to the base. Other characters unknown. Height (estimated) 55, maximum diameter about 20 mm.

Remarks

The affinities of the species appear to lie with the group of strongly sculptured *Rhinoclavis* species exemplified by *R. (R.) sinensis* (Gmelin). A species near both *R. sinensis* and the Barrow Island material has been recorded from the Late Miocene of Eniwetok Atoll by Ladd (1972: 34, pl. 8, fig. 11).

Rhinoclavis (Proclava) sp.

Figures 11C–F

Material

WAM 82.536 (9). Nine fragmentary shells.

Distribution

Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description

A medium-sized *Proclava* with numerous moderately convex whorls and deeply impressed sutures; a prominent varix is present opposite the outer lip. Columella short, obscured within; anterior canal short, oblique, not recurved; sculpture of numerous, close, strong, rounded axials that are disjunct at the sutures, which lie within a groove; four spiral ribs encircle the penultimate whorl, ten on the last whorl, forming nodules at the points of intersection with the axials. Height (estimated) 48, maximum diameter about 17 mm.

Remarks

The present species bears a more rugose sculpture than the extant *R. (P.) kochi* (Philippi) of Western Australia and elsewhere in the Indo-West Pacific region. The subgenus is well-represented in Miocene and younger deposits of the region (Houbrick 1978).

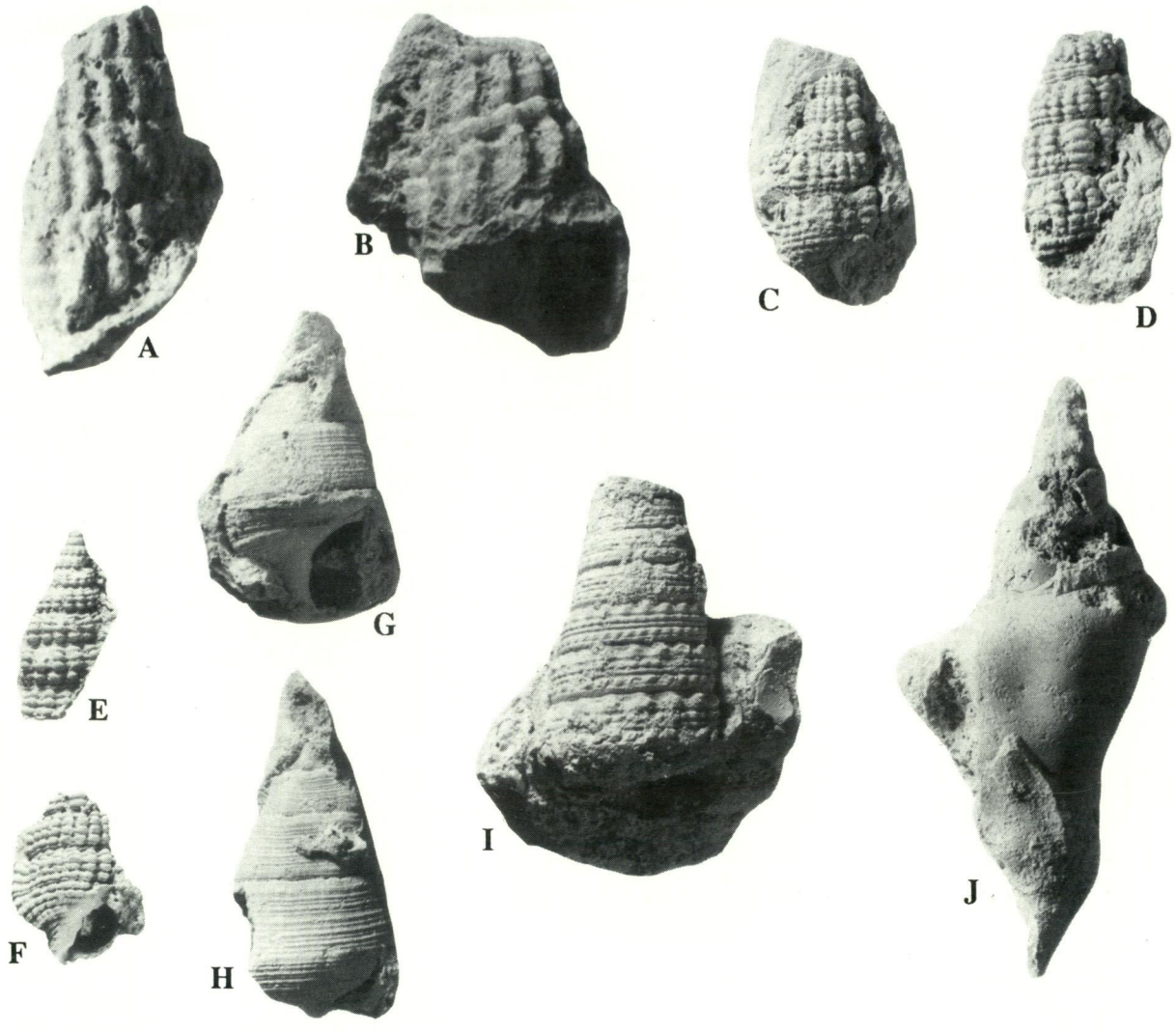

Figure 11 Gastropods from the Poivre Formation, Middle Miocene, Barrow Island, W.A.: A,B, *Rhinoclavis (Rhinoclavis)* sp., 82.480c,d, x1; C–F, *Rhinoclavis (Proclava)* sp., 82.536c,e,h,i, x1.5, except 82.536c which is x1; G,H, cerithiid gen. et sp indet., 82.506, x1; I, *Campanile* sp., 82.506, x1; J, *Strombus (Tricornis)* aff. *maximus*, 82.567. All x1.

Semivertagus sp.

Material

WAM 82.482 (1), 82.513 (1). Two fragmentary shells.

Distribution

Barrow Island, localities 1, 10. Poivre Formation, Middle Miocene.

Description

A small, turreted species of *Semivertagus* with slightly convex whorls and linear impressed sutures; base narrowly rounded; whorls sculptured with narrow, evenly-spaced, incised, spiral striae, six on the penultimate whorl and ten on the last whorl; aperture small, transversely oblique, becoming a little detached posteriorly; anal sinus well-defined; columella short. Other characters unknown. Height (estimated) 22, maximum diameter 6 mm.

Remarks

The limited available material suggests a species related to *S. subcalvatus* Tate from the Plio-Pleistocene of southern Australia (Ludbrook 1971, 1978). The present species differs from Tate's in its fewer, regularly spaced spiral striae. Specific determination would require the collection of further material.

Cerithiid gen. et sp. indet. A

Figures 11G, H

Material

WAM 82.483 (2), 82.537 (1).

Distribution

Barrow Island, localities 1, 11. Poivre Formation, Middle Miocene.

Description

A large, thick-shelled rather wide species of Cerithiidae with flattened spire whorls; the last whorl with a low rounded shoulder; base narrow; whorls occasionally weakly varicose; sutures linear, irregular, well defined; sculpture of numerous, thin, spiral chords, extending onto the base; aperture elliptically oblique with a persistent internal rib located a little below the suture; columella truncate. Other characters unknown. Height (estimated) 90, maximum diameter about 38 mm.

Remarks

This is a distinctive cerithiid, the generic location of which remains uncertain. Further material may allow a more positive determination.

Cerithiid gen. et sp. indet. B

Material

WAM 82.484 (1). One fragmentary shell.

Distribution

Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description

The specimen is the abapical portion of a large species of Cerithiidae with slightly concave whorls and weak nodulations above and below the sutures; the nodulations become obsolete on the last whorl; a weak spiral sculpture of thin, close striae; aperture damaged but apparently higher than wide. Other characters unknown. Height (estimated) 80, maximum diameter about 25 mm.

Remarks

The distinctive slightly concave, outline of the last and penultimate whorls and the subdued sculpture are difficult to relate to any known certhioidean taxa. Positive identification would depend on the collection of further material.

Family Campanilidae Douvillé

Campanile sp.

Figure 11I

Material

WAM 65.747 (1), 75.966 (1), 75.967 (1), 82.506 (1), 82.515 (1), 82.539 (1), 82.560 (1), 82.587 (3), 82.1332 (1). Four incomplete shells and seven fragmentary internal moulds.

Distribution

Barrow Island, localities 5, 8, 9, 10, 11. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description

A large subulate cerithioidean shell, consistent with species of *Campanile*, spire straight-sided, with numerous closely-coiled, rather flattened whorls; sutures offset by a shallow groove; columella thick; siphonal canal short, recurved; sculpture of the apical whorls unknown; brephic whorls with a well developed sculpture of four spiral chords, that below the suture being the widest and bearing low, wide plications which may be directed adapically; second chord narrower and gemmate with two beads for each single plication of the superior chord; third chord narrower still and simple; fourth chord intermediate in width between the first and second and gemmate like the second; sculpture of the mature whorls poorly indicated but apparently of weak, spaced spirals more or less smooth. Height 170, maximum diameter 50 mm (estimated dimensions of the largest specimen).

Remarks

The fragmentary nature of the available material precludes a more complete description of this large and distinctive species but is sufficient to indicate its location within the Tethyan genus *Campanile* Bayle, type species *Cerithium giganteum* Lamarck from the Lutetian of the Paris Basin. Compared with *"Telescopium" gigas* Martin (Martin 1881–1883, tab. vi, fig. 4, tab. vii, figs 1, 2) from the Miocene or Pliocene of Java, which appears from the figure to be a *Campanile*, the present species shows a more nodulose and diverse sculpture. *C. triseriale* Basedow and *C. virginiense* Ludbrook from the Pliocene of South Australia (Ludbrook 1971) differ from the present species in sculptural details.

An unnamed species of *Campanile* was recorded from the Middle Miocene Nullarbor Limestone by Ludbrook (*in* Lowry 1970) and by Ludbrook (1971) and has been collected subsequently from the Colville Sandstone, an inshore facies-equivalent of the Nullarbor Limestone (WAM 88.707, 88.917). Known only from internal moulds, this species features a straight-sided spire of size and proportions not unlike the Barrow Island specimens. However, without knowledge of the external and other characters, it is not possible at present to establish whether these two Australian Miocene forms represent one or two species.

Fossil occurrences of *Campanile* (s.l.) have been reviewed by Cossmann (1906), Wrigley (1940), Delpey (1941) and Jung (1987); other records are from the Eocene of North India (Vokes 1937), Hungary (Strauz 1966), Argentina (de Garcia and Levy 1977) and West Africa (Adegoke 1977).

Spengler (1923) has recorded a species from the Late Cretaceous of Assam and a possible early "Campanile" from the Cenomanian of Dorset was described by Abbass (1973).

Akopyan (1976) has erected a new genus, *Procampanile*, type species *Nerinea ganesha* Noetling, 1897, for Cretaceous campanilids from Armenia and elsewhere and including *"Cerithium (Fibula?)" inauguratum* Stoliczka from the Ariyalur and Trichinopoly Groups of South India. Akopyan's genus is ancestral to the Tertiary *Campanile* (Sohl 1987).

Campanilid history is marked by an explosive evolutionary radiation beginning in the Paleocene and peaking during the Middle Eocene with the appearance of numerous species throughout the Tethyan Realm (i.e. India to western Europe) and extending to the Americas and West Africa. From the Miocene and subsequently, the genus appears to be restricted to the Indian Ocean (Java, southern and western Australia). The present Barrow Island – Gnargoo Range material provides the first records of the genus from tropical Australia.

On the pronounced post-Eocene decline of *Campanile*, Houbrick (1984a) has suggested that a factor in this process may have been competition from mesogastropods of the family Strombidae, a group which expanded greatly in shallow, tropical and subtropical seas during the later Tertiary. The geographic ranges of modern *Campanile* and Strombidae are almost totally mutually exclusive (Wells and Bryce 1985). However, Jung (1987) has expressed reservations on Houbrick's conclusion, "...because an assemblage in a particular tropical marine niche is usually quite diverse and represents an equilibrium of complex interactions and interdependencies" (Jung 1987:895). The extended trophic diversity shown by the molluscs of both the Poivre Formation and Trealla Limestone, in which *Campanile* is associated with at least seven strombid species, lends support to Jung's view.

From anatomical studies of *C. symbolicum* Iredale, the sole extant species of the genus, Houbrick (1981a, 1984a, 1988) has confirmed the cerithioidean affinities of *Campanile* and the validity of the family Campanilidae Douvillé; this has been raised subsequently to suprafamilial rank (as Campaniloidea Douvillé) by Houbrick (1989). The recent decline to relictual status of *Campanile* and its contraction into southwestern Australian seas is parallelled by the history of the cerithiodean *Diastoma* lineage (Ludbrook 1971; Houbrick 1981b, 1984b).

Family Xenophoridae Troschel

Xenophora (Xenophora) sp.

Material

WAM 82.585 (2), 82.603 (1). Three internal moulds.

Distribution

Barrow Island, localities 3, 8. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description

Internal moulds of a broadly-conical, trochiform species of *Xenophora* (s.s.); upper surfaces and sides of the whorls show large, regularly spaced depressions, corresponding to the attachment areas of the shell; basal surface smooth, slightly convex, with a weak peripheral rim. Height about 22, maximum diameter about 41 mm.

Remarks

The material is poorly preserved, but as far as can be assessed, appears to have an affinity with the extant West Pacific *X. (X.) pallidula* (Reeve), which Martin (1905) records from the Miocene of Java. Martin's material has been reexamined by Ponder (1983:42) who assigns it, with qualification, to three species. One specimen, from Tjkarang, Java (Miocene) is "with reasonable certainty" considered to represent *X. pallidula*.

Internal moulds of identical form to the above occur in the Trealla Limestone of the Gnargoo Range and appear to represent the same species; they have been utilized in preparing this description.

Family Strombidae Rafinesque

Strombus (Tricornis) aff. *maximus* Martin

Figure 11J

Material

WAM 82.567 (1). An incomplete internal mould retaining the anterior extremity of the shell.

Distribution

Barrow Island, locality 7. Poivre Formation, Middle Miocene.

Description

An internal mould of a medium-sized species of *Tricornis*, biconic-fusiform, spire elevated, about equal to half the total height; last whorl shouldered and bearing three spaced axial plicae of increasing prominence with growth, presumed to correspond to spines on the shell; siphonal canal long, recurved dorsally. Other characters unknown. Height 88, maximum diameter about 40 mm.

Remarks

Though fragmentary, the specimen retains sufficient characters to indicate a species related to *S. (T.) maximus* Martin from the Miocene Tjilanang Beds of Java (Abbott 1960). The Barrow Island specimen is appreciably smaller than Martin's type and may be immature. The subgenus ranges from Early Miocene to Recent in the Indo-West Pacific region. Abbott (1960) suggests that *S. (T.) maximus* may be ancestral to the extant *S. (T.) thersites* Swainson.

Strombus (Tricornis ?) sp. A.

Figure 12A

Material

WAM 82.518 (1), 82.519 (1), 82.541 (1), 82.550 (2), 82.566 (3), 82.572 (2), 82.595 (4), 82.596 (3), 82.681 (1). Eight fragmentary shells and ten internal moulds.

Distribution

Barrow Island, localities 7, 8, 10, 11, 12, 14. Poivre Formation, Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description

A medium-sized species of *Strombus*, shell biconic, spire comprising two fifths of the total height; last whorl tapered; aperture long, narrow; outer lip unknown; whorls convex, stepped and shouldered with axial plication, about ten on the last whorl; secondary sculpture of numerous, fine, close spiral threads, about 27 on the last whorl, becoming more prominent on the base; columella callus present but poorly preserved.

Internal moulds with strongly stepped whorls, weakly to moderately plicate at the shoulders, which are rather thickened; below the shoulders, the whorl outline is flattened or a little concave, particularly on the last whorl. Height 70, maximum diameter (without outer lip) 31 mm.

Remarks

The available material is poorly preserved but indicates a species of *Strombus*, possibly of the subgenus *Tricornis* Jousseaume.

Strombus (Tricornis ?) sp. B.

Material

WAM 82.520 (1). One internal mould.

Distribution

Barrow Island, locality 10. Poivre Formation, Middle Miocene.

Description

The internal mould of a medium-sized species of *Strombus* with spire probably less than half the total height and stepped, shouldered whorls that are very weakly plicate; shoulder of whorls thickened, anterior to which is a broad concavity; base tapered. Outer lip and other characters unknown. Height about 113, maximum diameter about 55 mm.

Remarks

This specimen, referred tentatively to the subgenus *Tricornis*, is the largest strombid in the present collection. Clarification of its identity would depend on the collection of further material.

Strombus (Lentigo) sp. A

Figures 12B, C

Material

WAM 82.491 (1), 82.493 (1), 82.501 (1), 82.562 (1). Three incomplete shells and one internal mould.

Distribution

Barrow Island, localities 1, 2, 3d. Poivre Formation, Middle Miocene.

Description

A medium-sized, apparently biconic species of *Lentigo* with spire about equal to two fifths of the total height; spire whorls strongly shouldered and bearing about eleven strong, spinose, axial plicae on the shoulders per whorl; fine, close, spiral threads encircle the spire and base; base tapering with a row of low, axial plicae at the anterior fourth; aperture long, narrow, narrowing anteriorly; outer lip missing. Height (estimated) 63, maximum diameter about 37 mm.

Remarks

This is a distinctive species of *Lentigo*, which does not appear in Abbott's (1960) monograph of the Indo-West Pacific Strombidae and which may be undescribed. Compared with *S. (L.) preoccupatus* Finlay from the Miocene of Java and Borneo, the present species differs in the much-reduced basal sculpture and greater number of shoulder plicae per whorl.

Strombus (Lentigo ?) sp.

Material

WAM 82.554 (1). One internal mould.

Distribution

Barrow Island, locality 3b. Poivre Formation, Middle Miocene.

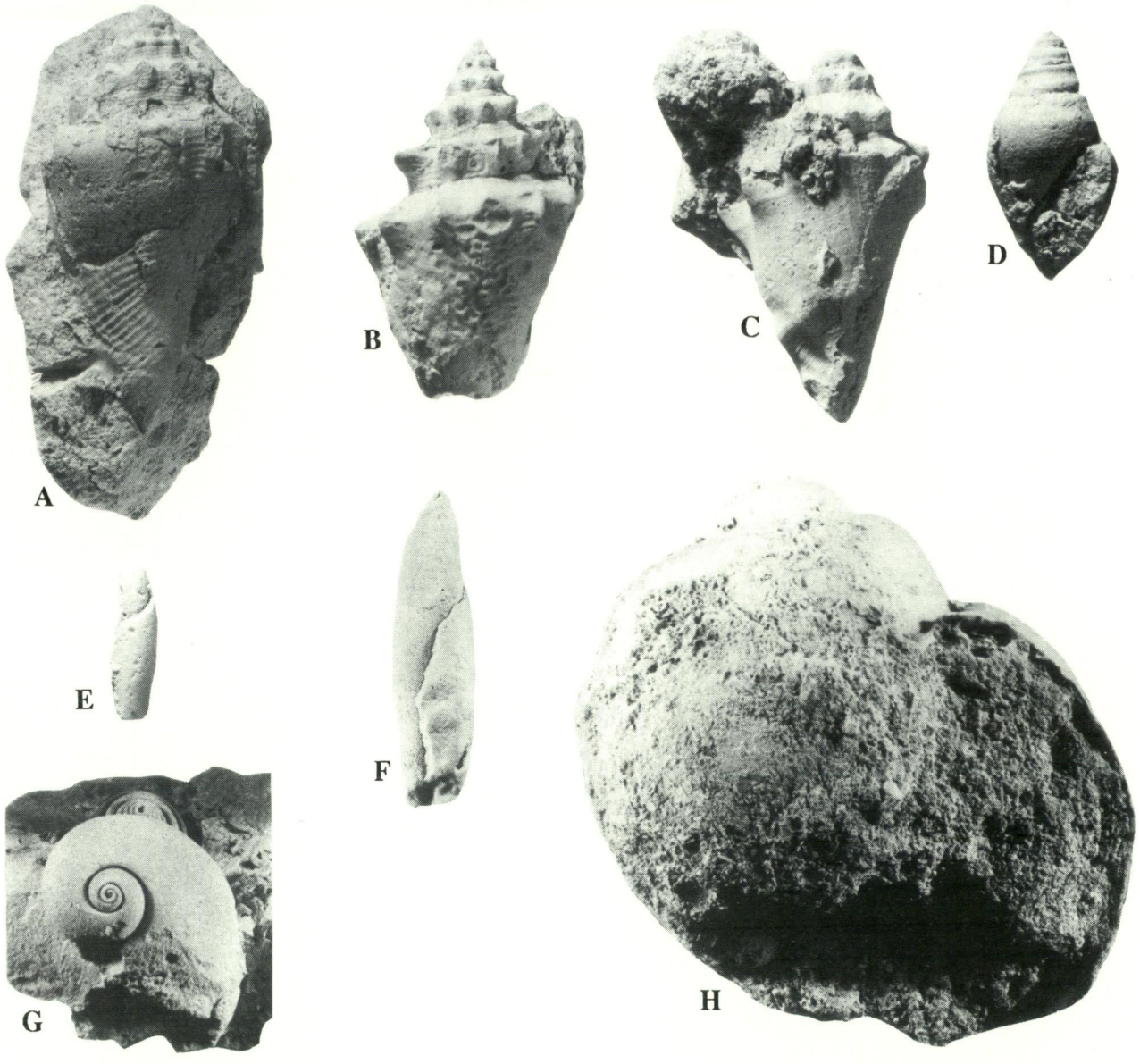

Figure 12 Gastropods from the Middle Miocene of the Gnargoo Range and Barrow Island, W.A.: A, *Strombus (Tricornis)* (?) sp. A, 82.518, x1, Poivre Formation, Barrow Island; B,C, *Strombus (Lentigo)* sp. A, 82.501, 82.493 x1, Poivre Formation, Barrow Island; D, *Strombus* (s.l.) sp., 82.597, x1, Poivre Formation, Barrow Island; E, *Terebellum terebellum* (Linnaeus), 82.589, x1.5, Poivre Formation, Barrow Island; F, *Terebellum terebellum* (Linnaeus), 81.1592b, x1, Trealla Limestone, Gnargoo Range, Lyndon River district; G, *Mammilla* cf. *melanostoma* (Gmelin), 81.1613, x1, Poivre Formation, Barrow Island; H, *Ampullina butleri* sp. nov., 65.782a, holotype, x1, Poivre Formation, Barrow Island.

Description

The internal mould of a medium-sized species of *Strombus*, subfusiform, the spire about equal to half the total height, whorls stepped, thickened below the suture and somewhat flattened. Outer lip and other characters unknown. Height about 60, maximum diameter about 28 mm.

Remarks

The single available specimen is poorly preserved but its general proportions recalls *Strombus (Lentigo) micklei* Ladd from the Late Miocene of Bikini (Ladd 1972). Positive determination would require the collections of further material.

***Strombus* (s.l.) sp.**

Figure 12D

Material

WAM 82.597 (1). One internal mould.

Distribution

Barrow Island, locality 8. Poivre Formation, Middle Miocene.

Description

A biconic, internal mould of a medium-sized strombiform shell, with a moderately elevated, stepped spire, about equal to half the total height; spire whorls channelled below the sutures; last whorl concave at the periphery; base roundly tapered; aperture elliptical, oblique. Other characters unknown. Height 37, maximum diameter 21 mm.

Remarks

The specimen is referred tentatively to the Strombidae from its general proportions and the slight concavity of the periphery of the last whorl, a feature noted in many species of this group. Assignment to a subgenus is not possible without further material.

Rimella sp.

Material

WAM 82.542 (1). One fragmentary shell.

Distribution

Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description

The specimen comprises part of the last three whorls of a small possibly juvenile *Rimella*; sculpture of about 20 axial costae on the spire whorls, extending partly onto the base of the last whorl; intercostal spaces bear close spiral threads, eleven on the penultimate and over 20 on the last whorl; outer lip thickened and extended to join the posterior canal at least to the antepenultimate whorl. Height (estimated) 18, maximum diameter about 8 mm.

Remarks

The species appears to be related closely to the extant *R. cancellata* (Lamarck) but differs in the presence of stronger spiral sculpture. Positive determination to species would require the collection of further material.

Family Seraphidae Gray

Terebellum terebellum (Linnaeus, 1758)

Figures 12E, F

Material

WAM 82.559 (1), 82.589 (2), 82.610 (1). Four internal moulds.

Distribution (Australia only)

Barrow Island, localities 4, 5, 8. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Nullarbor Limestone, Middle Miocene. Pleistocene beds of Barrow Island (this paper). Modern seas: tropical Australia; North West Cape to Queensland.

Description

The moulds, none of which is complete, indicate an evolute, cylindrical shell of few whorls; spire short, acuminate; last whorl relatively long; suture strongly defined, descending abruptly and encompassing about half the total height; greatest width toward the anterior. Height (estimated) 24, maximum diameter about 5 mm.

Remarks

In all retained characters (general proportions, position and strength of suture) the specimens resemble closely the extant Indo-West Pacific *Terebellum terebellum* (Linnaeus) and are referred provisionally to that species. Barrow Island specimens are small and presumably are juveniles; mature specimens measuring 57 x 14 mm have been collected from the Trealla Limestone of the Gnargoo Range and are considered to be conspecific. One of these is figured (Figure 12F).

T. terebellum is recorded from the Miocene of Kerala, Java and Saipan (see Jung 1974 for references). The species also occurs in the Middle Miocene Nullarbor Limestone of the Eucla Basin (author's identification, WAM 6054, 63.33). Harris (1897:218) records a "*Seraphs*" sp. from the "Tertiary of the Nullarbor Plains, South Australia", which may also represent the same species.

Family Cypraeidae Rafinesque

Zoila sp.

Material

WAM 82.549 (1). One incomplete shell.

Distribution

Barrow Island, locality 12. Poivre Formation, Middle Miocene.

Description

A medium-sized, ovate species of *Zoila* with a prominent dorsal hump; maximum diameter at about the middle; anterior extremity of aperture thickened and projecting; spire slightly exposed, revealing a weak sutural "scar". Other characters unknown. Height about 52, maximum diameter about 32 mm.

Remarks

The single specimen to hand is exposed only

partially on a piece of hard crystalline limestone, which masks all parts of the base, aperture, fossula, etc. What is visible suggests a species not unlike *Zoila kendengensis* Schilder from the younger Kendeng Beds (Plio-Pleistocene) of East Java (Schilder 1941:174–176, fig. 1). The genus is represented in the Miocene Quilon Beds of Kerala South India (Dey 1962) and has recently been recorded from the late Early Miocene Chipola Formation of Florida (Dolin 1991)

Cypraea spp.

Remarks
The collection includes two incomplete shells and six internal moulds of what appear to be five species of *Cypraea*. In all cases, preservation is poor and specific determination is unlikely without the collection of better-preserved specimens. Registration numbers and localities only are given.

Cypraea sp. A.

Material
WAM 82.485 (1). One incomplete shell.

Distribution
Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Cypraea sp. B.

Material
WAM 82.578 (1). One internal mould.

Distribution
Barrow Island, locality 15. Poivre Formation, Middle Miocene.

Cypraea sp. C.

Material
WAM 82.486 (1). One incomplete shell.

Distribution
Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Cypraea sp. D.

Material
WAM 82.504 (1), 82.579 (1), 82.590 (1). One fragmentary shell and two internal moulds.

Distribution
Barrow Island, locality 5, 8, 15. Poivre Formation, Middle Miocene.

Cypraea sp. E.

Material
WAM 82.487 (2). Two internal moulds.

Distribution
Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Family Naticidae Forbes

Natica sp.

Material
WAM 82.516 (1), 82.571 (1), 82.1069 (1). Two incomplete shells and one internal mould.

Distribution
Barrow Island, localities 5, 6, 10. Poivre Formation, Middle Miocene.

Description
A small, subglobose, naticiform shell resembling a species of *Natica*, spire moderately elevated, whorls smooth; suture linear, impressed; apertural and umbilical features unknown. Height about 20, maximum diameter about 19 mm.

Remarks
The available material suggests a species related to the extant *Natica marochiensis* Gmelin, recorded from the Indo-West Pacific region by Ladd (1977) in deposits ranging from Lower Miocene to Pleistocene. The Barrow Island specimens lack the subsutural plicae on the later whorls that characterise Gmelin's species. Further material is required to confirm the generic location of the species.

Mamilla cf. *melanostoma* (Gmelin, 1791)

Figure 12G

Material
WAM 75.964 (1), 82.599 (1). One incomplete shell, one incomplete internal mould.

Distribution
Barrow Island, localities 5, 8. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, Middle Miocene.

Description
A large species of *Mamilla*, the last whorl produced anteriorly, descending; spire short, rather blunt; umbilicus obscured. Height 42, maximum diameter 39 mm.

Remarks

In general form, the species resembles the extant *Mamilla melanostoma* (Gmelin), which occurs widely throughout the Indo-West Pacific region from Miocene time to the present (Ladd 1977). Diagnostic areas of the umbilicus, columella and parietal area are obscured in the present material; specific confirmation would require the collection of further specimens.

Ampullina butleri sp. nov.

Figures 12H, 13A–C

Material

Holotype WAM 65.782a. From the Poivre Formation, Barrow Island, Western Australia. Cliff at north end, 40'–60' (= 12–18 m) from the top (= Cape Malouet). Paratypes, WAM 65.782b–d (3), 82.488 a–e (5), 82.500a,b (2), 82.540a,b (2); twelve specimens. Other material. WAM 75.962a,b (2), 75.963a,b (2), 82.490a,b (2), 82.591 (1); seven specimens.

Distribution

Barrow Island. Locality 1 (type locality), localities 2, 5, 8. Poivre Formation, Middle Miocene.

Diagnosis

A very large *Ampullina* with stepped whorls, deeply channelled sutures and a strong callus around the inner lip and umbilicus; spirally striate above the periphery. Distinguished from *Ampullina bandongensis* (Martin) by its open umbilicus and absence of spiral striation below the periphery.

Description

Shell very large for the genus, robust, globose – ovate, usually higher than wide but occasionally the reverse; spire short; last whorl comprising up to about nine tenths of the total height; apex not wholly intact on any specimen but apparently paucispiral, subacute, smooth, turbinate; sutures deeply channelled; whorls flattened a little at the sutures, with a rounded shoulder and flattened at the periphery, sometimes flattened above the periphery resulting in a weak peripheral angulation; base abbreviated, with a small to medium-sized umbilicus; aperture poorly indicated on most specimens but apparently hemi-circular to reniform, oblique and a little flaired at the outer lip, which, from the growth striae, is sinuate and prosocline, narrowing adapically and rather more expanded abapically; inner margin oblique, almost straight; columella thickened and basally concave where it grades into the anterior margin, the latter thickened externally by a strong rimate callus which extends across the umbilical and parietal areas to connect with the posterior margin of the aperture; margin of the callus well demarcated; whorls bear fine, uneven spiral striation above the periphery, being smooth below except for very fine, sinuate growth striae and growth-pause marks.

Dimensions

Specimen	*Height*	*Height of aperture*	*Max. diam*	*No. whorls*
WAM 65.782a (holotype)	95.5mm*	78.4mm	87.5mm	5.5+(est.)
WAM 65.782c (paratype)	71.8mm*	67.9mm	79.1mm	5+(est.)
WAM 82.488a (paratype)	84.5mm	63.9mm	75mm (est.)	5+(est.)
WAM 82.488c (paratype)	50.0mm	41.3mm	49.7mm	4.5+(est.)
WAM 82.500a (paratype)	64.9mm	?	60mm (est.)	5 (est.)
WAM 82.500b (paratype)	86.5mm*	67.3mm	69mm (est.)	5+(est.)

* denotes apex damaged; original heights probably about 5 mm extra. The largest specimen to hand, WAM 75.962a, has a maximum diameter of 111 mm; it is an internal mould with a deformed spire.

Remarks

Ampullina butleri somewhat resembles the variable *A. bandongensis* (Martin) from the Middle Miocene (Rembangian-Preangerian Stages) of Java (Martin 1879–1880: 82, 83, pl. 13, figs 15, 16; Shuto, 1977, Table 1), differing in the presence of an open umbilicus and in the restriction of spiral sculpture to the whorls above the periphery. It appears also to attain a much greater size than Martin's species. From its exceptional size and slightly flattened last whorl, the present species resembles superficially shells of the genus *Lunatia* Gray but the characters of the inner lip and the deeply channelled sutures preclude its location there.

A. butleri is a common, widely distributed and characteristic species of the Poivre Formation; however most of the material comprises internal moulds and well preserved specimens are uncommon. The species is at present known only from Barrow Island. A medium-sized naticid (WAM 87.505) from the Trealla Limestone of the Gnargoo Range appears to represent a distinct species and probably another genus.

Etymology

The species is named after Mr W.H. Butler in appreciation of his many contributions to Natural History studies of Barrow Island, this included.

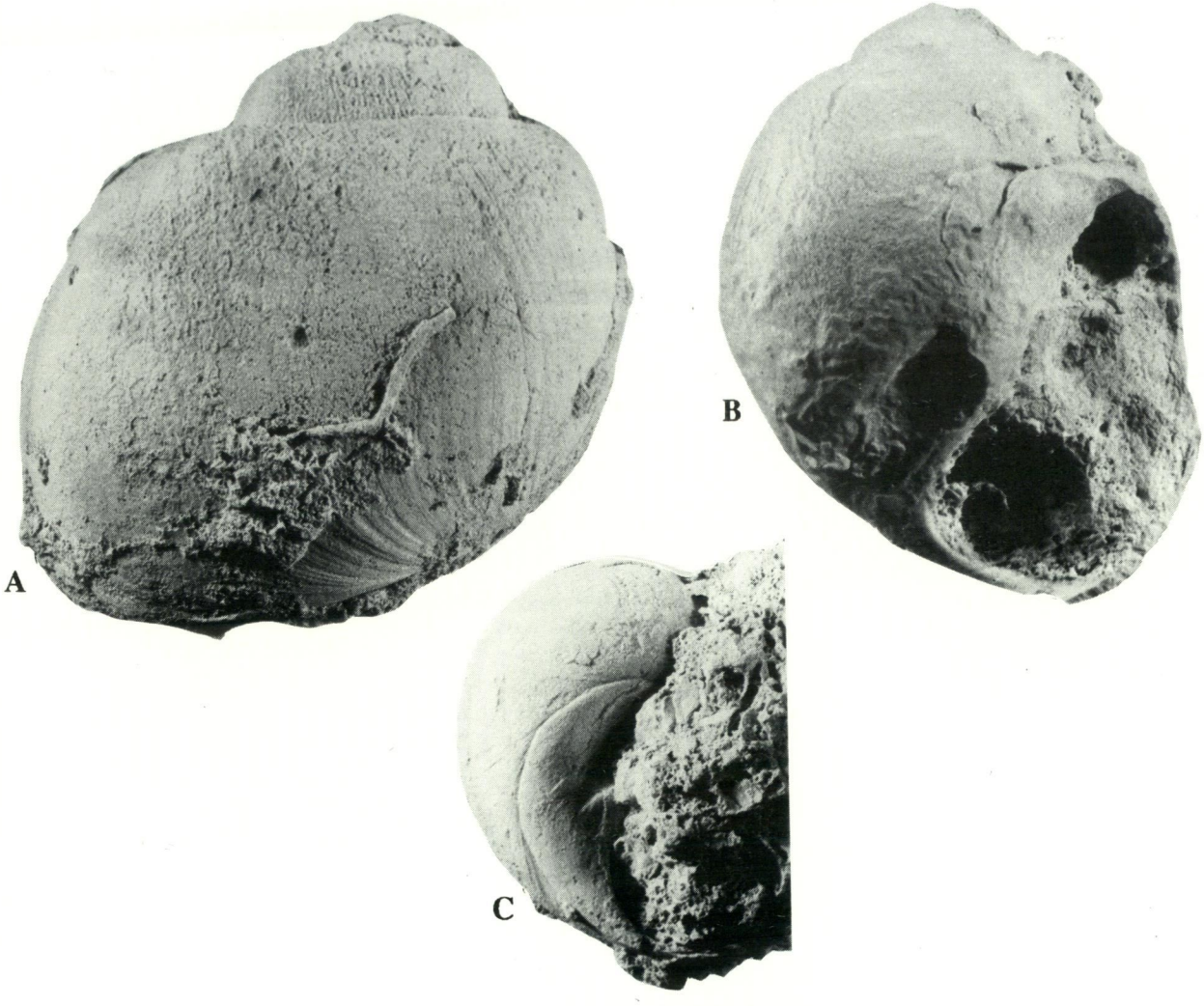

Figure 13 *Ampullina butleri* sp. nov., from the Poivre Formation, Barrow Island: A, 65.782a, holotype; B, 82.500b, paratype; C, 82.500a, paratype. All x1.

Naticid gen. et sp. indet.

Material
WAM 82.490 (2). Two internal moulds.

Distribution
Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description
Small naticiform internal moulds with a short, acute spire and rounded, rapidly enlarging whorls, flattened subsuturally; sutures impressed; aperture wide. Other characters unknown. Height about 28, maximum diameter about 23 mm.

Remarks
In general form, the species resembles *Ampullina depressa* (Lamarck), type species of the genus *Ampullina* Bowditch, from the Lutetian of the Paris Basin. The genus seems to have become extinct by the close of Miocene time. Positive determination of the present material would require the collection of further material.

Family Cassidae Latreille

Cassid gen. et sp.indet.

Material
WAM 82.580 (1), 82.593 (1). Two internal moulds.

Distribution
Barrow Island, localities 8, 15. Poivre Formation, Middle Miocene.

Description
The two sub-globose, cassidiform moulds indicate shells with low, rather broad spires, shouldered a little below the suture on the last whorl; base tapered; last whorl bearing impressions of the denticulate, infolded outer lip.

Remarks

Positive determination would require the collection of further material.

Family Columbellidae Fischer

Pyrene sp.

Material

WAM 82.517 (1), 82.538 (1). Two incomplete shells.

Distribution

Barrow Island, localities 10, 11. Poivre Formation, Middle Miocene.

Description

A small biconic-subfusiform species of *Pyrene* with a short, acuminate, stepped spire and an enlarged last whorl, which features a concave subsutural ramp; columella short, straight; sculpture of weak axial plicae below the sutures and fine, close, spiral striae, intensified on the base. Height 11, maximum diameter 7 mm.

Remarks

The limited available material may represent immature shells only but indicates a species related to the group of Indo-West Pacific *Pyrene*, which includes *P. turturina* (Lamarck), *P. testudinaria* (Link) and *P. scripta* (Lamarck). Positive determination would require the collection of further material.

Family Melongenidae Gill

Melongena sp.

Figures 14A,B

Material

WAM 65.767 (1), 82.492 (1). Two incomplete shells.

Distribution

Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description

A medium-sized, solid, subfusiform and strongly spinose species of *Melongena*; spire short, equal to about two-sevenths of the total height, with wide, stepped, angular-shouldered whorls, each bearing about ten prominent, hollow, variceal spines; on the early whorls the spines are directed more or less normal to the axis but on mature specimens, those on the last whorl become directed adapically;

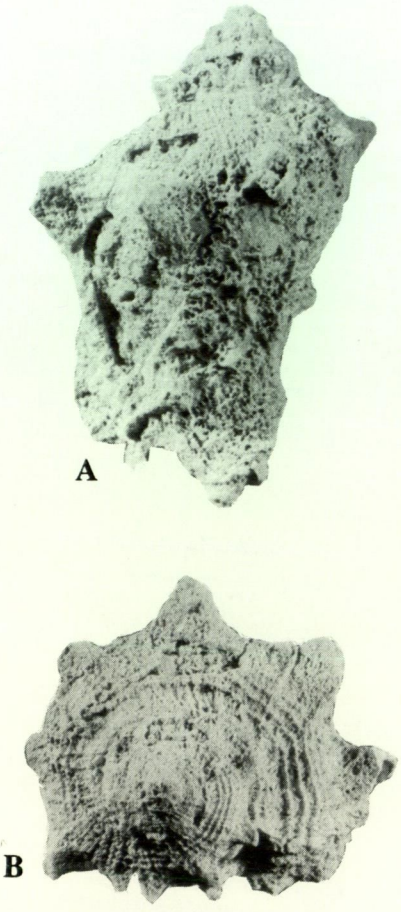

Figure 14 *Melongena* sp., from the Poivre Formation, Barrow Island, A, B, 65.767, x1.

aperture higher than wide; columella smooth (without plaits), apparently concave but partly obscured by matrix; base with a well-developed fasciole; sculpture on the spire of irregular spiral threads of which a more prominent group of three occupies the centre of the subsutural ramp; basal sculpture of spaced, spiral threads, alternately weak and strong; a row of prominent spines encircles the base, a little anterior of centre; weak colabral growth striae cross the spirals. Height (estimated) 85, maximum diameter between spines 48, across spines 75 mm.

Remarks

The present species is related to *Melongena gigas* Martin from the Miocene of Java and other areas of the Indo-West Pacific (see Popenoe and Kleinpell 1978, pl. 5, figs 69, 70), differing in its stronger, more uniformly distributed spiral sculpture. In Martin's species, the sutural ramp bears two prominent spiral chords only. From the limited material to hand, *M. gigas* appears to attain a larger size than the Barrow Island species. Further material is required for full specific determination.

Family Olividae Latreille

Olivid gen. et sp. indet.

Material
WAM 82.521 (1). One fragmentary shell.

Distribution
Barrow Island, locality 10. Poivre Formation, Middle Miocene.

Description
The spire and part of the last whorl of a small olivid gastropod; spire elevated, with a distinct groove above the suture, all overlain by a callus; traces of spiral grooving visible on the base; apertural height equal to about half the total height. Height about 16, maximum diameter about 7 mm.

Remarks
The species appears to be referable to the subfamily Ancillinae and possibly to the genus *Amalda* Adams. Positive determination would require the collection of further material.

Family Costellariidae MacDonald

Vexillum (Costellaria) sp.

Material
WAM 82.522 (1). One incomplete shell.

Distribution
Barrow Island, locality 10. Poivre Formation, Middle Miocene.

Description
A small, elongate species of *V. (Costellaria)*, the spire whorls bearing a cancellate sculpture of axial and spiral ribbing, the former a little stronger than the latter; spirals over-ride the axials; base with spirals only. Height (estimated) 25, maximum diameter 8 mm.

Remarks
The single incomplete specimen may be a juvenile. It indicates a species not unlike the extant Indo-Pacific species *V. (C.) obeliscus* (Reeve), which Ladd (1977) records from Pliocene deposits on Fiji and Timor. Positive determination must await the collection of further material.

Family Volutidae Rafinesque

Lyria (s.l.) sp.

Material
WAM 82.543 (1). One incomplete shell.

Distribution
Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description
An incomplete small (juvenile ?) specimen of a species of *Lyria*, with about 22 (estimated) axial costae of equal strength on the last whorl, terminated anteriorly at a prominent spiral fasciole. Apertural characters unknown. Height about 33, maximum diameter about 14 mm.

Remarks
The limited available material is inadequate for sub-generic and specific determination. Darragh (1989:211) records poorly preserved specimens of a species of *Lyria* from the Trealla Limestone of the Cape Range and compares these with *L. edwardsi* d'Archiac (=*L. jugosa* Sowerby) from the Miocene of Java.

Family Conidae Fleming

Conus sp. A

Material
WAM 82.494 (1). One incomplete internal mould.

Distribution
Barrow Island locality 1. Poivre Formation. Also, Gnargoo Range, Lyndon River district. Trealla Limestone, ? Nullarbor Limestone. Middle Miocene.

Description
The single specimen is poorly preserved but indicates a small species of *Conus* with a short, broad spire and a strong anterior taper. It resembles closely two better-preserved specimens (WAM 81.1616, 81.1617) from the Trealla Limestone of the Gnargoo Range, which have about six whorls in a height of 27 mm. Height (of Gnargoo Range specimen) 27, maximum diameter 17 mm.

Remarks
The specimens represent a short, moderately wide species similar to the extant *C. coronatus* Gmelin or *C. miliaris* Hwass *in* Bruguière 1792, sometimes referred to the subgenus *Virroconus* Iredale. An internal mould of similar proportions (WAM 75.30) from the Nullarbor Limestone near Forrest, agrees in the few retained characters with the Trealla Limestone material and is possibly conspecific. Positive determination would require the collection of further material.

Conus sp. B

Material
WAM 82.545 (1). One internal mould.

Distribution
Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description
A small species of *Conus* with a short spire and a strong anterior taper; shoulder of the last whorl angularly rounded. Height 21, maximum diameter 13 mm.

Remarks
The species differs from *Conus* sp. A in being more tightly coiled, with about 7 whorls in a diameter of 13 mm.

Conus sp. C

Material
WAM 82.544 (1). One internal mould retaining traces of the spire shell.

Distribution
Barrow Island, locality 11. Poivre Formation, Middle Miocene.

Description
A small species of *Conus* with a short spire and a strong anterior taper; apex acuminate; shoulder of the last whorl well rounded. Height 16, maximum diameter 10 mm, whorls 5.

Remarks
The species is distinguished from *Conus* sp. B by its slightly more attenuate base and more rounded shoulder. It may be a juvenile specimen.

Conus sp. D

Material
WAM 82.598. An internal mould in hard, pinkish-brown, crystalline limestone.

Distribution
Barrow Island, locaity 8. Poivre Formation, Middle Miocene.

Description
A medium-sized *Conus* with a very short spire and low, sub-acute apex; strongly tapered anteriorly. Whorls about eight, height 60 mm, maximum diameter (a little anterior of shoulder) 32 mm (est.)

Remarks
The specimen is indeterminable to species but in size and proportions resembles a number of medium-sized Indo-Southwest Pacific species of *Conus*, such as *C. planorbis* Born, *C. flavidus* Lamarck and *C. virgo* Linnaeus.

Family Turridae Swainson

Turrid gen. et sp. indet.

Material
WAM 82.495 (1). One fragmentary shell.

Distribution
Barrow Island, locality 1. Poivre Formation, Middle Miocene.

Description
Shell small, with elevated spire (apex missing); sutures impressed; whorls five, convex, sculptured with two strong spiral chords and three or four weaker spirals between the cords. Height (estimated) 17, maximum diameter 6 mm.

Remarks
In general form and sculpture, the specimen resembles a turrid of the genus *Tomopleura* Casey (Drilliinae) but positive generic determination would require examination of better preserved material, including, in particular, the protoconch and aperture.

Class Echinoidea Leske

Order Cidaroida Claus

Family Cidaridae Gray

Eucidaris sp.

Figures 15A–C

Material
WAM 82.252 (20 specimens).

Distribution
Barrow Island, locality 7. Poivre Formation, Middle Miocene.

Description
This genus is only represented by spines. These are relatively short, squat and fusiform, broadening at about one-third length from collar, then narrowing to apex, before flaring slightly. They are

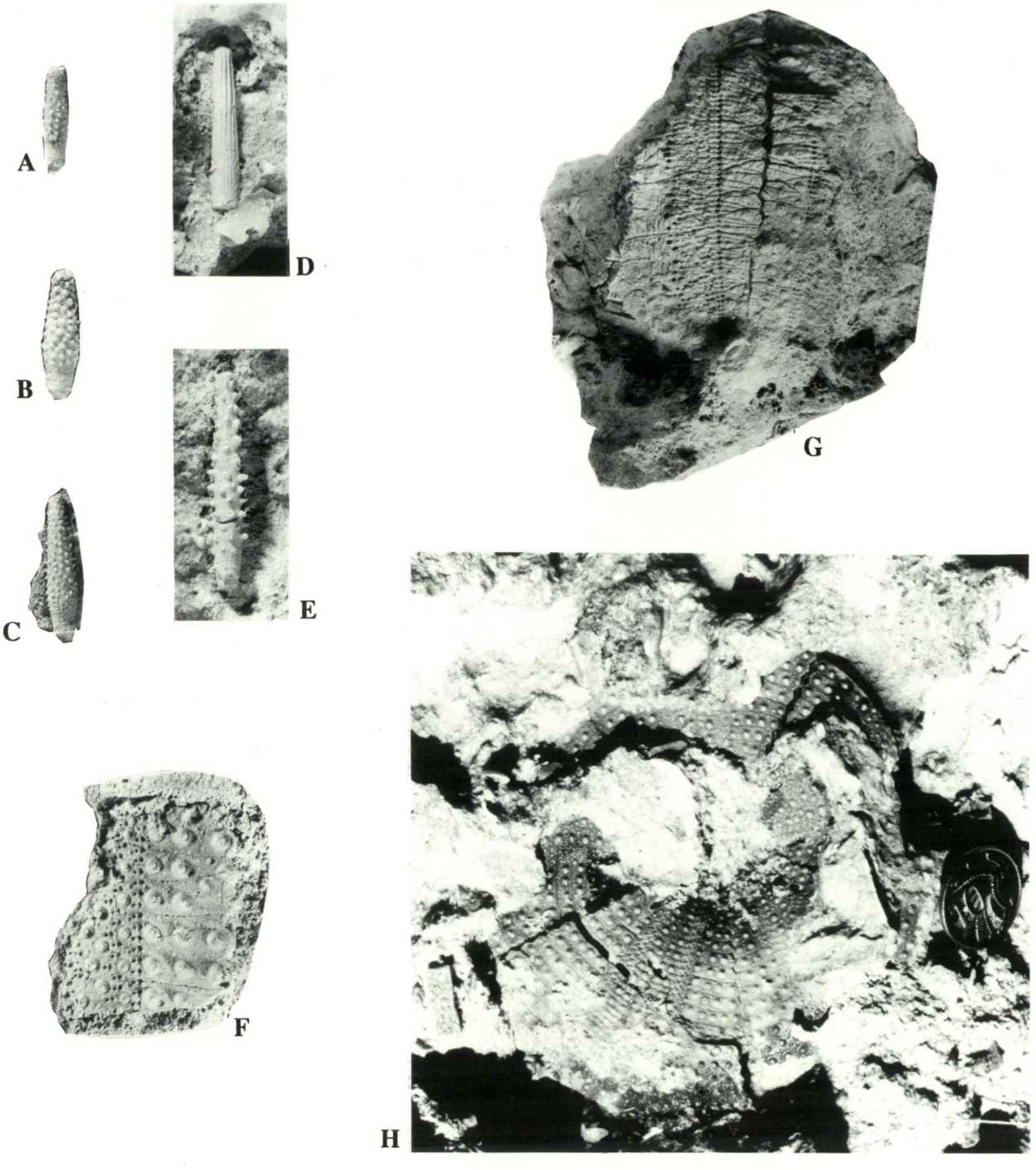

Figure 15 Echinoids from the Poivre Formation, Middle Miocene, Barrow Island, W.A.: A–C, *Eucidaris* sp., 82.252a–c; D, *Phyllacanthus* cf. *clarkeii* Chapman and Cudmore, 82.336; E, *Goniocidaris* cf. *murrayensis* Chapman and Cudmore, 82.335; F–H, *Tripneustes pregratilla* sp. nov., F, 82.322, G, 82.292, H, field photograph of specimen at The Ledge, Barrow Island. All x1.

covered by small tubercles that are variable in their intensity and distribution, ranging from closely spaced small tubercles aligned in parallel rows, to larger, more prominent tubercles more haphazardly arranged.

Remarks

Living species of *Eucidaris* occur off northern Australia, and fossil species occur commonly in the Late Oligocene to early Miocene of southern Australia (Philip 1963). The Barrow Island species probably represents an undescribed species. It differs from other fossil species in its more prominent tubercles which form more irregular rows than the other southern Australian form, *Eucidaris strombilata* Fell *felli* Philip.

Phyllacanthus cf. *clarkeii* Chapman and Cudmore, 1934

Figure 15D

Material

WAM 82.336. One spine.

Distribution

Barrow Island, locality 7. Poivre Formation, Middle Miocene.

Description

This single spine is 25 mm long and tapers gently to a rounded tip. Toward the collar faint tubercles occur. These merge into closely spaced, raised ridges toward the tip where they become more prominent.

Remarks

This form is similar to both *Phyllacanthus duncani* Chapman and Cudmore, 1934 from the Early Miocene of southern Australia and *P. clarkii* Chapman and Cudmore, 1934, from the Middle to Late Miocene of southern Australia (Philip 1963). The single specimen from Barrow Island is closer to the latter species in its possession of more prominent distal ridges.

Goniocidaris cf. *murrayensis* Chapman and Cudmore, 1934

Figure 15E

Material

WAM 82.335. One spine.

Distribution

Barrow Island, locality 5. Poivre Formation, Middle Miocene.

Description

A relatively long spine, 32 mm in length, slightly fusiform, broadening a little at one-third length, then tapering, before flaring into a crown. Bears prominent spinose tubercles arranged roughly linearly.

Remarks

This Barrow Island spine is very similar to spines of *Goniocidaris murrayensis* from the Middle Miocene of southern Australia described by Philip (1964). Although quite variable in form (see, for example, Philip 1964, Pl.66, fig.12), the Barrow Island spine could be accommodated quite easily within the range of variation shown by this species. However, as only a single spine is known, the specific assignment is qualified.

Order Temnopleuroida Mortensen

Family Toxopneustidae Troschel

Tripneustes pregratilla sp. nov.

Figures 15F–H

Material

Holotype WAM 82.326 from the Poivre Formation, "The Ledge", Barrow Island. Paratypes WAM 82.292–325, 82.327, 82.328, 82.408, 82.413 and 94.435 from same horizon and locality as holotype.

Distribution

Barrow Island, locality 5. Poivre Formation, Middle Miocene.

Diagnosis

Large species of *Tripneustes* with numerous interambulacral tubercles and irregular poriferous columns.

Description

This large species (up to 150 mm in diameter, uncrushed) was only collected in a fragmented state. One complete, broken specimen was observed, but it was not possible to collect it. Apart from its large size this species is characterised by the three parallel, but widely spaced rows of pore pairs in each half of the ambulacrum. The outer row is set farther from the middle row than it is from the inner. The pore pairs of the middle row are more irregular than the other two rows which form nearly regular columns. Ambulacral plates bear two tubercles, the outer generally being slightly smaller than the inner. Interambulacrual plates possess six irregular rows of tubercles.

Remarks

This is the first fossil record for this genus from Australia. Eight fossil species have been described. *Tripneustes pregratilla* resembles the Indian species *T. antiquus* and *T. proavia*, both described by Duncan and Sladen (1885). However, the Barrow Island form can be distinguished by its more numerous interambulacral tubercles. *Tripneustes gratilla* (Linnaeus) is a relatively common living species in Australian waters. It differs from the fossil species in its generally smaller size, less tuberculated ambulacra and more irregular poriferous columns.

Order Cassiduloida Claus

Family Echinolampadidae Kier

Echinolampas tumulus sp. nov.

Figures 16A–D

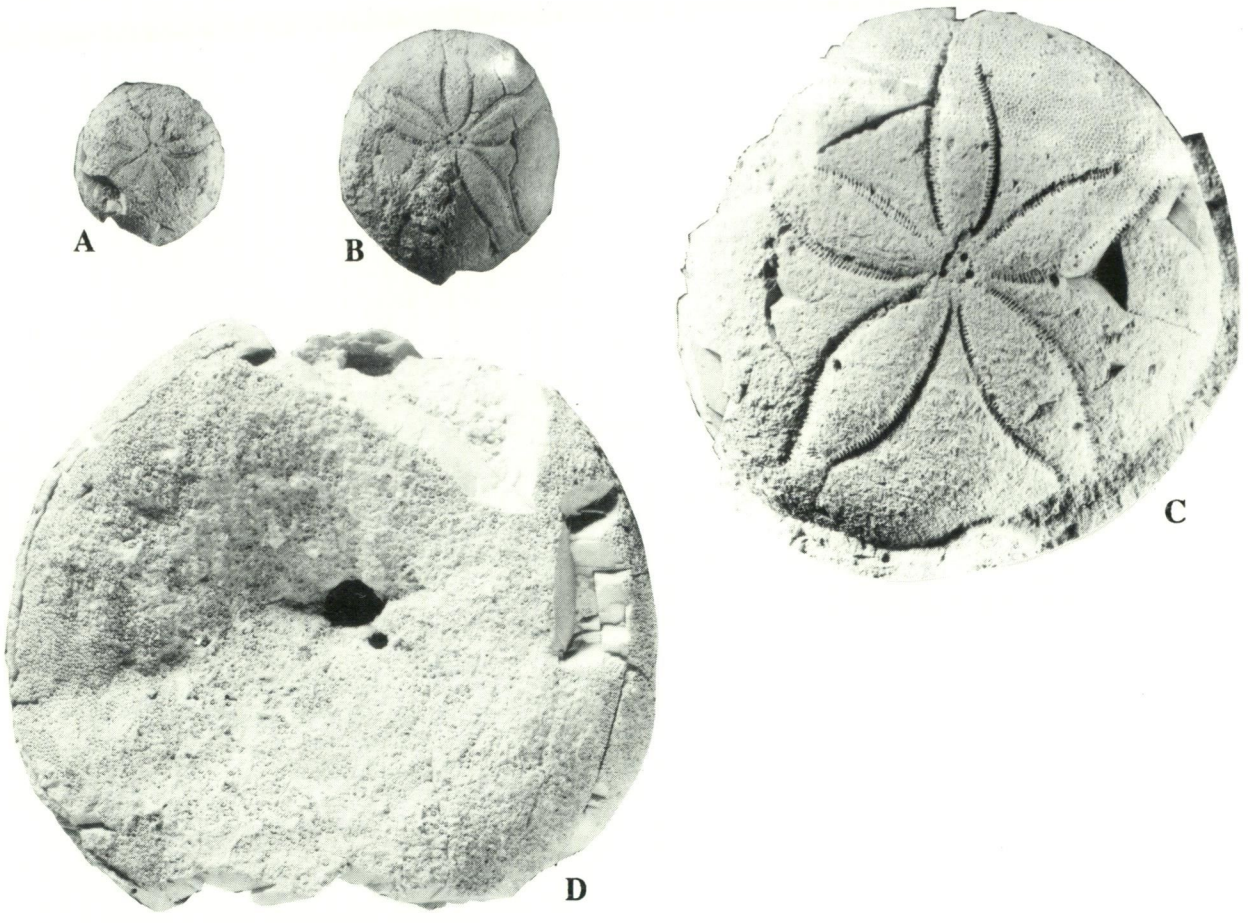

Figure 16. *Echinolampas tumulus* sp. nov. from the Poivre Formation, Middle Miocene, Barrow Island, W.A.: A, 82.223, paratype; B, 82.229, paratype; C, 82.269, holotype; D, 82.268, paratype. All x1.

Material

Holotype WAM 82.269 (Figure 16D) from the Poivre Formation, in the coastal cliff about 1 km north of Eagle's Nest, (locality 6) Barrow Island. Paratypes WAM 82.207–20, 82.222–251, 82.274, from the same horizon as the holotype in coastal cliffs at north end of Flacourt Bay (locality 3); WAM 82.259–269 from the same horizon and locality as the holotype; WAM 82.282–288 from the same horizon as the holotype near the base of the cliffs at Cape Malouet (locality 2).

Distribution

Barrow Island, localities 1–3 5, 6 and 8. Poivre Formation, Middle Miocene. Also, rarely, in the Trealla Limestone of the Gnargoo Range.

Diagnosis

Test thick, tumid in small specimens, flattening with increased test size. Petals swollen, broad, strongly constricted distally with poriferous tracts of markedly different lengths

Description

Test large, reaching up to 87mm maximum test length (TL). Test shape undergoes appreciable morphological change during ontogeny. Small specimens, up to 40 mm TL, are generally globose, with a test width between about 80% and 90%TL, and a height that varies between 55 and 75% TL; the higher values tends to occur in the smaller specimens. In largest specimens test becomes circular in outline and much flatter, with height varying between 38 to 55%TL. Mean height overall is 58.3%TL (SD=9.0; n=25). Adoral surface of test is pulvinate in small specimens; with growth it becomes flatter. Test thick, varying between 6% in small specimens and 7% in large ones.

The two rows of pore pairs in each petal exhibit a high degree of inequality of length, such that in specimens 20 mm TL poriferous tracts of ambulacra Ib, IIa, IIIa, IVb and Va are twice the length of those in ambulacra Ia, IIb, IIIb, IVa and Vb. In these smaller specimens the longer poriferous tracts increase rapidly in number of pore pairs during ontogeny, attaining up to 48 at 40 mm TL. In large specimens twice this size, poriferous tracts are relatively longer, with 55 to 66 pores pairs, and relative difference in lengths of poriferous tracts decreases, such that shorter row

is about three-quarters the length of the longer rows. Pore pairs conjugate; circular in small specimens; in large specimens outer pore tear-shaped, inner circular. Petals strongly curved, resulting in an appreciable broadening at about mid-petal length. Petals of ambulacra I, II, IV and V are similar in width, but a little wider than ambulacrum III. Extent of this curvature increases slightly during ontogeny as the petals become relatively a little broader. Overall petal width is 14.1%TL (SD=2.1; n=40). Distally the petals are constricted as the poriferous tracts curve in strongly. Interporiferous region slightly swollen in small specimens, more so in large specimens. Apical system anterior of centre in small specimens, becoming nearly central in large specimens.

Adoral surface pulvinate in small specimens, becoming flatter in larger specimens, but inclined toward sunken peristome. Peristome pentagonal in small specimens, becoming more rounded in larger specimens; decreases in relative size during ontogeny. In small specimens length varies between 11 and 15%TL; in large specimens 6 to 11%TL. Width decreases from 7 to 9%TL to 4 to 7%TL. Floscelle with well-developed bourrelets throughout ontogeny. Phyllodes narrow adorally, doubling in width aborally. Periproct transversely oval.

Remarks

Echinolampas tumulus can be clearly distinguished from the other northwest Australian Miocene species, *E. westralensis* Crespin, 1947, that occurs in the slightly older Tulki Limestone in the Cape Range. The Barrow Island species has a lower test profile at large sizes; shorter, more swollen, wider petals, the poriferous tracts of which are more unequal in length; more sunken peristome that is less ovoid in shape and is surrounded by more well developed bourrelets.

Among the species of *Echinolampas* that most closely resemble *E. tumulus*, *E. barcinensis* Lambert, from the Helvetian of Antioch, Turkey, differs in having petals that are not as distally constricted, nor as swollen. *E. hemisphericus* Agassiz, from the Pliocene of Cyprus has straighter poriferous tracts that lack the strong distal constriction, and a more sunken adoral surface with more prominent bourrelets. *E. orbignyi* Cotteau, from the Pliocene of Rhodes is similar to *E. tumulus*, but as with the preceding species it has less pronounced distal constriction of the petals. *E. kleini* (Goldfuss) from the Oligocene of Germany is superficially similar to *E. tumulus*, but again differs in having less distally constricted petals, poriferous rows that are not as unequal in length and more well-developed bourrelets. *E. scutiformis* Desmoulins, from the Langhien of France has, like *E. tumulus*, poriferous tracts of unequal length, but it differs in that the rows are straighter and also in having a more sunken peristome.

The rather dramatic morphological changes that *E. tumulus* underwent during its ontogeny, such as the diminishing tumidity of the test; changing adoral surface convexity and relative changes to lengths of the poriferous rows of the petals, are not unusual for some species of *Echinolampas*. Pronounced ontogentic changes have also been recorded in *E. posterocrassa* Gregory (McNamara and Philip, 1980b) and in *E. fraasi* de Loriol (Kier, 1957). However, in these species, rather than the test decreasing in tumidity during ontogeny, it increased. The increase in petal length with increasing numbers of pore pairs observed in *E. tumulus* has also been recorded in *E. posterocrassa* and *E. fraasi*.

Etymology

From the Latin *'tumulus'* – a gentle mound, alluding both to the shape of the test and the Roman name for the six thousand year old burial mounds known as barrows.

Order Clypeasteroida A. Agassiz

Family Clypeasteridae L. Agassiz

Clypeaster butleri sp. nov.

Figures 17A–D

Material

Holotype WAM 75.970, from the Poivre Formation at The Ledge (locality 5), Barrow Island. Paratypes WAM 75.972, 75.973, 82.271, 82.330, 94.428 and 94.430 from locality 5, and 82.412 from locality 6. Other material, 75.971, 82.270, 82.329, 94.426, 94.427, 94.429 and 94.431 from locality 5; 82.290 from locality 1; 82.256 from locality 3; 82.410, 82.411 and 82.416 from locality 6; and 82.414, 82.415, 82.1891 from locality 11.

Distribution

Barrow Island, localities 1, 3, 5, 8 and 11. Poivre Formation, Middle Miocene.

Diagnosis

Large species of *Clypeaster* with thickened, rolled margins; relatively long petals that are almost closed distally.

Description

Test large, up to 81 mm TL; subpentagonal in outline; margins slightly indented at interambulacra; slightly longer than wide, width 89–98%TL. Margin very thick, 10–17%TL thick; rolled, passing adapically to horizontal flattened

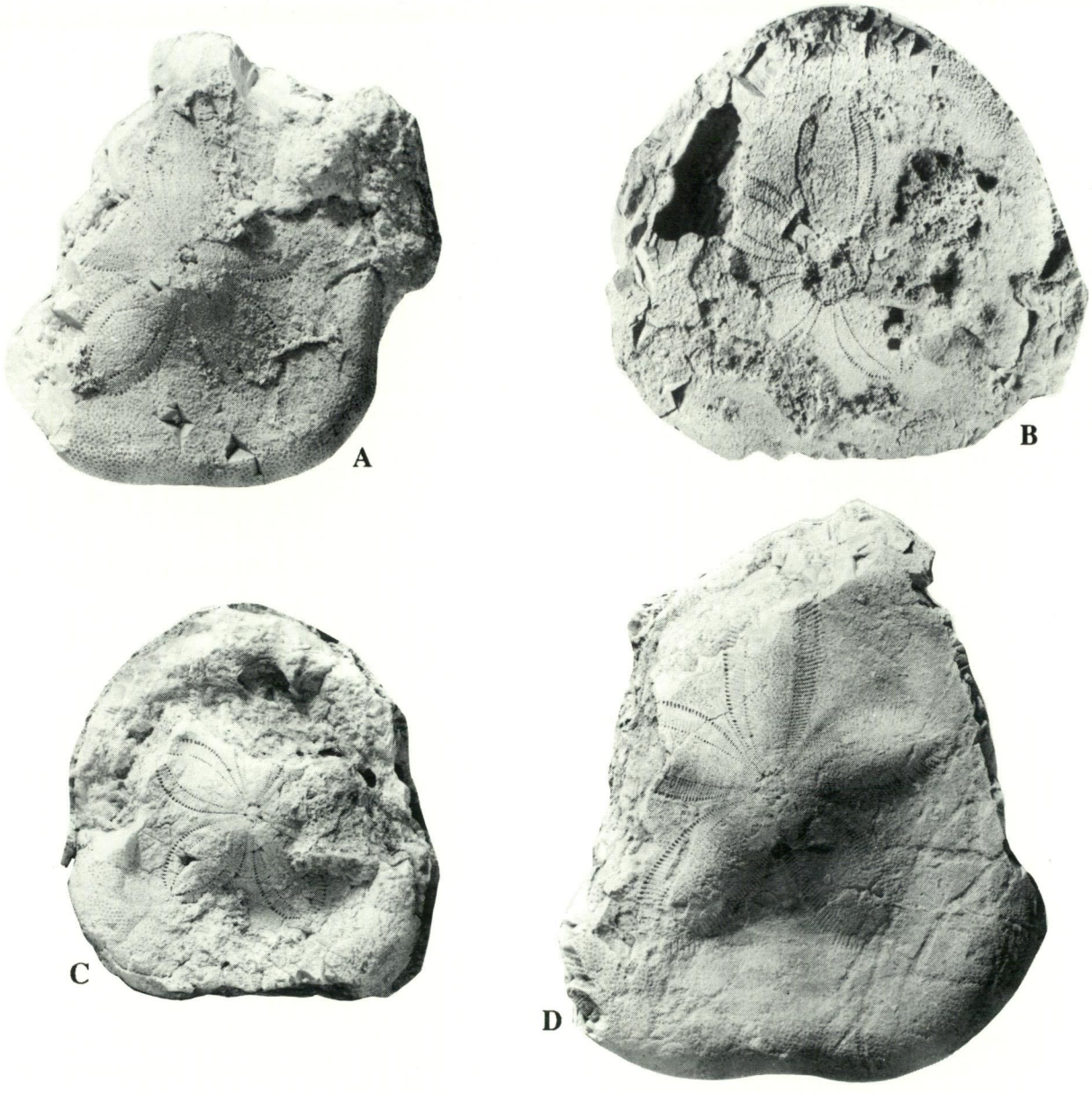

Figure 17 *Clypeaster butleri* sp. nov. from the Poivre Formation, Middle Miocene, Barrow Island, W.A.: A, 82.271, paratype; B, 82.326, paratype; C, 75.972, paratype; D, 75.970, holotype. All x1.

zone before rising to moderately inflated petaliferous region. Test thick, 3.5–6.5%TL. Petals not swollen; distally almost closed; 29–35%TL long, bearing up to 45 conjugate pore pairs, inner of which are circular, outer elongate; distance between pores increases abapically close to distal extremity of petal. Petals with a maximum width of 16–19%TL. Interporiferous zone 8–10%TL in width. Persitome small (10%TL in diameter) and sunken. Periproct small (6%TL) and set 7%TL from posterior margin.

Remarks

Another, hitherto undescribed, species of *Clypeaster* occurs in the Early Miocene Tulki Limestone in the nearby Cape Range (McNamara in prep.). *C. butleri* can be distinguished, however, by its much thicker, rolled border, relatively longer and distally more closed petals. It can also be distinguished from the only other species of fossil *Clypeaster* to have been described from Australia, the Middle to Late Miocene species *C. gippslandicus* McCoy from southern Australia, in similar ways. *C. humilis* (Leske) from the Miocene of Java (Gerth 1922) has similar petals to *C. butleri*, but it lacks the distinctive thickened rolled border of *C. butleri* and has a much thinner test.

C. butleri is similar to some of the Indian Miocene species of *Clypeaster*, in particular *C. pulvinatus* Duncan and Sladen, 1882–86. However, the Barrow Island species can be distinguished by its more divergent posterior petals and more tumid form. A living species, *C. reticulatus* (Linnaeus) has been collected from White's Beach, Barrow Island. This

species is similar to *C. butleri*, but can be distinguished by its narrower test, with less strongly swollen margins, and more deeply sunken peristome.

While few other species of *Clypeaster* possess such a thickened border as *C. butleri*, a few are superficially similar. *C. crassus* Agassiz from the Miocene of Corsica and *C. pentadactylus* Peron and Gauthier from the Miocene of Algeria each have a somewhat swollen border; however their petaliferous areas are more tumid and their pores are more widely spaced. *C. intermedius* Desmoulins from the Miocene of France and *C. isthmicus* Fuchs from the Miocene of Egypt have petals of a similar shape and size to *C. butleri*, but borders that are less swollen.

Etymology

Named after Mr W.H.Butler, who not only found the first specimens of this species, and guided us to the localities, but who also facilitated the field work upon which this study was based.

Family Fibulariidae Gray

***Fibularia* sp.**

Material

WAM 82.253–5, 82.273.

Distribution

Barrow Island, locality 5. Poivre Formation, Middle Miocene.

Remarks

These four tiny subspherical echinoids offer little opportunity for any detailed description, owing to their poor preservation. Species of this genus in Australia are in urgent need of study. At present there is one described Australian fossil species, *F. gregata* Tate, an Oligocene to Early Miocene species from southern Australia. The living western Australian species is *F. volva* Agassiz and Desor. Further material of the Barrow Island species is required before a specific assignment can be made.

Order Spatangoida Claus

Family Schizasteridae Lambert

***Schizaster (Schizaster)* aff. *compactus* Koehler, 1914**

Figures 18A–C

Material

WAM 82.275–81, 82.258, 82.1886–90.

Distribution

Barrow Island, localities 1 and 5 and 50 m south of oil well Q83. Poivre Formation, Middle Miocene. It also occurs commonly in the Trealla Limestone of the Gnargoo Range and in the Tulki Limestone of the Cape Range.

Description

A small species, reaching up to 30 mm in test length; characterised by its globose form; its near central apical system; its possession of four genital pores; its deep anterior ambualcrum III and broad, curved petals. Anterior notch is shallow and broad and bearing more than 20 pore pairs in each row, arranged in single rows. Petals are moderately impressed, the anterior pair being about twice length of posterior. Posterior of test is high and adoral surface convex. Peristome is barely sunken and labrum is weakly developed. Plastron is relatively narrow.

Remarks

Schizaster (Schizaster) aff. *compactus* is quite unlike any of the Tertiary schizasterid echinoids described from southern Australia by McNamara and Philip (1980a). The contemporaneous *S.(S.) abductus* Tate from the Morgan Limestone, South Australia has a less globose test, much more strongly developed keel in interambulacrum 5, narrower petals and more prominent labrum.

Since McNamara and Philip (1980c) described a living form from off the Dampier coast, close to Barrow Island, as *S.(S.) lacunosus* (Linnaeus), the collection of further material has demonstrated that this form should be assigned to *S.(S.) compactus* Koehler, 1914 (McNamara in press). Originally described from the Bay of Bengal, this species is superficially very similar to the Middle Miocene Barrow Island form. However, the Barrow Island form can be distinguished by its slightly narrower peripetalous fasciole; and its more posteriorly positioned peristome.

The fossil form occurs more frequently in the Trealla Limestone of the Gnargoo Range, and will be formally named and described more fully elsewhere (McNamara in prep.).

Family Loveniidae Lambert

***Breynia* aff. *carinata* d'Archiac and Haime, 1853**

Figures 18D–G

Material

WAM 65.1047, 82.289, 82.3322–4.

Distribution

Barrow Island, localities 1 and 7. Poivre Formation, Middle Miocene. It also occurs in the Trealla Limestone in the Cape Range and also in the Gnargoo Range, where it is very common.

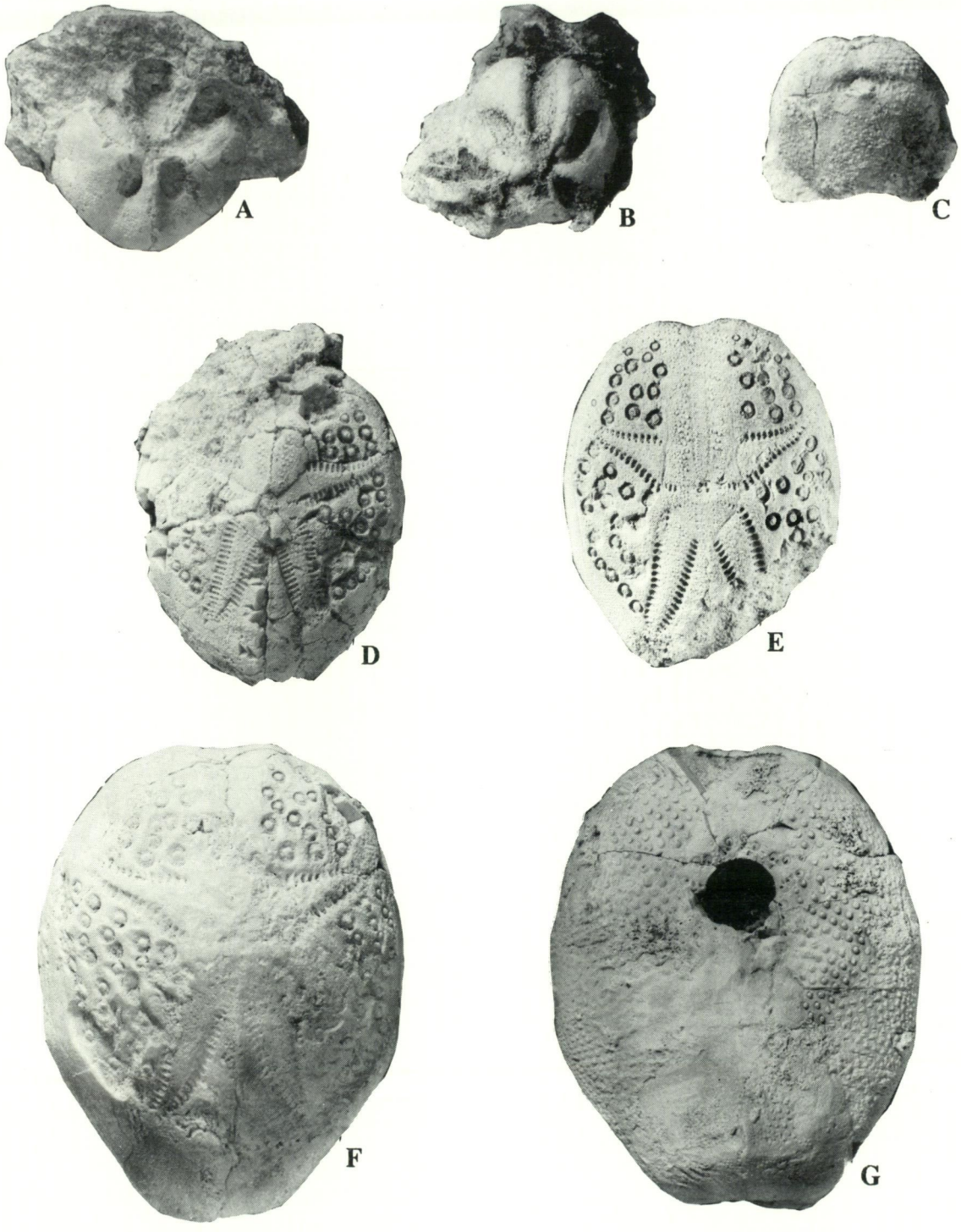

Figure 18 Echinoids from the Middle Miocene of the Gnargoo Range and Barrow Island, W.A.: A–C, *Schizaster (Schizaster)* aff. *compactus* Koehler, A, 82.280, B, 82.279, C, 82.275, Poivre Formation, Barrow Island; D–G, *Breynia* aff. *carinata* d'Archiac and Haime, D, 82.289, Poivre Formation, Barrow Island; E, 82.1726, Trealla Limestone, Gnargoo Range, Lyndon River district; F,G, 65.1047, Poivre Formation, Barrow Island. All x1.

Description

Small, narrow species of *Breynia*, reaching up to 80 mm in length, though generally less than 70 mm. Aboral surface low; widest anterior of mid-length, width varying between 70–75% TL. Long petals, anterior pair reaching almost to ambitus; 9–11 pore pairs in anterior row, 13–16 in posterior row. Posterior petals longer than anterior, with 14–18 pore pairs in inner row, 16–20 in outer. Primary tubercles large and cover most of aboral surface, except interambulacrum 5. Peristome small, slightly sunken, plastron small and posteriorly carinate. Labrum separated from plastron in adults (>30 mm test length) by plate translocation of third

pair of ambulacral plates (see McNamara 1987, 1988). Periproct near circular; narrow subanal fasciole encloses seven sets of pore pairs.

Remarks

Breynia aff. *carinata* is similar to the contemporaneous Indian species *B. carinata*, but differs in possessing longer petals, greater tuberculated aboral surface; narrower test; fewer pore pairs in phyllode; greater number of pore pairs within subanal fasciole; and wider periproct. *Breynia* aff. *carinata* is also similar to the Early Miocene *B. paucituberculata* (Gerth, 1922) from Java, but it can be distinguished by its greater number of tubercles and longer petals. The living species *B. desorii* Gray, is present around Barrow Island and is a wide-ranging Western Australian species (McNamara 1982). It differs from *B.* aff. *carinata* in its attainment of a larger test size; relatively higher test; its smaller primary tubercles; and much larger plastron. One specimen of *B. desorii* was found in the Late Pleistocene deposits on Barrow Island.

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Reviews, observations and results of research into all branches of natural science and human studies will be considered for publication. However, emphasis is placed on studies pertaining to Western Australia. Longer papers will be considered for publication as a Supplement to the *Records of the Western Australian Museum*. Short communications should not normally exceed three typed pages and this category of paper is intended to accommodate observations, results or new records of *significance*, that otherwise might not get into the literature, or for which there is a particular urgency for publication. All material must be original and not have been published elsewhere.

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The title should be concise, informative and contain key words necessary for retrieval by modern searching techniques. An abridged title (not exceeding 50 letter spaces) should be included for use as a running head.

An abstract must be given in full length papers but not short communications, summarizing the scope of the work and principal findings. It should normally not exceed 2% of the paper and should be suitable for reprinting in reference periodicals.

The International System of units should be used.

Numbers should be spelled out from one to nine in descriptive text; figures used for 10 or more. For associated groups, figures should be used consistently, e.g. 5 to 10, not five to 10.

Spelling should follow the *Concise Oxford Dictionary*.

Systematic papers must conform with the International Codes of Botanical and Zoological Nomenclature and, as far as possible, with their recommendations.

Synonymies should be given in the short form (taxon, author, date, page) and the full reference cited at the end of the paper. All citations, including those associated with scientific names, must be included in the references.

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