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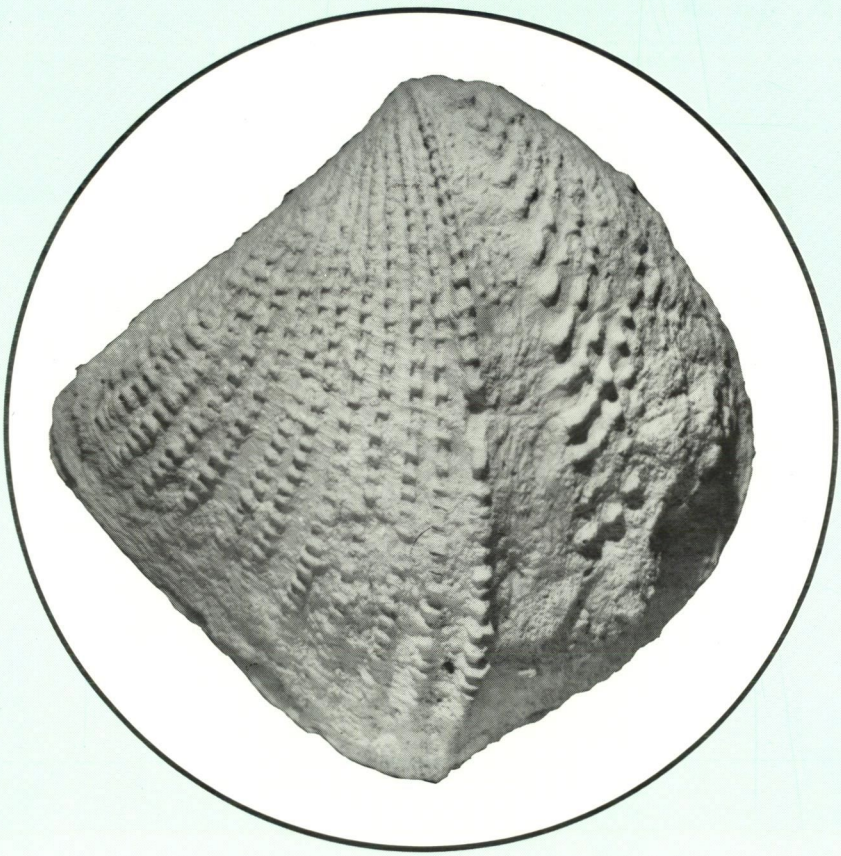

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Thomas A. Darragh and George W. Kendrick

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Cover: *Trigonia miriana* Skwarko, x 2.4.

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Maastrichtian Bivalvia (excluding Inoceramidae) from the Miria Formation, Carnarvon Basin, north western Australia

Thomas A. Darragh* and George W. Kendrick†

Abstract

Thirty species of Bivalvia (excluding Inoceramidae) from the Late Maastrichtian Miria Formation of the Carnarvon Basin are examined. Preservation is selective, favouring pteriomorph groups of primary-calcitic mineralogy; aragonitic groups, in particular the Heterodonta, may be under-represented.

Sixteen species are considered to be endemic representatives of long-ranging or cosmopolitan genera of the Late Cretaceous; five species appear to have been widely distributed at that time; five species may represent up to four endemic genera. One new genus — *Giraliapecten* gen. nov. is erected and seven species — *Grammatodon (Nanonavis) subdiscors* sp. nov., *Pseudolimea flabellulina* sp. nov., *Giraliapecten oboloides* sp. nov., *Chlamys (Microchlamys) propesalebrosa* sp. nov., *Chlamys* (s.l.) *cracenticostata* sp. nov., *Spondylus schekkermanae* sp. nov. and *Panopea stenopleura* sp. nov. — are newly described and named.

The Miria bivalve assemblage shows no particular affinity with any other known from Australia or from the Indo-Southwest Pacific region, reflecting the geographic isolation of Australia from other land masses, except Antarctica, during the Late Cretaceous. Generic endemism of up to 20% is consistent with the existence of a biogeographic subprovince in northwestern Australia at that time. The environment of deposition was that of the middle shelf, moderately energised. The climatic regime was temperate.

Introduction

The Late Maastrichtian Miria Formation (Condon 1954, as Miria Marl; Condon *et al.* 1956; Henderson and McNamara 1985a, b; Hocking *et al.* 1987) is a moderately fossiliferous, thin (0.6-2.1 m), friable foraminiferal calcarenite and calcisiltite, of which the principal outcrop extends along a strike distance of about 80 km in the Giralia Range, south of Exmouth Gulf in the Carnarvon Basin, Western Australia. Fossil localities are covered by the Mia Mia (1751) and Giralia (1752) Australia 1:100 000 topographic sheets.

The Miria Formation overlies disconformably the Campanian — Early Maastrichtian Korojon Calcarenite and is overlain disconformably by the Late Paleocene Boongarooda Greensand of the Cardabia Group (Condon *et al.* 1956: 29-41), since reduced to formation status by Hocking *et al.* (1987: 166-168). Reworking of fossil material is a feature of both of these contacts. Poor exposures of the Miria Formation occur on the Marilla Anticline, east of the Giralia Range, but have not contributed material to this study.

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The ammonites of the Miria Formation have been studied by Spath (1941), Brunnschweiler (1966) and Henderson and McNamara (1985b); other palaeontological contributions (outcrop only) have described a nautiloid (Glenister *et al.* 1956), an echinoid (McNamara 1987), a cirripede (Buckeridge 1983) and foraminifers (Edgell 1957; Belford 1958; McGowran 1968). Groups such as the sponges, bryozoans, corals, brachiopods and vertebrates remain undescribed. The single bivalve recorded hitherto is *Trigonia miriana* Skwarko (Skwarko 1963; Darragh 1986). This paper records 30 species of Bivalvia (not including Inoceramidae) from the Miria Formation; seven species and one genus are newly described and named. Studies of the Inoceramidae and Gastropoda are in preparation.

Material utilized in this study has been drawn principally from the collections of the Western Australian Museum and Museum of Victoria, with contributions from the Geology Department, University of Western Australia, the Geological Survey of Western Australia and the Australian Bureau of Mineral Resources, Geology and Geophysics.

Abbreviations used in the text and captions are:

WAM — Western Australian Museum, Perth,
NMV — Museum of Victoria, Melbourne,
UWA — Geology Department, University of Western Australia, Perth,
GSWA — Geological Survey of Western Australia, Perth,
CPC — Commonwealth Palaeontological Collection, Bureau of Mineral Resources, Geology and Geophysics, Canberra.
RV — right valve,
LV — left valve.

Specimen dimensions are given in millimetres.

Preservation.

The condition of bivalve and other mollusc material varies greatly and shows strong selection favouring groups with primary-calcitic shells at the expense of aragonitic forms (Taylor *et al.* 1969, 1973). All aragonitic shell material has been destroyed and fossils of such groups occur either as phosphatized internal moulds (steinkerns) or, less frequently, as sparry calcite replacements to varying degrees of completeness and usually with hard phosphatic infilling or encrustation. Among the aragonitic groups, delicate structures such as bivalve hinges and prodissoconchs, gastropod protoconchs and apertural margins as well as most juvenile, small and thin-shelled forms are usually poorly preserved or not at all. For these reasons, we consider that the present aggregate total of 30 species is substantially less than the original bivalve fauna.

Fossils may be found, at times in abundance, in localized concentrations associated with gullying and other erosional processes but preservation is often inferior and collecting has tended to be highly selective, a factor which may be a source of bias in the study material.

Henderson and McNamara (1985a) and McNamara (1987) present evidence of dissolution, mechanical abrasion, fracture and bioturbation of cephalopod and echinoid fossils from the Miria Formation, often severe and consistent with energetic, episodic exhumation and reworking. Both shells and steinkerns show an array of endolithic borings, epibiont encrustations and burrows and the same processes and their consequences are as evident for the bivalves and gastropods. The presence of steinkerns among the reworked material suggests that phosphatization of infilled sediment and dissolution of aragonitic shell both occurred rapidly, the former preceding the latter.

Aragonitic inclusions of those bivalves with a predominantly calcitic mineralogy have rarely avoided substantial or total dissolution. Thus, with the Limacea, Plicatulacea and Pectinacea the cardinal areas and the inner shell layers bearing the adductor scar impressions are, with rare exceptions, missing. Likewise affected are the myostracal layers of the Ostreacea. Missing characters such as these may be discerned occasionally as impressions on internal moulds. For a number of species, moulds both internal and external have provided morphological details not otherwise available. In contrast, calcitic shells, even where small and thin, such as small pectinaceans, are often well preserved and may show fracture and abrasion but no trace of calcite dissolution.

A consequence of the state of preservation of the study material is that the bivalve assemblage appears to be skewed substantially in favour of epifaunal-calcitic elements of the Pteriomorpha at the expense of other groups (see Table 2). Thus seven families - Inoceramidae, Limidae, Gryphaeidae, Plicatulidae, Entoliidae, Pectinidae and Spondylidae - provide over 70% of all known bivalve species in the Miria Formation. In contrast, infaunal bivalves with primary aragonitic shell mineralogy provide only about one fifth of the total (eight species), drawn from the families Malletiidae, Trigoniidae, Carditidae, Hiatellidae, Pholadomyidae and Periplomatidae and appear to be under-represented in the assemblage. Particularly striking is the low number (two) of veneroid taxa. This bias resembles to some degree that recorded in numerous studies of bivalve suites from Late Cretaceous chalks and comparable sediments (Carter 1972 and references; Dhondt 1982, 1985; Zinsmeister & Macellari 1988).

Palaeoecology.

Inferred life habits of Miria Formation and associated bivalves can be summarized in the following five groups. All except the species heading the list are considered to have been suspension feeders. Frequency of occurrence is indicated.

1. Infaunal species.
   Malletiid, genus and species undetermined. Protobranchiate deposit feeder; rare.
   Grammatodon (Nanonavis) subdiscors sp. nov. Shallow burrower; moderately common.
   Trigonia miriana. Shallow burrower; common.
   Linotrigonia (Oistotrigonia) sp. Shallow burrower; rare.
   Carditid, sp. A. Shallow burrower; rare.

Carditid, sp. B. Shallow burrower; rare.
Panopea stenopleura sp. nov. Deep burrower; common.
Pholadomya sp. Deep burrower; rare.
"Periploma" sp. Deep burrower; rare.

2. Infaunal or nestling — epifaunal species.
Arcoid, family, etc. undetermined. Possibly associated with hard-ground substrates with semi-infaunal or nestling habit; rare.

3. Epifaunal — byssate species.
"Mytilus" sp. Associated with hard-ground substrate; common.
Pseudolimea flabellulina sp. nov. Uncommon.
Pseudolimea sp. Rare.
Limea (Limea) sp. Rare.
Limea (?) sp. Rare.
Plagiostoma sp. Rare.

4. Epifaunal — attached species.
Atreta sp. cf. *A. nilssoni.* Attached to ammonite and oyster shells; uncommon.
Spondylus schekkermanae sp. nov. Juveniles attached, adults probably resting on substrate; common. One specimen (the holotype WAM 86.1398) bears a cluster of about 20 small caryophylliid corallites on the LV umbone, indicating that this part was clear of the substrate.
Spondylus sp. cf. *S. latus.* Rare.
Pycnodonte vesiculare. Attached to ammonite (mainly heteromorph) shells; size reduced; common.

5. Free — swimming and/or byssate pectinaceans.
Entolium sp. cf. *E. membranaceum.* Probably free-swimming; rare.
Giraliapecten oboloides gen. et sp. nov. Juveniles byssate, adults possibly free-swimming; moderately common.
Giraliapecten sp. Habit as for the preceding; rare.
Chlamys (Microchlamys) propesalebrosa sp. nov. Probably byssate; moderately common.
Chlamys (Nipponectes) sp. Probably byssate; rare.
Chlamys (s.l.) *cracenticostata* sp. nov. Byssate; moderately common.
Chlamys (s.l.) sp. A. Probably byssate; rare.
Chlamys (s.l.) sp. B. Possibly byssate; rare.
Neithea sp. Possibly free-swimming and nestling; rare.
Pectinid, genus and species undetermined. Habit uncertain; rare.

Generally the proportion of conjoined bivalves is high, particularly among infaunal species for which *in situ* burial with minimal valve displacement may be assumed.

However, most species, both infaunal and epifaunal, show a range of *post-mortem* histories as the following examples show. The available material of the presumed deep burrower *Panopea stenopleura* sp. nov. comprises about one sixth of single valves, preserved as phosphatized internal moulds. The infaunal *Trigonia miriana,* which features a robust and not readily disarticulated hinge, presents about half of the study material as single-valve internal moulds. The above examples suggest *post-mortem* histories of exhumation, valve separation, reburial, phosphatization and aragonite dissolution, in that order.

The epifaunal *Spondylus schekkermanae* sp. nov., with a strong, interlocking hinge, shows about half of the sample as single valves with phosphatized internal moulds. The epifaunal *Pycnodonte vesiculare,* which combines an edentulous hinge with a weak ligament, would be expected to separate easily and occur mainly as singles but in fact about half of our material comprises conjoined pairs, all strongly phosphatized between the valves.

The epifaunal-byssate and edentulous *"Mytilus"* sp., which seems to have had a strong ligament, shows about two thirds of all specimens as conjoined pairs. These preserve as phosphatized moulds, usually without shell, and are associated with the nodule bed at the Korojon-Miria contact. Presumably phosphatization of this material followed the onset of deposition of the Miria Formation. Shafik (1990: 82) concluded that, from coccolith evidence, the Korojon — Miria nodule bed "was formed at the onset of the Miria Marl sedimentation, having included reworked material from the top of the Korojon Calcarenite", thus initiating his Upper Maastrichtian sedimentary Cycle C. Our *"Mytilus"* sp. evidently colonized a "hard ground" substrate, consistent with substantial current scour, during the interval equivalent broadly to "Middle" Maastrichtian time (McNamara *et al.* 1988) between the deposition of the Korojon Calcarenite and the Miria Formation.

Thus the occurrence in the Miria Formation of single and paired valves and moulds, representing both infaunal and epifaunal groups, suggests histories of rapid burial, with or without exhumation for some and separation and dispersal for others (and subsequent burial), accompanied initially by rapid phosphatization around fossil nuclei and the dissolution of all primary aragonite. The latter processes we consider probably took place within the substrate a little below the sediment-water interface.

Shelled fossils of what were originally aragonitic groups have in many cases been reproduced secondarily in brown sparry calcite around strongly lithified phosphatic cores. Replication of the original structures varies greatly with good quality specimens much in the minority. External phosphatic encrustation over secondary calcite may occur.

Bottjer (1981), comparing macroinvertebrate (mainly bivalve) assemblages in two Late Cretaceous chalks of dissimilar textures from Arkansas, found that each was dominated by epifaunal, suspension feeding, mainly-calcitic, pteriomorph bivalves. His finer or marly chalk contained in addition only rare, infaunal aragonitic bivalves (as moulds) and no gastropods and was interpreted as an "outer shelf" deposit of water

depths estimated at 75-125 m. The coarser chalk of sandy texture contained, in addition to the epifaunal-calcitic pteriomorphs, a range of infaunal-aragonitic bivalves and gastropods, the latter two groups as moulds. This unit was interpreted as a "middle shelf" deposit of water depths estimated at 25-50 m. Thus a correlation was indicated between faunal diversity, sediment grain size, water depth and shelf position.

The different assemblages in Bottjer's two chalks were considered by him to reflect the primary substrate-organism relationship rather than differing rates of aragonite dissolution. Both epifaunal and infaunal bivalves were compatible with the coarser textured "middle shelf" substrate but only the former were able to occupy the finer, softer muds of the "outer shelf". Thus the two assemblages were seen as representatives of two distinct faunal types and shelf palaeoenvironments. Of these, the Miria Formation and malacofauna approximates to Bottjer's "middle shelf" sandy chalk and fauna.

In lithology, in the character of their bivalve-gastropod assemblages and their preservation, substantial differences are evident between the Miria Formation and the other Late Cretaceous (Santonian-Early Maastrichtian) chalks of Western Australia (i.e., Korojon Calcarenite, Toolonga Calcilutite and Gingin Chalk). In the latter group, taken together, epifaunal-calcitic pteriomorphs comprise almost all known bivalves. No infaunal-aragonitic bivalves are known in any preservational mode and gastropods (as moulds) are rare (Playford *et al.* 1976: 188; Hocking *et al.* 1977: 158, 160). We suggest that these chalks and their malacofaunas approximate to Bottjer's fine textured "outer shelf" chalk and indicate deposition in significantly deeper water than that for the Miria Formation in the study area. Foraminiferal evidence suggests that the palaeodepth of the Miria Formation in the Giralia Range section is of the order of 50-100 m (D.W. Haig, pers. comm., December 1988).

Further evidence in support of deposition below wave base is the lack of sedimentary structures; however such structures, if originally present, would probably have been destroyed by bioturbation, given the presence of a variety of burrowing and boring organisms in the sediment (Henderson & McNamara 1985).

A substantial uniformity of lithology, contact relationships and malacofauna is apparent along the entire outcrop length of the Miria Formation, suggesting little variation in water depth, position relative to the shoreline and sedimentary environment for this part of the formation. No inshore lateral equivalent is known and this may have been removed by erosion.

An approximation of relative frequencies (excluding Inoceramidae) in the Miria Formation is shown in Table 1, which lists specimen totals for each species in the study material. Collection bias is undoubtedly present in this tally, favouring larger and better preserved material. From these data, species 1-8 constitute a group of relatively common and characteristic elements. Species 9 (*"Mytilus"* sp.) may be restricted, wholly or substantially, to the nodule bed at the Korojon-Miria contact. Species 10 (*Atreta* sp. cf. *A. nilssoni*) is less common than the total of specimens would suggest because 15 of the 18 specimens to hand were obtained by the chance collection of a single ammonite, to which they were attached.

Table 1. Bivalvia, excluding Inoceramidae, from the Miria Formation: quantities of specimens in study material.

Species	No. of specimens examined
1. *Spondylus schekkermanae* sp. nov.	170
2. *Pycnodonte vesiculare***	130
3. *Panopea stenopleura* sp. nov.	100
4. *Chlamys (Microchlamys) propesalebrosa* sp. nov.**	89
5. *Trigonia miriana*	80
6. *Grammatodon (Nanonavis) subdiscors* sp. nov.**	57
7. *Giraliapecten oboloides* gen. et sp. nov.	40
8. *Chlamys* (s.l.) *cracenticostata* sp. nov.	35
9. *"Mytilus"* sp.*	34
10. *Atreta* sp. cf. *A. nilssoni*	18
11. *Pseudolimea flabellulina* sp. nov.	9
12. *Giraliapecten* sp.	7
13. *Plagiostoma* sp.**	6
14. *Linotrigonia (Oistotrigonia)* sp.	5
15. *Chlamys* (s.l.) sp. A	4
16. *"Periploma"* sp.	4
17. *Chlamys (Nipponectes)* sp.	3
18. *Pseudolimea* sp.	3
19. carditid, sp. A	3
20. *Limea (Limea)* sp.	2
21. pectinid, sp.	2
22. carditid, sp. B	2
23. *Limea* (?) sp.	1
24. *Entolium* sp. cf. *E. membranaceum*	1
25. malletiid, sp.	1
26. arcoid, sp.*	1
27. *Chlamys* (s.l.) sp. B	1
28. *Neithea* sp.	1
29. *Spondylus* sp. cf. *S. latus*	1
30. *Pholadomya* sp.	1
Total of specimens	811

*denotes species from nodule bed at contact of Korojon Calcarenite - Miria Fm.
**denotes species from Miria Formation and nodule bed at contact of Korojon Calcarenite - Miria Fm.

Common, widely distributed bivalve families from inner shelf environments of the Late Cretaceous, which have not been recognized in collections from the Miria Formation, include the Nuculidae, Nuculanidae, Arcidae, Limopsidae, Glycymerididae, Pinnidae, Ostreacea (other than *Pycnodonte*), Lucinidae, Fimbriidae, Astartidae, Crassatellidae, Cardiidae, Tellinidae, Veneridae and Corbulidae and their apparent absence we attribute primarily to unfavourable palaeoenvironmental factors possibly compounded by aragonite loss. These groups are well represented in the shallow water faunas of the Upper Cretaceous Uttattur, Trichinopoly and Ariyalur Groups of the Cauvery Basin of South India (Stoliczka 1871). Characteristically, those beds comprise calcareous conglomerates, sandstones, sandy to gritty limestones, shales and siltstones,

with a substantial component of fine to coarse terrigenous clastic material. Coralline and algal limestones occur as well as fossil wood of terrestrial origin (Rama Rao 1956). The South Indian Late Cretaceous (onshore) beds differ profoundly in depositional environments, lithofacies and faunal content from the Miria Formation to the extent that little meaningful comparison of the two seems possible.

From the foregoing, we conclude that there is a convergence of evidence in support of a "middle shelf" character for the outcropping Miria Formation and its malacofauna.

Few direct indications regarding palaeotemperature are offered by the Miria Formation bivalves. The absence of rudists, a group characteristic of warm-Tethyan faunas, the rarity of echinoids and the solitary character of the infrequent corals suggests cool-temperate to temperate conditions. The apparent absence of all genera representing Kauffman's (1973: 359) restricted warm-water element lends further support to the view of the Miria fauna and environment as essentially temperate in character. This conclusion is consistent with Late Cretaceous palaeolatitudes for Australia in Barron (1987, Figures 4-6). However the possible influence on fauna of other environmental factors, discussed above, should be kept in mind.

Predation.

Gastropod predation of bivalves, indicated by the presence of characteristic boreholes (Carriker and Yochelson 1968) is a common feature of Late Cretaceous and younger, inner shelf malacofaunas but its extent in the Miria Formation appears to be limited, a factor of possible palaeoenvironmental significance. In the study material, eight out of 130 specimens (6%) of the epifaunal *Pycnodonte vesiculare* have been bored, four with naticiform and three with muriciform holes (one of uncertain profile). One of these (CPC 27832) carries three completed naticiform boreholes. The probably infaunal *Grammatodon (Nanonavis) subdiscors* sp. nov. shows one specimen (UWA 91462) with a naticiform borehole on the ligamental area. The likely agent of most of the above is a species of *Gyrodes* (Naticidae), which occurs regularly throughout the formation. The identity of the muricid predator remains uncertain.

Palaeobiogeography

The only Australian Late Cretaceous marine sediments known from surface outcrop are those of the Perth and Carnarvon Basins of Western Australia. Of these, the Late Maastrichtian Miria Formation is the youngest and, with the exception of the subsurface Breton Marl (Shafik, 1990: 20), no other unit of equivalent age or comparable lithofacies is recognized from either basin. Thus within the geological record, the formation is substantially isolated in space, time and character. Despite certain elements in common (up to four species of bivalves disregarding the Inoceramidae) with the Santonian chalks of Western Australia, the Miria bivalves have no particular affinity with any other Late Cretaceous fauna either from within or beyond Australia. This contrasts with the wide-ranging ammonite species, which show close similarities with the Late Cretaceous assemblages of the Pondicherry area of South India, Malagasy and, to a lesser extent, Antarctica (Henderson and McNamara 1985b: 82-84).

Table 2. Miria Formation bivalves (excluding Inoceramidae) grouped according to distributional mode.

(a) Wide-ranging or cosmopolitan species	(b) Endemic species of wide-ranging or cosmopolitan genera	(c) Endemic species of endemic genera	(d) Species of undetermined generic identity and affinity
Pycnodonte vesiculare	*Grammatodon (Nanonavis) subdiscors* sp. nov.	*"Mytilus"* sp.	malletiid
Atreta sp. cf. *A. nilssoni*	*Pseudolimea flabellulina* sp. nov.	*Giraliapecten oboloides* sp. nov.	arcoid
Entolium sp. cf. *E. membranaceum*	*Pseudolimea* sp.	*Giraliapecten* sp.	carditid sp. A
Neithea sp.*	*Limea (Limea)* sp.	pectinid, genus undetermined	carditid sp. B
Spondylus sp. cf. *S. latus*	*Limea* (?) sp.	*"Periploma"* sp.	
	Plagiostoma sp.		
	Chlamys (Microchlamys) propesalebrosa sp. nov.		
	Chlamys (Nipponectes) sp.		
	Chlamys (s.l.) *cracenticostata* sp. nov.		
	Chlamys (s.l.) sp. A		
	Chlamys (s.l.) sp. B		
	Spondylus schekkermanae sp. nov.		
	Trigonia miriana		
	Linotrigonia (Oistotrigonia) sp.		
	Panopea stenopleura sp. nov.		
	Pholadomya sp.		

*species close to *N. sexcostata* (Woodward).

(a)	(b)	(c)	(d)
Five species = 16.6% of all species	16 species = 53.3% of all species	Five = 16.6% of all species	Four species = 13.5% of all species
151 specimens = 18.4% of all specimens	573 specimens = 70.1% of all specimens	87 specimens = 10.6% of all specimens	Seven specimens = 0.9% of all specimens
	Total specimens = 818.		Total species = 30.

Within the limitations of present taxonomic and distributional knowledge, the Miria bivalves may be viewed as a blend of three broadly conceived groupings. These are:
(a) wide-ranging or cosmopolitan species, few in number;
(b) endemic species of wide-ranging or cosmopolitan genera, the majority group, and
(c) endemic species of endemic genera, few in number.

There is also a small group (d), represented by poorly preserved material of uncertain identify and significance. Table 2 lists the species according to these criteria.

The justification for "group a" is, firstly, our conclusion that the Miria *Pycnodonte* species is an ecomorph of the near-cosmopolitan *P. vesiculare* (Lamarck) and secondly the expectation that our qualified identifications of the other four species will be confirmed from future studies. We suggest that all five species of "group a" occurred widely across the Tethyan Realm in the Late Cretaceous, consistent with well-developed larval dispersal capacities. Of this group, only *Pycnodonte vesiculare* is common in the Miria Formation, the others being uncommon to rare. The five genera of "group a" (*Pycnodonte, Atreta, Entolium, Neithea* and *Spondylus*) also occur beyond the Late Cretaceous Tethyan Realm, being characteristic of White Chalks of Europe and also for Temperate North America (A.V. Dhondt, personal communication, July 1989). *Entolium* s. str. and *Neithea* are represented in Australian Early Cretaceous faunas (Etheridge 1902; Skwarko 1966) but *Pycnodonte, Atreta* and *Spondylus* appear first in the Santonian chalks (Feldtmann 1963).

The majority "group b" comprises species which, with varying levels of confidence, appear to be northwestern Australian representatives of genera known to be widely distributed in the Late Cretaceous. At least six of these genera (*Grammatodon* s.l., *Pseudolimea, Plagiostoma, Chlamys* s. str., *Trigonia* and *Pholadomya*) were established in Australian seas as early as the Middle Jurassic (Skwarko 1974). Genera from "group b" recorded from the Early Cretaceous of Australia are *Grammatodon* s.l., *Chlamys* s.l., *Trigonia, Panopea* and *Pholadomya* (Cox 1961; Ludbrook 1966; Skwarko 1967, 1974, Hill *et al.* 1968). Some or all of these groups may have evolved continuous or sporadic local lineages through to the Maastrichtian but the meagre fossil record from the Australian Late Cretaceous permits little more than conjecture as to the details.

Genera or subgenera from "group b", which on present knowledge appear first in Australia in the Santonian, are *Spondylus, Nipponectes* and possibly *Microchlamys* (Etheridge 1913; Feldtmann 1963; this paper). Several small and poorly preserved limids (WAM G3859, G3970, G3971, 74.1165) from the Gingin Chalk are assigned tentatively to *Limea,* adding a possible fourth Miria genus with an earliest Australian record in the Santonian, though this may change when the Early Cretaceous limids (Skwarko 1966) are better known. Miria generic taxa first recorded (this paper) from the Maastrichtian are *Nanonavis* and *Linotrigonia (Oistotrigonia)* but, in this context, the paucity of the Australian Late Cretaceous fossil record is apparent. For example, occurrences of species of *Oistotrigonia* from the "probably Cenomanian" of Papua (Glaessner 1958), the Senonian of New Caledonia (Freneix 1980, 1981) and the Campanian-Maastrichtian of New Zealand (Fleming, 1987) suggest that this group was probably present in Australian seas since well before the Late Maastrichtian.

A noteworthy element in "group b" is *Panopea stenopleura* sp. nov., the affinities of which will be shown to lie with the New Caledonian-Neozelanic-Antarctic *P. clausa* Wilckens. This is the sole bivalve species in the study material of apparent Weddellian derivation (after Zinsmeister 1979, 1982) and matching Miria ammonite species of the genera *Neograhamites, Gunnarites* and *Maorites* recorded by Henderson and McNamara (1985b). (Another possible Weddellian derivative, *Plagiostoma* sp., is too poorly represented to be certain of its affinity). The apparent absence of a marine seaway between Australia and Antarctica prior to the Tertiary suggests that any Miria-Weddellian connection may have been established via eastern and northern Australia (Freneix 1981, figure 1; Zinsmeister 1982: 85-87, text figure 2).

The extent of generic endemism presently recognizable among the Miria bivalves is indicated by "group c", all distinctive taxa which cannot be assigned unreservedly to available genera. From these, one new genus, *Giraliapecten* gen. nov., is erected to receive material representing probably two species. Other material of inferior preservation is assigned for the time being to the genera *Mytilus* and *Periploma* in the expectation that better specimens, when available, may confirm the need for new genera or subgenera. A rare and distinctive pectinid, collected from both the Miria Formation and the Santonian chalk of the Carnarvon Basin, may represent a fourth endemic genus or subgenus, subject to confirmation from further material.

The present study has indicated the presence among the Miria bivalves (exclusive of Inoceramidae) of approximately 20 generic/ subgeneric taxa of which up to four ("group C") may be restricted to the Carnarvon Basin. This would suggest an approximate endemism at generic level of up to 20% for the bivalves, acknowledging a likely reduction in that percentage with the addition of inoceramid data. Kauffman (1973: 354) has suggested as an "arbitrary guideline", that generic endemism of 10-25% among Cretaceous bivalves would be consistent with a biogeographic subprovince "for any group, area and interval of time". The Miria Formation bivalves thus appear to reflect that level of endemism, modifying Kauffman's (ibid., p. 373) conclusion on the degree of endemism in his Late Cretaceous Australian subprovince.

Subprovincial endemism of this extent, viewed together with the relatively high (70%) level of species-endemism (as indicated by the sum total of groups b and c) would be consistent with Australia's marked isolation throughout the Late Cretaceous from land masses other than Antarctica, as shown on the maps of Barron (1987, figures 4-6).

The endemic Santonian pectinancean genus *Cteniopleurium* Feldtmann from the Gingin Chalk of the Perth Basin (Feldtmann, 1951) has not been recognized in the study material, nor as yet from the Santonian chalks of the Carnarvon Basin. Likewise absent are the genera *Climacotrigonia* Cox and *Actinotrigona* Cox (Cenomanian of Bathurst Island), both characteristic of Kauffman's Late Cretaceous Australian subprovince (Kauffman 1973: 373).

A particularly noteworthy feature of the Miria fauna when compared with other southern hemisphere faunas is the diversity of the Pectinidae. Despite the fragmentary nature of some of the material, it is clear that there are nine species present, representing at least four genera of that family. Pectinids are absent from the Antarctic faunas

described by Wilckens (1910) and Zinsmeister & Macellari (1988) and only one species is recorded in the Maastrichtian Quiriquina Formation, Chile, by Stinnesbeck (1986). Wilckens (1910) recorded four species from the Late Cretaceous of Patagonia and Warren & Speden (1977) listed four species in four genera from the Maastrichtian of Haumuri Bluff, New Zealand.

However, Wood (1906) recorded five pectinid species (probably representing three genera) from the Late Cretaceous of Pondoland and Feldtmann (1951) described six species of *Chlamys* from the Coniacian-Santonian of the Coolyeena Group at Gingin, Perth Basin. The combined Gingin-Miria pectinids, numbering up to 15 species, may reflect the relative proximity of the Australian margin of the Indian Ocean to the Tethyan Realm during the Late Cretaceous, when compared with other regions of the southern hemisphere.

Systematic palaeontology

Class Bivalvia Linnaeus, 1758
Subclass Palaeotaxodonta Korobkov, 1954
Order Nuculoida Dall, 1889
Superfamily Nuculanacea H. and A. Adams, 1858
Family Malletiidae H. and A. Adams, 1858

Malletiid, genus and species undetermined
(Figure 1A)

Material.
WAM 74.590 (internal mould of both valves). One specimen.

Description.
An internal mould of paired valves with a narrow gape, probably *post-mortem.* Small, transversely sub-elliptical, moderately inflated; umbones broad, elevated; beaks at the anterior two fifths; antero - and postero-dorsal margins slightly concave, forming an angle of about 140°; anterior and posterior margins roundly truncate, the latter not rostrate; ventral margin broadly rounded. Hinge taxodont, occupying the entire dorsal margin; anterior series about 12, posterior about 17; teeth weak or absent in the median area; resilifer not apparent; pallial line impressed and located well above the ventral margin; sinus if present not determinable; adductor scars obscure, the anterior pair located near the dorsal extremities. External characters unknown.

Dimensions.

	Length	Height	Inflation
WAM 74.590, paired int. mould	11.8	7.0	4.5

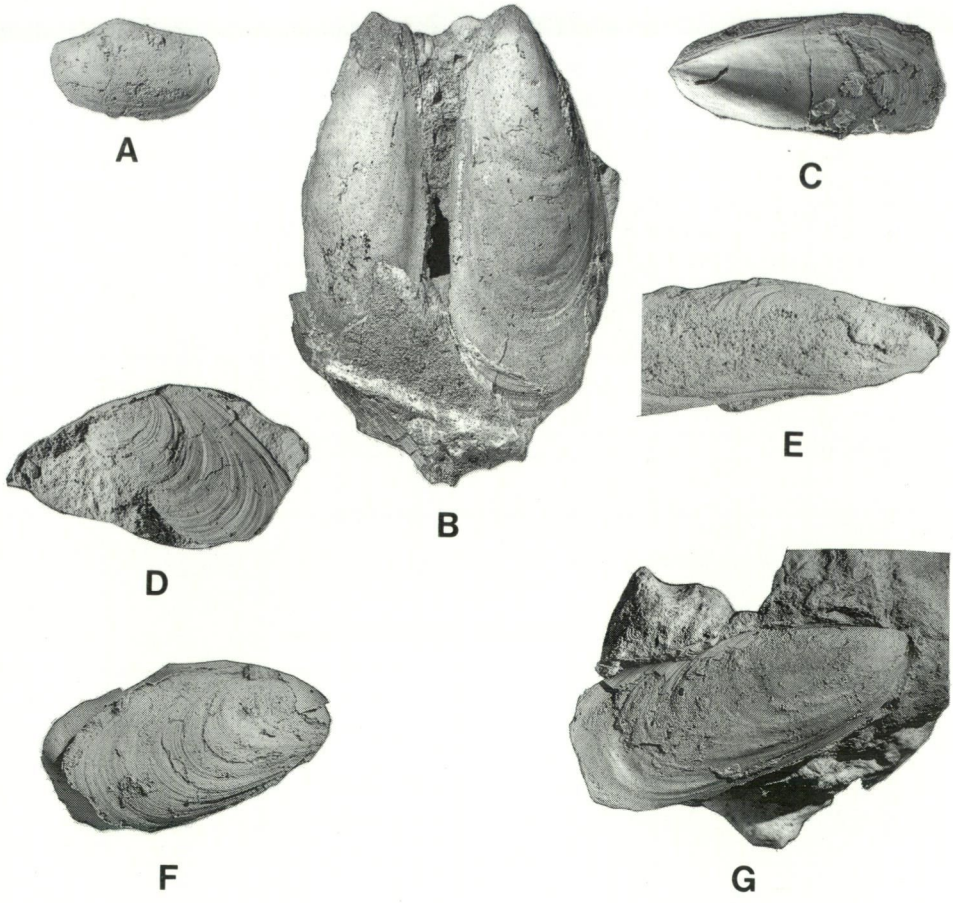


Figure 1. **A** Malletiid, genus and species undetermined. WAM 74.590. Locality 30. Internal mould of conjoined valves, LV x 2. Miria Fm. **B-G** *"Mytilus"* sp. **B** WAM 80.682. Locality 28. Internal mould of open, conjoined valves, x 1. Nodule bed at contact of Korojon Calc. — Miria Fm. **C** WAM 71.254. Locality 25. Internal mould of conjoined valves showing anterior adductor scar and nymph, LV x 1. Miria Fm? **D** WAM 80.681d. Locality 28. Latex cast of external mould, LV?, x 1. Probably from nodule bed at contact of Korojon Calc. — Miria Fm. **E** WAM 83.2975. Locality 5. Internal mould of conjoined valves with shell remnants, showing septum of LV, x 1. Miria Fm? **F** WAM 71.280b. Locality 25. Latex cast of posterior portion of RV showing growth lines, x 1. Probably from nodule bed at contact of Korojon Calc. — Miria Fm. **G** WAM 86.1237. Locality 26. Internal mould of RV, x 1. Nodule bed at contact of Korojon Calc. —Miria Fm. All whitened.

Remarks.

The species is referred provisionally to the Malletiidae because of the apparent absence of a resilifer and of any posterior rostration. In general form and proportions, the species resembles a range of Late Cretaceous nuculoids, such as *Yoldia striatula* Forbes and *"Yoldia" scaphuloides* Stoliczka from the Maastrichtian Ariyalur Group of Southern India (Stoliczka 1871, pl. 4, figure 2; pl. 17, figures 11, 12), *Malletia evansi* (Meek and Hayden) from the Maastrichtian Fox Hills Formation of South Dakota (Speden 1970, pl. 3, figures 15-19, pl. 4, figures 1-7) and *Malletia (Malletia?) himenourensis* Tashiro from the Santonian of the Himenoura Group of Kyushu (Tashiro 1976, pl. 2, figures 16-18). From *Yoldia levitestata* Stinnesbeck from the Maastrichtian Quiriquina Formation of central Chile, (Stinnesbeck 1986, pl. 1, figures 10,11) the present species differs in more anteriorly located beaks and a slight convexity of the antero-dorsal margin; inflation is a little greater. In general outline it also bears resemblance to *Australoneilo gracilis* Wilckens, early Tertiary, Patagonia and Antarctica and *A. casei* Zinsmeister & *Macellari,* Maastrichtian, Seymour Island (Zinsmeister & Macellari 1988).

Stratigraphic range. Miria Formation. Maastrichtian.

Subclass Pteriomorpha Beurlen, 1944.

In the familial arrangement of the Pteriomorpha, we follow Waller (1978), modified by Waller (1984).

Order Mytiloida Férussac, 1822
Superfamily Mytilacea Rafinesque, 1815
Family Mytilidae Rafinesque, 1815
Subfamily Mytilinae Rafinesque, 1815

Genus *Mytilus* Linnaeus, 1758

Type species: *Mytilus edulis* Linnaeus, 1758. By subsequent designation of Gray, 1847.

***"Mytilus"* sp.**
(Figure 1 B-G)

Material.

WAM 60.62, 71.253, 71.254, 71.255, 71.280, 71.281, 71.282, 75.1216, 80.625, 80.681, 80.682, 80.821, 80.872, 83.2975, 83.3040, 84.721, 86.1237. Twenty five specimens. NMV P101606, P101663, P101893, P101979, P102243, P102325, P102351, P119554. Nine specimens.

Description.

Shell of medium size for the genus, narrowly mytiliform, thin, beaks terminal, subacute and with an internal septum; postero-dorsal margin long, obtusely rounded to subangulate and merging into the short, strongly rounded ventral margin; antero-ventral margin long, slightly concave; maximum inflation at about the anterior two fifths, convexly tapered toward the ventral margin; anterior adductor scars small, elongate, faintly striated and located dorsally and close to the beaks, visible only on an occasional unworn or undamaged specimen (e.g., WAM 71.254, P101893); posterior adductor

scars not detected; nymphs strong for the genus, linear, smooth and with no pitting or serration, extending from near the beaks to the postero-dorsal angulation (WAM 71.254); hinge endentulous; no dysodont teeth apparent; pallial line well impressed, extending from near the septum to the postero-ventral area and distant from the margin; sculpture of low, smooth, transverse growth rugae and weak, irregular growth lines; neither radial sculpture nor marginal crenulation evident.

Dimensions.

	Beak to ventral extremity	Height	Inflation
WAM 80.681a, pair	84 (est.)	40	20.5
83.2975, pair	51	23	11.5
83.304a, LV	93	44	16.0 (est.)
NMV P101979, pair	92	48	27
P102244, pair	58	29	16

Remarks.

Most of the available material is preserved as internal moulds, of which only a few (e.g., WAM 71.280b, 80.682, NMV P101606) retain traces of the shell. Others (e.g., WAM 71.280b, 80.682) feature external moulds on which the nature of the sculpture is indicated. Of the 34 specimens examined, 23 represent what were articulated pairs, having the valves either conjoined as in life (20 specimens) or opened widely (three), testifying to the *post-mortem* durability of the ligament.

Because of the inadequate preservation of our material, we have been unable to determine an unqualified generic location for this species and therefore defer naming it for the present. The observed aggregate of characters would seem to distinguish it from all the mytiline genera and subgenera listed by Soot-Ryen and Newell (in Moore 1969). Septate groups therein include the Permian *Coxesia* Mendes, the Jurassic-Cretaceous *Lycettia Cox* and the Triassic-Recent *Septifer* Récluz but none of these seems appropriate for the present species. A close affinity with *Mytilus s.* str. also seems unlikely in view of its umbonal septum, the edentulous hinge, absence of dysodont teeth and absence of pitting along the nymph. However, its derivation as an endemic Australian genus or subgenus from a pre-existing *"Mytilus"* stock seems possible. As a group, the Cretaceous mytilines appear to need revision and the systematic relationships of our species with those described previously remain unclear.

Compared with *"Mytilus" decipiens* Wilckens from the Late Cretaceous of Patagonia (Wilckens 1907), the present species attains a greater size and is more concave ventrally. From *"Mytilus" attenuatus* Meek and Hayden, from the Fox Hills Formation of Montana (Meek and Hayden 1856), our species appears to be larger, more elongate and less triangular in outline. Compared with *Mytilus primigenius* Stinnesbeck from the Maastrichtian Quiriquina Formation of Chile (Stinnesbeck 1986) the Miria Formation species is much larger, more elongate and more concave ventrally. *Mytilus arrialoorensis*

Stoliczka from the Campanian-Maastrichtian Ariyalur Group of South India (Stoliczka 1871: 381, pl. 23, figures 2,3,5) has a "subquadrangular shape" and is smaller than our species; its internal characters are unknown. Of the three mytilids recorded by Moore (1870) from the Early Cretaceous of Australia, our species most resembles *"Mytilus" rugocostatus* Moore; the Miria species has a more elongate form and is thin-shelled, unlike Moore's species, which is said to have "a very thick test". Ludbrook (1966: 164-5, pl. 20, figures 1-2, 4-5) assigns *M. rugocostatus* to the genus *Modiolus* Lamarck. Nayak and Badve (1985: 79, pl. 1, fig. 7) have recorded an indeterminate species of *Mytilus* from the calcareous upper horizon of the Cenomanian-Turonian Nimar Sandstone, Bagh Beds of Madhya Pradesh. Though much smaller than our species, the Bagh Beds *"Mytilus"* is not unlike it in outline; its internal characters are unknown and a location in the genus *Lycettia* Cox could not be ruled out (see Tashiro 1976: 48-49, pl. 4, figure 7). *Lycettia foaensis* Freneix, from the "Sénonian Formation à charbons" of New Caledonia, is septate like the Miria species but is much smaller and shows a greater postero-dorsal convexity; its exterior is smooth ("lisse").

By analogy with modern mytilines, the slight concavity of the antero-ventral margin suggests that the present species was byssate and associated in life with firm substrates, a feature probably of limited occurrence in the general depositional environment of the Miria Formation (Henderson and McNamara 1985a). The species has been collected and observed regularly from the prominent and widespread nodule bed at the contact of the Korojon Calcarenite and Miria Formation. There, and elsewhere in unlocalized "float", it occurs within phosphatic nodules enclosing fragments of a large inoceramid, characteristic of the Korojon Calcarenite and we consider it likely that the primary source of these specimens was the "hard ground" environment now represented by the nodule bed. Occasional specimens (e.g., WAM 80.625, 80.682, 83.3040) are seen to be multiples with a suggestion of clumping of shells, possibly aligned. This feature, with possible relevance to the ecology of the species, requires further investigation. None of our material is known with certainty to have originated from undisturbed Miria Formation, though this possibility cannot at present be excluded. The precise stratigraphic occurrence of the species requires further field study.

Stratigraphic range.

Nodule bed at the contact of the Korojon Calcarenite and Miria Formation. Maastrichtian.

Order Arcoida Stoliczka, 1871
Superfamily Arcacea Lamarck, 1809
Family Parallelodontidae Dall, 1898

Genus *Grammatodon* Meek and Hayden, 1861

Type species: *Arca (Cucullaea) inornata* Meek and Hayden, 1859. By original designation.

Subgenus *Nanonavis* Stewart, 1930

Type species: *Arca carinata* J. Sowerby, 1813. By original designation.

Grammatodon (*Nanonavis*) *subdiscors* sp. nov.

(Figure 2 A-I)

Material.

Holotype, CPC 27834. Articulated pair retaining nearly all of the RV and most of the LV. From "outcrop in CY Creek", Giralia Range, Cardabia station.

Paratypes.

WAM 75.1209a (pair), 80.624a, b (2 LVs), 80.820 (int. mould, pair), 80.871 (int. mould, pair), 87.319 (pair). Six specimens. NMV P101623 (pair). One specimen. UWA 91436 (int. mould, pair), 91462 (2 int. moulds). Three specimens. GSWA F9388 (pair). One specimen. CPC 27835 (LV). One specimen.

Other material.

WAM 60.114, 71.252, 75.1209b, c, 80.745, 80.746, 80.851, 80.953, 83.2888, 83.2893, 83.2949, 83.3111, 83.3116, 84.953, 87.624. Nineteen specimens. NMV P98239-40, P98267, P98271, P98283, P101545, P101580, P101655-7, P101981-2, P119584-6, P119700-1, P102006-8, P102320, P102356, P102371. Twenty three specimens. UWA NW144. Three specimens.

Diagnosis.

A tumid *Nanonavis* combining a length to height ratio of 3:2, the LV with 35-40 costae and crenulate margin, the RV with over 40 costae and smooth margin; larger than and without the carination of *G. (N.) carinata* (Sowerby); smaller, with finer, less discrepant, less variable sculpture than *G. (N.) japeticum* (Forbes).

Description.

Shell of medium size, rather tumid, trapezoidal, transversely elongate, short anteriorly, produced and tapered posteriorly; length to height ratio of 3:2; valves subequal, the LV slightly larger than the RV and extending a little beyond it along the ventral margin; umbones broad, inflated, prosogyrate, projecting well above the hinge margin and transgressing slightly over the cardinal area; beaks incurved, located at the anterior two sevenths; maximum inflation posterior to the beaks and only slightly below the plane of the hinge margin; postero-dorsal area clearly defined and weakly sulcate; ligament duplivincular, with up to eight spaced, incised chevron grooves (insertion lines) extending over the entire ligamental area of each valve, the anterior series exceeding by one the posterior series; cardinal area elliptical, the width variable relative to length, the margins carinate.

Hinge margin straight or very slightly arched, about five sixths of the total length and forming not quite a right angle with the anterior margin, which merges roundly with the gently convex ventral margin; posterior margin more or less straight, obliquely truncate, meeting the postero-dorsal margin at an angle of about 130^0, subacuminate where it joins the ventral margin; ventral margin lacking a byssal gape and associated dorso-ventral sulcus; margin internally crenulated on the LV, obscurely or not at all on the RV. Hinge plate narrow; teeth all serrated, in three series; anterior pseudolaterals two, short, subparallel to the hinge margin, slightly descending; posterior pseudolaterals four, occupying about half the length of the hinge margin and converging to a point below the beaks; median teeth seven to nine, short, irregularly aligned.

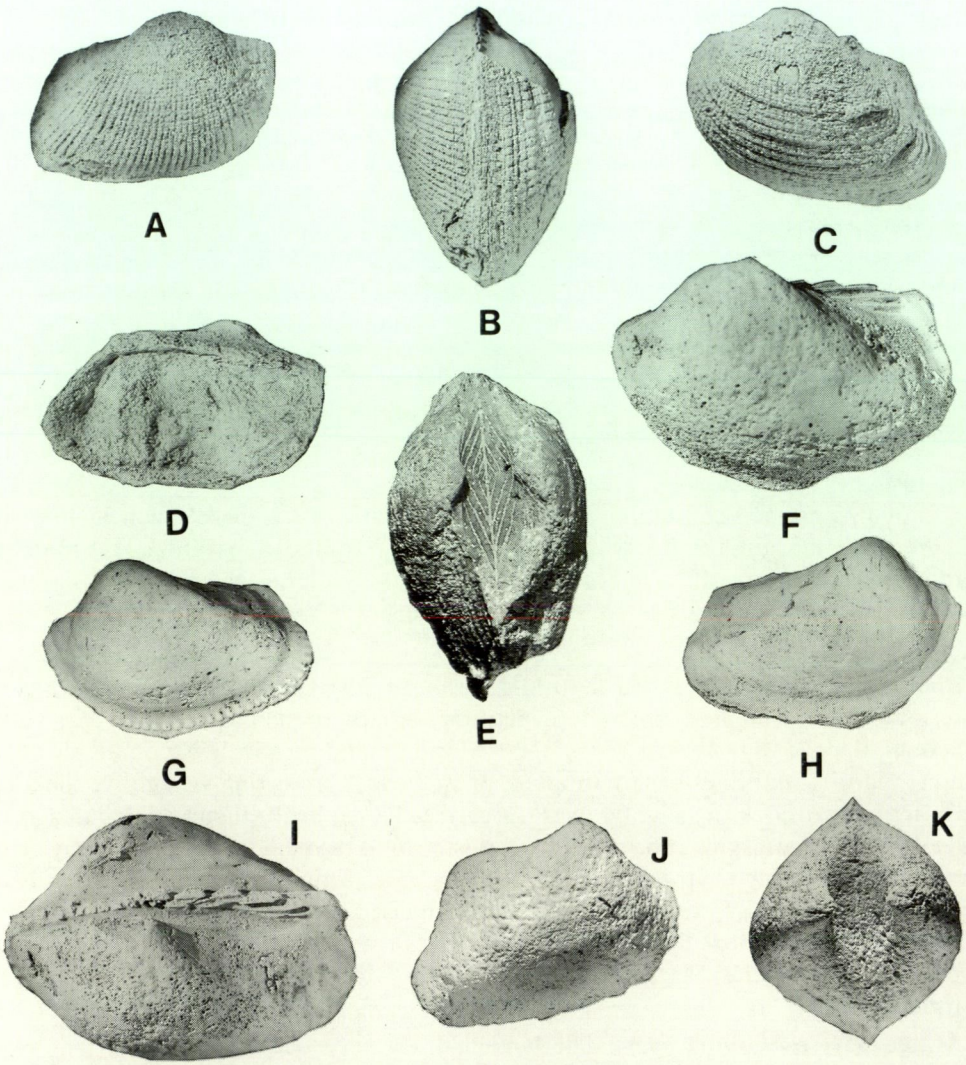


Figure 2. **A-I** *Grammatodon (Nanonavis) subdiscors* sp. nov. **A-C** CPC 27834. Holotype. Locality 38. Conjoined valves: **A** RV, **B** ventral aspect showing discrepant sculpture, **C** LV; all x 1. Miria Fm. **D** WAM 80.624b. Paratype. Locality 26. Interior of LV, x 1. Miria Fm. **E** GSWA F9388. Paratype. Locality 8. Conjoined valves, dorsal aspect showing ligamental area, x 1.3. Miria Fm. **F, I** WAM 80.871. Paratype. Locality 29. Internal mould of conjoined valves showing LV and dorsal area, x 1.5. Miria Fm. **G, H** WAM 80.820. Paratype. Locality 23. Internal mould of conjoined valves, LV (**G**) with crenulate margin, RV (**H**) with smooth margin, x 1. Miria Fm. **J, K** Arcoid of uncertain identity. WAM 75.1210. Locality 30. Internal mould of conjoined valves, RV(**J**) and dorsal aspect (**K**), x 1. Probably from nodule bed at contact of Korojon Calc. —Miria Fm. All whitened except **E**.

Sculpture discrepant; LV (excluding the posterior area) with 35-40 narrow, low radial costae, occasionally paired or grooved in the median area, separated by narrow linear interspaces and crossed by weak transverse rugae and finer growth striae; sculpture of the posterior area about seven weak costae; RV with in excess of 40 radials, narrower and a little more prominent than those of the LV and separated by narrow interspaces which are wider than those of the LV. Costae of the RV bear low transverse scales and growth striae; posterior area of the RV with obscure radials. Anterior adductor scars subequal, triangular, well defined, located close to the antero-dorsal extremity; posterior adductor scars subequal, subrectangular, weakly defined, located close to the postero-dorsal extremity; pallial line entire, parallel to and well above the ventral margin.

Dimensions

	Length	Height	Inflation
CPC 27834, Holotype, pair	36.5	24.0	25.2
CPC 27835, Paratype, LV	38.4	26.5	13.6
WAM 80.624b, Paratype, LV	37.9	24.3 (broken)	12.7
WAM 80.820, Paratype, int. mould	37.5	26.0	22.1
WAM 87.319, Paratype, pair	35.1	24.2	25 (est.)
NMV P101623, Paratype, pair	30.5	20.5	24 (est.)
GSWA F9388, Paratype, pair	30.5	21.3	18.2

Remarks.

We follow Newell (in Moore 1969) in assigning *Nanonavis* to subgeneric rank within *Grammatodon*. No specimen in our material is complete and the description has been taken from a range of specimens.

Compared with *"Arca" carinata* Sowerby, the type species of *Nanonavis* from the English Gault and Upper Greensand, the present species is of broadly similar shape though larger; sculpture is stronger than on Sowerby's species, the prominent carination of the latter is lacking and the ligamental area is wider with fewer insertion lines.

From *"Arca" natalensis* Baily from the Senonian of Pondoland (Natal) (Woods 1906: 289-291, pl. 34, figures 3-7) and Malagasy (Collignon 1931: 32, pl. 4, figure 3a; Basse 1932), our species differs in the form of the sculpture of each valve, in the smooth internal margin of the RV and in the more rounded postero-ventral shoulder. Compared with *G. (N.) japeticum* (Forbes) from the Campanian-Maastrichtian Ariyalur Group of South India (Stoliczka 1871, pl. 18, figures 6-11), the present species appears to be smaller, with finer, less discrepant and less variable sculpture and less prominent umbones.

The subgenus is well-represented in the Cretaceous (Neocomian to Maastrichtian) of Japan (Hayami 1965; Tashiro 1976) and in the Albian to Maastrichtian of western North America (Stewart 1930; Anderson 1958), but all species differ from *G. (N.) subdiscors* in various aspects of shell form, sculpture, ligamental area and marginal crenulation. *"Cucullaea" hendersoni* Etheridge (in Jack and Etheridge 1892: 468, pl. 26, figures 2, 3) from the Albian of Queensland, which appears to be a *Nanonavis* (see Hill *et al.* 1968, pl. KV, fig. 9), features narrow radials and wide interspaces, a form of sculpture

suggesting an affinity with the Jurassic-Aptian *Indogrammatodon* Cox (see Hayami 1965: 240). The present species may be regarded as the Australian-Maastrichtian representative of the subgenus, which speciated extensively during the Cretaceous to attain near-cosmopolitan distribution.

Though nowhere common, *G. (N.) subdiscors* is distributed generally throughout the outcrop area of the Miria Formation in the Giralia Range, usually as internal moulds of articulated pairs. Specimens retaining even parts of the valves are uncommon; the holotype is an exceptional specimen. One of our specimens, UWA 91462, shows a naticiform borehole on the ligamental area of the RV between the beaks.

The specific name, from the Latin *sub,* less than and *discors,* different, unlike, refers to the weakly discrepant characters of the valves.

Stratigraphic range.

Nodule bed at contact of Korojon Calcarenite and Miria Formation. Miria Formation. Maastrichtian.

An arcoid internal mould (WAM 75.1210, Figure 2 J,K), otherwise indeterminable, from Locality 30, is larger than any specimen of the foregoing and appears from its distinctive shape to represent a second species of the Order. With dimensions of 39.0 (length), 26.5 (height) and 39.7 (inflation), it appears that the inflation may have exceeded slightly the length. The LV may have been larger than the RV; the posterior area is relatively large with an obliquely truncate margin, suggesting a trigonal form of shell, rather shortened anterior to the beaks. Despite wear, there is an impression on the posterior area of the LV near the adductor scar of a weak cucullaeoid radial flange. The ventral margin of the LV only bears impressions of a fine, weak crenulation.

The lithology of the specimen suggests an origin in the nodule bed at the contact of the Korojon Calcarenite and Miria Formation.

Order Limoida Waller, 1978
Superfamily Limacea Rafinesque, 1815
Family Limidae Rafinesque, 1815

Genus *Pseudolimea* Arkell (in Douglas and Arkell 1932)

Type species: *Plagiostoma duplicata* J. de C. Sowerby, 1827. By original designation.

Pseudolimea flabellulina sp. nov.

(Figure 3 A-D)

Material.

Holotype. WAM 87.385. A LV, intact but for the inner layers. From gully draining to E, 1 km NW of West Tank, Giralia Range, Giralia station (KV 175 883).

Paratypes.

WAM 71.258 (LV), 83.3041 (RV), 87.386 (RV). Three specimens. NMV P101935 (LV), P119705 (RV). Two specimens.

Other material.

NMV P98248, P119533, P119589. One LV and two fragments.

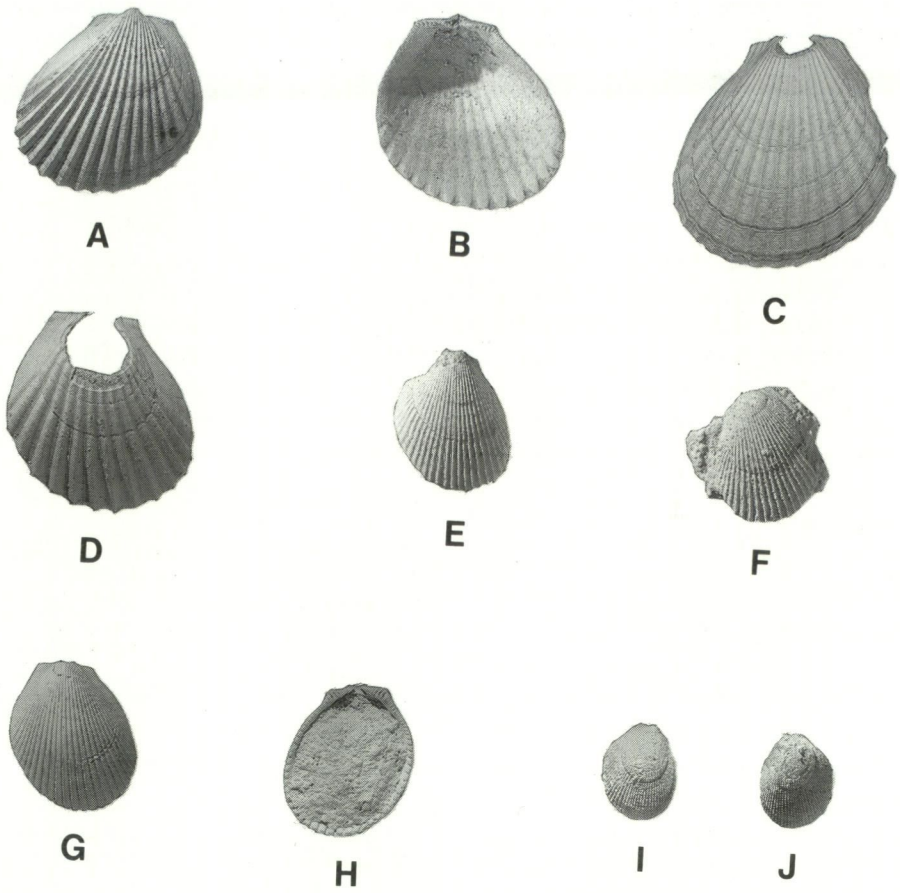


Figure 3. **A-D** *Pseudolimea flabellulina* sp. nov. **A, B** WAM 87.385. Holotype. Locality 10. LV exterior, interior, x 1.5. **C** WAM 71.258. Paratype. Locality 25. LV exterior, x 1.5. **D** WAM 87.386. Paratype. Locality 10. RV exterior, x 1.5. **E, F** *Pseudolimea* sp. **E** WAM 71.257. Locality 25. RV exterior, x 3. **F** WAM 86.1417. Locality 3. LV exterior, x 3. **G, H** *Limea* sp. NMV P102191. Locality 21. RV exterior, interior, x 2. **I, J** Limea (?) sp. WAM 80.631. Locality 26. Conjoined pair, LV, RV, x 3. All Miria Fm. All whitened.

Diagnosis.

A small *Pseudolimea* with 13 (RV) and 15 (LV) smooth costae, sharply triangular in cross-section. Has fewer costae than *P. parallela* (Sowerby), *P. intermedia* (d'Orbigny) and *P. sellardsi* Stephenson; with slightly more costae than *P. oldhamiana* (Stoliczka) and without secondary striation.

Description.

Shell small, equivalve, obliquely subtrigonal, slightly higher than long, produced antero-ventrally, short posteriorly, umbone broadly inflated, opisthogyrate and, if

intact, projecting slightly above the hinge margin; auricles small, subequal, the anterior a little more defined than the posterior; ligamental area broadly and narrowly triangular with a central ligamental pit; hinge margin straight, about one third of the total shell length; anterior margin long, descending, slightly sinuate, with a very slight byssal gape; ventral margin asymmetrically rounded; posterior margin short, rounded; sculpture of strong, radial costae, 13 on RV and 15 on LV, which widen posteriorly, triangular in cross-section; an additional low to obscure rib present on each flank; all costae lack scales, spines or other ornament and are wider than the interspaces; a fine radial thread occupies the centre of each interspace but is absent from those on each flank; antero -and postero - dorsal areas and auricles without radial sculpture; entire surface crossed by very fine transverse growth striae; hinge taxodont, infrequently intact due to loss of aragonitic shell, with about (on the holotype) six short, oblique teeth on each side of the ligamental pit, the teeth continuing for a little around each margin as fine crenulae; ventral margin with strong internal crenulation, corresponding to the external sculpture; internal layers bearing adductor scars missing due to loss of aragonite.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 87.385, Holotype, LV	15.5	5.5	16.0	4.5
WAM 71.258, Paratype, LV	21 (est.)	8.4	22 (est.)	6.5 (est.)
WAM 87.386, Paratype, RV	15.5	6.5	16.5 (est.)	4.5
NMV P101935, Paratype, pair	21 (est.)	?	21 (est.)	11.5 (est.)
NMV P119705, Paratype, RV	14.0	5.5	15.0	4.5

Remarks.

The genus was widely distributed in the Late Cretaceous but no Tertiary records are known to us. The Miria species differs from *Pseudolimea parallela* (Sowerby) from the late Cretaceous of Europe (Woods 1904: 28-30, pl. 5, figures 14, 15) by its fewer ribs (18-20 in Sowerby's species), the crests of which are not as sharp and in its less oblique outline. *P. intermedia* (d'Orbigny) from the same sources (ibid., pp. 33-34, pl. 6, figures 2-4) has 20-23 ribs which bear intermediate riblets (not present on our species) and is also rather more oblique. *"Lima" sellardsi* Stephenson from the Late Cretaceous Navarro Group of Texas (Stephenson, 1941: 142, pl. 24, figures 10, 11), which appears to be a congenor, resembles in outline the Miria species but has 20-24 ribs with rounded crests (except in proximity to the margin where they become sharp) and which bear small tubercles. *"Limea" oldhamiana* Stoliczka, apparently a *Pseudolimea,* represents the genus in the Campanian-Maastrichtian Ariyalur Group of South India (Stoliczka 1871: 423, pl. 30, figures 6, 7; pl. 36, figure 5) but differs from the present species in its slightly fewer ribs (12-14) bearing a fine secondary striation, an arched hinge margin and in a greater height relative to length.

The wide-ranging *P. duplicata* (J. de C. Sowerby), type species of the genus, occurs in the Bajocian Newmarracarra Limestone of the Perth Basin (Skwarko 1974) from which

the present species is distinguished by its fewer, broader ribs (up to 30 in *P. duplicata).*

Pseudolimea flabellulina is an uncommon species, widely distributed along the outcrop area of the Miria Formation in the Giralia Range. The specific name is derived as a diminutive from the Latin noun *flabellum,* a fan, from the fan-like appearance of the exterior.

Stratigraphic range.

Miria Formation. Maastrichtian.

***Pseudolimea* sp.**

(Figure 3 E,F)

Material.

WAM 71.257 (RV), 85.318 (RV), 86.1417 (LV). Three specimens.

Description.

Shell very small for the genus, obliquely subtrigonal, extended anteriorly, higher than long; auricles small, subequal; hinge margin short, internally taxodont, the teeth merging continuously with the internal crenulation of the margins; sculpture of 26-31 radial costae, triangular in cross-section and fading on the flanks; a very fine radial thread occupies the base of each intercostal space.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 71.257, RV	5.1	?	6.5	2.0
WAM 86.1417, LV	5 (est.)	2.4	6.0	1.8

Remarks.

In shape, sculptural mode, dentition and marginal crenulation, this species resembles the associated *Pseudolimea flabellulina,* differing in its more numerous, finer radials and smaller size. In the absence of recognized juveniles of *P. flabellulina,* the possibility cannot be excluded that the differences between the two are ontogenetic, though the disparity between rib counts (13-15 : 26-31) suggests otherwise. Further material is necessary for this distinction to be confirmed.

Limea perlata Freneix from the "Sénonian Formation à charbons" of New Caledonia (Freneix, 1980: 95-96, pl. 111, fig. 9) recalls the present species by its small size, similar rib-count and in the presence of a fine, intercostal riblet. It differs in the presence of granular (perlate) microsculpture on the ribs together with a less elevated rib profile, features which the author considers closer to *Limea* than to *Pseudolimea,* to which the species was previously assigned.

This rare species has been collected from widely dispersed localities along the Giralia Range on Cardabia and Giralia stations. Its small size may have resulted in its being overlooked by collectors.

Stratigraphic range.
Miria Formation. Maastrichtian.

Genus *Limea* Bronn, 1831

Type species: *Ostrea strigilata* Brocchi, 1814. By monotypy.

Subgenus *Limea* s. str.

Limea (Limea) sp.
(Figure 3 G,H)

Material.
WAM 87.387 (RV). One specimen. NMV P102191 (RV). One specimen.

Description.
Shell small, robust, obliquely-ovate, produced anteriorly, higher than wide, margins not gaping; umbone moderately inflated and projecting a little above the hinge margin; auricles small, the posterior slightly the larger; hinge margin short, less than half the shell length, straight, bearing oblique taxodont teeth which converge to a point well below the margin and merging continuously with the internal marginal crenulation; cardinal area narrow, centrally missing due to preferential dissolution of aragonite; sculpture of about 29 flat, smooth, radial costae with narrowly incised interspaces; costae become obsolete and fading on the flanks.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 87.387, RV	8.6	4.0	11.0 (est.)	3.8
NMV P102191, RV	8.1	3.9	10.5 (est.)	3.7

Remarks.
A possibly related species, apparently a *Limea* s. str., is *"Radula" interplicosa* Stoliczka from the Campanian to Maastrichtian Ariyalur Group of South India (Stoliczka, 1871: 418-419, pl. 30, figures 10, 11), differing in its more numerous, granulated ribs; the Miria species is higher relative to length and has a straight hinge margin, a feature which appears to be arched on Stoliczka's species.

Further consideration of this rare species is deferred until more material becomes available.

Stratigraphic range.
Miria Formation. Maastrichtian.

Limea (?) sp.
(Figure 3 I, J)

Material.
WAM 80.631 (pair). One specimen.

Description.

Shell minute, obliquely subovate, higher than long; umbones moderately inflated, beaks incurved and well-spaced across a short, relatively broad ligamental area; hinge margin short; auricles small, the posterior the larger; byssal gape if present very small; sculpture of about 40 very fine, regular, radial costae, a little wider than the interspaces, crenulating the ventral margin and becoming obsolete on the flanks; costae possibly granulated or scaled, some uncertainty due to imperfect preservation; internal characters not seen.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 80.631, pair	3.3	1.1	4.0	2.2

Remarks.

The generic location of this unique, probable juvenile, specimen and its relationship to the preceding species are subject to confirmation from the collection of further material of each. Differences in rib counts (40 and about 29) suggest that two species are represented but the material to hand is inadequate for this to be determined conclusively.

Stratigraphic range.

Miria Formation. Maastrichtian.

Genus *Plagiostoma* Sowerby, 1814

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

Plagiostoma (?) sp.

(Figure 4 A-C)

Material.

WAM 71.306, 85.327, 86.1229, 87.388. Five fragments. NMV P97596. One fragment.

Description.

A large, thin-shelled (though robust), compressed limid sculptured with numerous narrow, flattened, slightly wavy costae of uneven width and separated by narrow interspaces; a microsculpture of punctation on some and fine transverse scales on others characterizes the interspaces, the difference possibly deriving from different parts of the disc; one specimen (WAM 86.1229b) retains a marginal flank (whether anterior or posterior is not clear) on which the intercostal microscales of the central disc change to very fine, raised and scaled costellae near the margin. On the largest fragment to hand (WAM 71.306, apparently the postero-ventral portion of a RV), the primary costae become wider, fewer and weaker in the median area, compared with the presumed posterior part, while the intercostal microsculpture combines both punctate and scaled

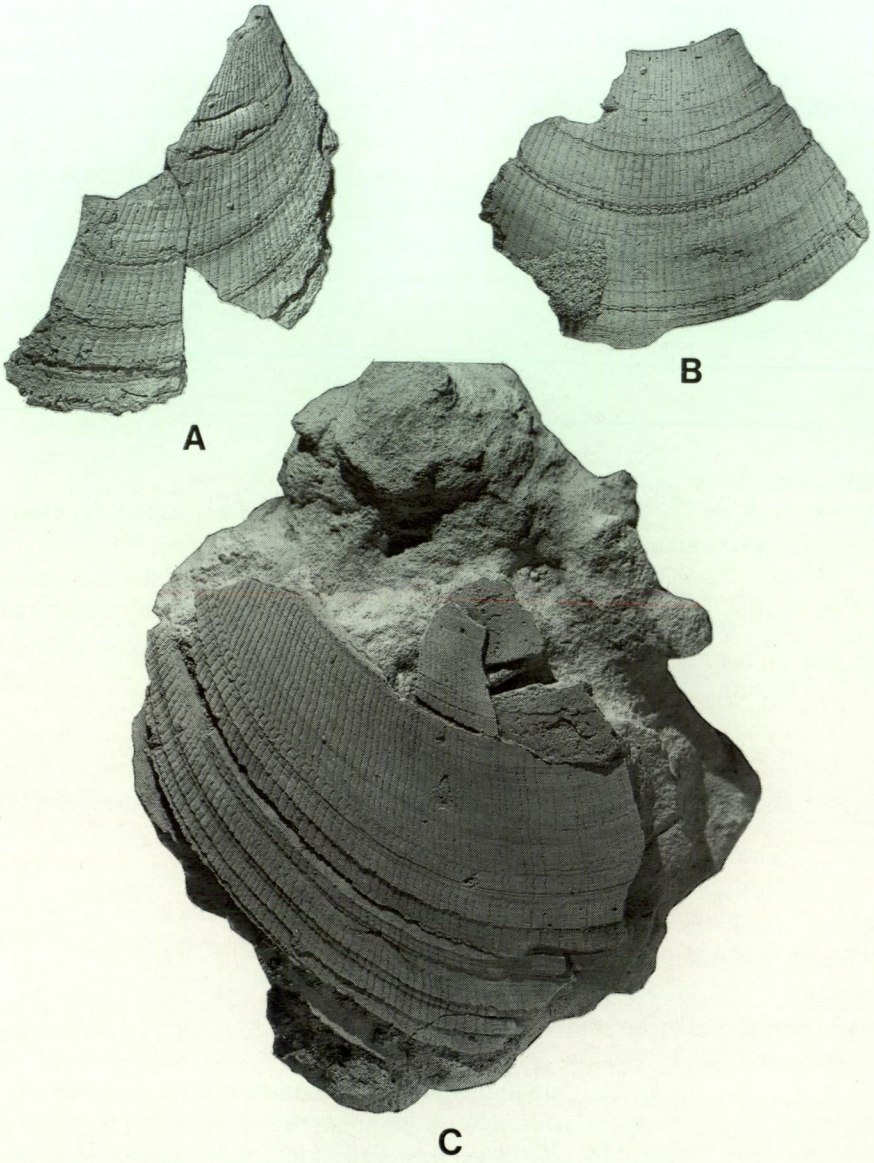


Figure 4. **A-C** *Plagiostoma* sp. **A** WAM 86.1229. Locality 32. Postero-ventral portion of LV?, x 1. Miria Fm. **B** WAM 87.388. Locality 10. Fragment of uncertain orientation, x 1. Miria Fm. **C** WAM 71.306. Locality 20. Postero-ventral portion of RV, x 1. Probably from nodule bed at contact of Korojon Calc. — Miria Fm. All whitened.

elements; in addition the costae of the presumed posterior extremity bear a fine, close, transverse microsculpture. The sculpture of NMV P97596 resembles that of the above mentioned but is much finer, consistent with a smaller shell, about half the size of the other specimens. A thickened internal margin is present on WAM 86.1229b. Co-marginal growth-pause irregularities are a feature of most specimens.

Dimensions.

WAM 71.306 is estimated to have had when complete a length of about 100 mm; height was probably similar. The thickened marginal flank of WAM 86.1229b measures 3.7 mm between the inner and outer surfaces.

Remarks.

The limited range of material to hand precludes our establishing with certainty a generic position for this species but the choice seems to lie between *Plagiostoma* and *Acesta* H. and A. Adams. Hayami (1965: 327), comparing these groups (regarded by him as subgenera of *Plagiostoma* s.l.) remarked that "The distinction between the two subgenera for Mesozoic species would often be difficult from external features only".

For the present, we favour *Plagiostoma* from the presence of punctate microsculpture on some of the intercostal spaces, after Newell (in Moore 1969: N391). This character is shared with other Cretaceous species, for example, *Plagiostoma interpunctuata* (Stoliczka) from the Albian-Turonian Uttattur Group of South India (Stoliczka, 1871: 417, pl. 10, figure 5) and *P. cretaceum* (Woods) from the Turonian-Maastrichtian of Europe (Dhondt 1987: 71-2, pl. 4, figures 10-12). Both of these species appear to be rather smaller than ours. Positive determination of the Miria species would require the collection of further material.

Other species bearing a closer resemblance to ours in size and sculpture are *Lima (Acesta) snowhillensis* Wilckens, 1910 from Snow Hill Island, Late Cretaceous, Antarctica and *Acesta shackletoni* Zinsmeister & Macellari, 1988. Unlike the Miria species both are almost smooth on the central portion of the valve.

The present species occurs very sparsely but widely along the Miria Formation outcrop in the Giralia Range. Two specimens (WAM 71.306 and NMV P97596) occur in phosphatic nodules containing inoceramid fragments and are believed to have originated in the nodule bed at the contact of the Korojon Calcarenite and Miria Formation.

Stratigraphic range.

Nodule bed at contact of Korojon Calcarenite and Miria Formation. Miria Formation. Maastrichtian.

Order Osteroida Férussac, 1822
Superfamily Ostreacea Rafinesque, 1815
Family Gryphaeidae Vyalov, 1936
Subfamily Pycnodonteinae Stenzel, 1959

Genus *Pycnodonte* Fischer de Waldheim, 1835

Type species: *Pycnodonte radiata Fischer de Waldheim, 1835.* By original designation.

Pycnodonte vesiculare (Lamarck, 1806)

(Figs 5A-N, 6 A-L, 7 A-C)

Ostrea vesicularis Lamarck 1806: 160-161.

Ostrea vesicularis Lamarck: Lamarck 1809: 375, pl. 22(27), figure 3.

Gryphaea vesicularis (Lamarck): Stoliczka 1871: 465-466, pl. 42, figures 2-4, pl. 43, figure 1.

Gryphaea hypoptera Wanner 1902: 118-119, pl. 17, figures 13-14.

Ostrea vesicularis Lamarck: Woods 1913: 360-374, pl. 55, figures 4-7, text figures 143-182, with synonymy.

Pycnodonta ginginensis Etheridge 1913: 17-19, pl. 3, figures 6-9, pl. 4 figures 3-7.

Pycnodonta vesicularis (Lamarck): Abbass 1962: 71-72, pl. 10, figures 1-2.

Pycnodonta ginginensis Etheridge: Feldtmann 1963: 119-121, pl. 4, figure 7, pl. 5, figures 1-3.

Pycnodonta strathalbynensis Feldtmann 1963: 121, pl. 5, figures 4, 4a, 4b, pl. 6, figure 1.

Pycnodonte (Pycnodonte) vesicularis (Lamarck): Freneix 1972: 102-106, pl. 10, figures 1-7, text figures 11, 12.

Pycnodonte (Phygraea) vesiculare (Lamarck): Dhondt 1982: 90-91, pl. 4, figure 7.

Pycnodonte (Phygraea) vesiculare (Lamarck): Dhondt 1985: 54-55.

Pycnodonte (Phygraea) vesiculare (Lamarck): Dhondt 1987: 72-73.

Pycnodonte vesiculare vesiculare (Lamarck): Dhondt and Jagt 1987: 84, figure 3 : 6.

Material.

WAM 60.34, 60.96, 60.117, 71.187, 71.298, 71.299, 75.1214, 80.632, 80.749, 80.750, 80.856, 83.2882, 83.2897, 83.2914, 83.2926, 83.2942, 83.2950, 83.2967, 83.2981, 83.3001, 83.3017, 83.3036, 83.3043, 83.3067, 83.3078, 83.3083, 84.711,84.724, 84.725, 86.1460, 87.389, 88.300-7. Fifty five specimens.

NMV P98250, P98262, P98298-301, P101530, P101542-3, P101550, P101554, P101566, P101605, P101608, P101609, P101624, P101702-4, P101706-8, P101735, P101774, P101994-8, P102059, P102102, P102248, P102251, P102275, P102282-3, P102357, P119590-5, P119690, P126802. Fifty nine specimens. UWA 91447. Fifteen specimens. CPC 27832. One specimen.

Description.

Shell small for the genus and species, somewhat thin though robust and well-preserved, of diverse and irregular form but usually longer than high and sometimes extended along the antero-posterior axis; non-grypheate; individual form influenced greatly by that of the attachment object; shell usually inflated with a well-developed umbonal cavity on the LV, occasionally compressed with a shallow cavity; umbone of the LV usually truncated by the attachment area, the latter always present (LV), small to large, the margins rimmed and with weak clasping processes; auricles (LV) small to obscure; RV smaller and thinner than the LV, frequently wholly or partly convex (due to xenomorphism) and reflexed along the commissural shelf of the ventral margin; beak (RV) small, low to inconspicuous, submedian to well anterior of centre; vesicular structure present on both valves, on the LV as patches on or continuously around the commissural shelf and on the interface of the attachment area; on the RV as part of the inner structure, where it becomes visible only on worn or broken areas; valves without chambers or chalky inclusions; chomata generally few, very fine, variable in number, located about the dorsal area and thence along the antero-and postero-dorsal rims of the commissural shelf (LV) or dorsal margin (RV); chomata similar on each valve, commonly as simple transverse bars, some of which may be arborescent, others at the distal ends may be irregularly vermiform; commissural shelf wide to narrow, obscured

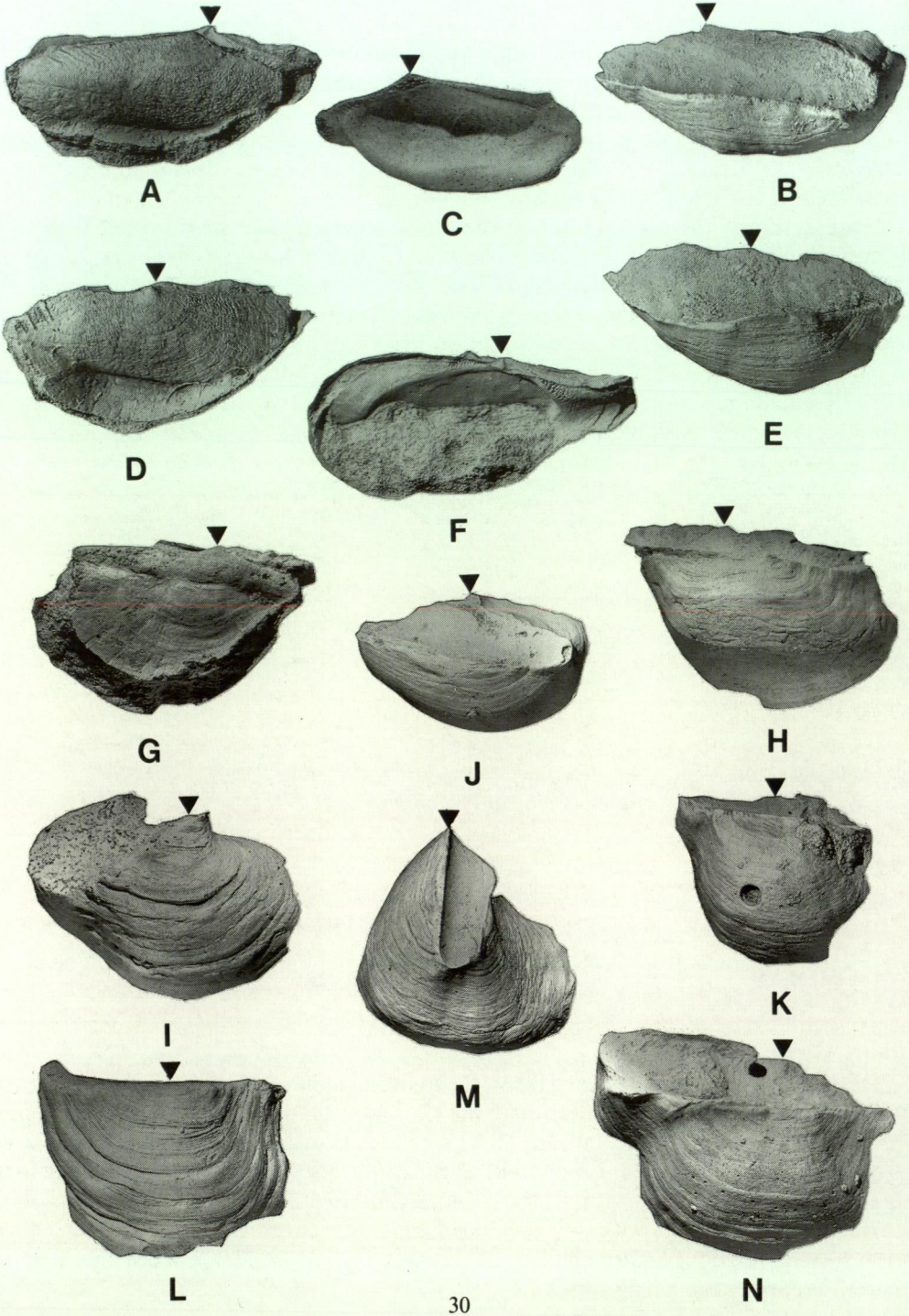
by sediment on most LVs; ligamental area small, asymmetric, opisthogyrate but occasionally deflected by xenomorphism and finely transversely striate; resilifer sunken, of variable width and prominence; bourrelets irregular and unequal, generally weak; adductor muscle scars large, observed mainly on the RV, convexly subovate, the height exceeding the length, centred generally high in the postero-dorsal quadrant and occasionally corroded preferentially in the half nearer to the ligamental area (corresponding to the myostracum of the quick muscle); Quenstedt muscle insertions usually apparent as well-defined or shallow pits a little below and on either side of the ligamental area; sculpture of the LV of fine, close, undulating, non-foliaceous transverse striae crossed by a few broad, weak, radial folds; anterior and posterior flanks defined sometimes by a weak sulcus or less often on the posterior flank by one or several low radial ridges; sculpture of RV of fine irregular transverse growth striae, often crossed by weak, irregular radial gashes and diverse, obscure patterns of xenomorphic origin; commissure simple, broadly undulating, without plication.

Dimensions.

	Length	Height	Inflation
WAM 71.298a, LV	46.9	20.0	16.0
pair			16.0
WAM 71.298b, RV	39.5	17.5	5.5
WAM 80.750, RV	31.5	19.8	4.6
WAM 80.856a, LV	44.5	30.4	25 (est.)
WAM 83.2926a, LV	42.3	22 (est.)	12.5
WAM 83.2967b, LV	48.4	21.6	17 (est.)
WAM 88.300a, LV	41.2	36.0	12.2
pair			12.6
WAM 88.300b, RV	37.8	31.5	3.1
WAM 88.304a, RV	32.7	18.5	4.0
WAM 88.304b, RV	23.1	32.0	4.9
WAM 88.304c, RV	27.5	27.0	3.5
WAM 88.304d, RV	28.3	15.9	4.0
WAM 88.305, pair	44.5 (est.)	29.0	19.0

Remarks.

Despite much variation in shell form, the material to hand (130 specimens) shares the following characters: shell rather small, the LV larger than the RV, thin though robust, vesicular structure present; umbone (RV) small to inconspicuous; ligamental area not prominent; chomata similar on each valve: generally few and located in proximity to the ligamental area; adductor scars large, roundly subovate and centred in the postero-dorsal quadrant; all LVs with well developed attachment areas and truncated or reduced umbones; generally not attached to other oysters. We conclude from this that the material represents a single species.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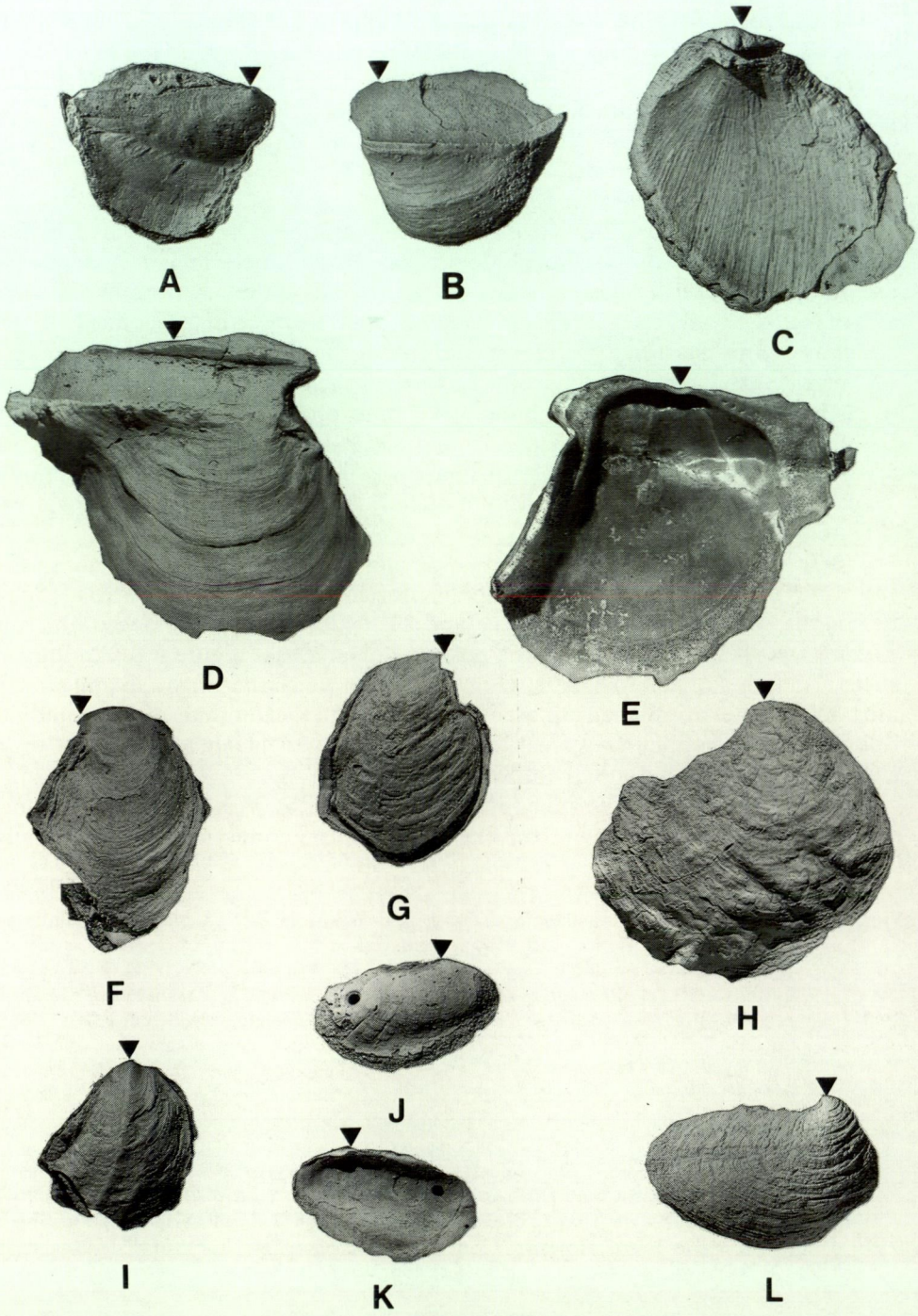
The various shell forms in the study sample appear to reflect the growth responses of individual oysters to a range of substrate morphologies, of which the most frequently determinable appear to have been shells of heteromorph ammonites, mostly *Eubaculites* species, which occur frequently throughout the Miria Formation. Evidence for direct oyster-ammonite contact is confined usually to the impressions of the latter on the attachment areas of the former. An exception is NMV specimen P101998, a *Pycnodonte* LV still attached to a worn *Eubaculites* shell.

Thus, where *Eubaculites* shells have been utilized as post-larval substrates, a distinctive range of oyster morphologies has ensued, determined evidently by the orientation of the settled oyster relative to the long axis of the substrate. Where the hinge axis of the oyster and the long axis of the substrate were more or less coincident, then the attachment area has developed transversely along the entire antero-posterior axis of the LV, resulting in a transversely produced form of shell, of which the length may exceed twice the height and with a corresponding xenomorph along the entire length of the RV. Examples are WAM 71.298, 83.2967b and 83.2981 (Figures 5A-F, 6 J,K). A variant involving coincident orientation with a narrowly cylindrical substrate is exemplified by WAM 88.305, an articulated pair, and 88.307, a cylindrically convex, immature RV (Figure 5 G,H).

Where the hinge axis of the oyster was aligned obliquely to the long axis of the substrate (*Eubaculites*), then the former has developed an attachment area along part of its length only. Thus WAM 83.2926a and 83.3043b were both attached anteriorly to *Eubaculites* shells but not along the postero-dorsal areas (Figure 5 I). An uncommon shell form is that of WAM 83.2950 (Figure 5 M), in which the hinge axis and attachment area of the oyster are aligned almost at a right angle to the long axis of the ammonite. On this specimen the attachment area is small and truncated; height and length of the intact shell were probably not greatly different.

A shell form unlike any of the foregoing is shown by WAM 83.3067 (Figure 6 C), which evidently settled upon a convexly rounded aragonitic shell with light transverse

◀ **Figure 5.** **A-N** *Pycnodonte vesiculare* (Lamarck). **A-C** WAM 71.298. Locality 22. Conjoined valves showing **A** RV exterior with strong, transverse xenomorph; **B** LV exterior with transverse attachment area (mould of *Eubaculites* shell); **C** RV interior; all x 1. **D, E** WAM 83.2981. Locality 10. Conjoined valves showing RV exterior with strong, transverse xenomorph; LV exterior with transverse attachment area (mould of *Eubaculites* shell); x 1. **F** WAM 83.2967b. Locality 3. LV interior showing ligamental area, chomata, commissural shelf and phosphatic infilling, x 1. **G, H** WAM 88.305. Locality 7. Conjoined valves showing RV exterior with narrow, transverse xenomorph; LV exterior with narrow, transverse attachment area, x 1. **I** WAM 83.2926a. Locality 16. LV showing attachment area (mould of *Eubaculites* shell) oblique to hinge axis, x 1. **J** WAM 83.2926b. Locality 16. LV showing attachment area oblique to hinge axis, x 1. **K** WAM 83.2926c. Locality 16. LV with transverse attachment area and naticiform borehole, x 1. **L** WAM 60.117. Locality 36. LV exterior, x 1. **M** WAM 83.2950. Locality 12. LV with attachment area (mould of *Eubaculites* shell) aligned almost at right angle to hinge axis, x 1. **N** WAM 80.856a. Locality 18. LV with naticiform borehole close to beak on attachment area, x 1. All Miria Fm. Triangles indicate positions of beaks. All whitened.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sculpture, possibly that of a non-heteromorph ammonite. To its large attachment object, the response of the oyster was to develop a large attachment area and narrow commissural shelf, resulting in a compressed and strongly curved form of shell, somewhat produced posteriorly so that the length exceeds slightly the height. WAM 88.301 was attached likewise to a convex aragonitic substrate and developed a similar compressed-curved form with a narrow commissural shelf and a height exceeding the length (Figure 6G). A further variant of this form-group is WAM 88.300, which grew in attachment to a large concave object, perhaps within the body chamber of an empty nautiloid or ammonite shell; the oyster is compressed and curved, with a narrow shelf, length exceeding height and with a distinct xenomorph on the RV.

In the study material, clusters of adult *Pycnodonte* shells are absent and even the attachment of one oyster to another is rare. One specimen (WAM 88.303) comprises two small LVs with a common attachment area and occasional juveniles are seen attached to adult shells; none of these secondary attachments attained adult size, as if in some way inhibited by the association. The great majority of oysters appear to have lived as separate individuals, secured through life to firm "anchors", generally the shells of heteromorph ammonites as noted above. Henderson and McNamara 1985a: 65) invoke *post-mortem* rolling and tumbling on the Miria sea floor to account for wear and breakage patterns of ammonite shells, consistent with unstable conditions at the sediment-water interface. Under such exacting conditions, it would appear that successful development of the larval Miria *Pycnodonte* would have been conditional upon successful attachment to a firm, stable substrate.

Pycnodonte shells with large attachment areas, compressed form and narrow commissural shelves, which we refer to the present species, occur in the Campanian-Maastrichtian Korojon Calcarenite, and also in the nodule bed at the contact with the Miria Formation (e.g., WAM 69.802, 71.175, 84.724, 86.1464). These are generally found attached to tabulate inoceramid fragments as crowded aggregates of small LVs (Figure 7 C), occasionally with the RV present, and may be regarded as "hard ground" ecomorphs reflecting conditions of bottom scour with an abundance of flat attachment objects. Though smaller in size, the Korojon oysters are very similar to some *Pycnodonte*

◀**Figure 6.** **A-L** *Pycnodonte vesiculare* (Lamarck). **A, B** WAM 83.2967a. Locality 3. Conjoined pair, RV exterior with xenomorph; LV with broad attachment area (mould of *Eubaculites* shell), x 1. **C** WAM 83.3067. Locality 14. Conjoined valves of compressed form showing large concave attachment area of LV and beaks, x 1. **D, E** WAM 60.34. Locality 37. LV exterior, interior, x 2. **F** WAM 88.302. Locality 13. RV of conjoined valves of compressed form, x 1. **G** WAM 88.301. Locality 13. RV of conjoined valves of compressed form, x 1. **H** WAM 87.389a. Locality 10. RV of compressed form, exterior, x 1. **I** WAM 86.1318. Locality 13. Conjoined valves of compressed form, RV exterior with xenomorph possibly of *Trigonia miriana,* x 1. **J, K** WAM 83.3036. Locality 9. RV with naticiform bore hole, exterior (note radial striae), interior, x 1. **L** WAM 60.96. Locality 31. RV exterior with xenomorph, possibly of *Trigonia miriana,* x 1. All Miria Fm. Triangles indicate positions of beaks. All whitened.

from the Santonian Toolonga Calcilutite (Carnarvon Basin) and Gingin Chalk (Perth Basin) e.g., WAM 77.3525, 88.192. Shells of this form and habit resemble those of the North American Late Cretaceous ostreid genus *Pseudoperna* Logan (Stenzel 1971: N1131-4, figure J103), differing in the presence of vesicular microstructure, a diagnostic character of Stenzel's (ibid.) Pycnodonteinae. Freneix (1980: 98-99) records *Pseudoperna* from the Senonian of New Caledonia, apparently the first report of the genus from the Indo-Southwest Pacific area.

Despite its small size and somewhat atypical morphology, we are unable to accept the present material as other than a local ecomorph of the long-ranging (Albian-Maastrichtian) and cosmopolitan *Pycnodonte vesiculare* (Lamarck), described originally from the Campanian "white chalk" of Meudon (Anglo-Parisian Basin), France. In its many and varied forms, the species, *sensu lato,* has been recorded subsequently from much of Europe across to western and central Asia, the Levant, north, east and west Africa, Malagasy, South India, the Americas and probably Antarctica (Stoliczka 1871; Collignon 1931; Basse 1932; Abbass 1962; Freneix 1972; Dhondt 1982, 1985, Zinsmeister and Macellari 1988) and its presence in the Late Cretaceous of Western Australia is hardly surprising. The species ranges into the Danian (Early Paleocene) according to Freneix (ibid.) and Basse (ibid.).

The study material lacks the common, gryphaeate form of *Pycnodonte* shell characterized (on the LV) by a prominent, incurved, raised umbone and persistent growth spiral, small or no attachment area, concave-geniculate posterior margin and prominent posterior auricle; such shells have been identified with the subgenus *Phygraea* Vyalov (see Stenzel 1971: N1107, figure J83). On virtually all Miria specimens, the LV umbone and growth spiral are truncated due to the obligatory and relatively large attachment area and the auricle is small or absent. In the present material, we regard the presence or absence of these features, in whatever combination, as aspects of an adaptive syndrome and of no phylogenetic or taxonomic significance. Our evidence suggests that successful development of the larval Miria *Pycnodonte* required attachment to a firm and stable substrate and that the resultant small size and atypical form represent an ecophenotypic response to an energetic, somewhat unfavourable environment, associated with relatively coarse-grained sediment and significant water flow.

Our material includes occasional specimens (e.g., WAM 88.305, Figure 5 G,H) which resemble the holotype of *"Gryphaea" hypoptera* Wanner from the Late Cretaceous of Libya (Wanner, 1902: 118-119, pl. 17, figure 13), assigned by Abbass (1962: 71-72) to the synonymy of Lamarck's species.

Both Etheridge (1913: 17-19) and Feldtmann (1963: 119-121) have remarked on the similarity of *"Pycnodonta" ginginensis* Etheridge from the Santonian Gingin Chalk (Perth Basin) and Toolonga Calcilutite (Carnarvon Basin) to *P. vesiculare* (Lamarck) and we concur with the latter's view (ibid., p. 121) "that they belong to the same species and that any differences are those of individuals", with the qualification that such differences are likely to be environmentally derived. The species is abundant in both chalk formations.

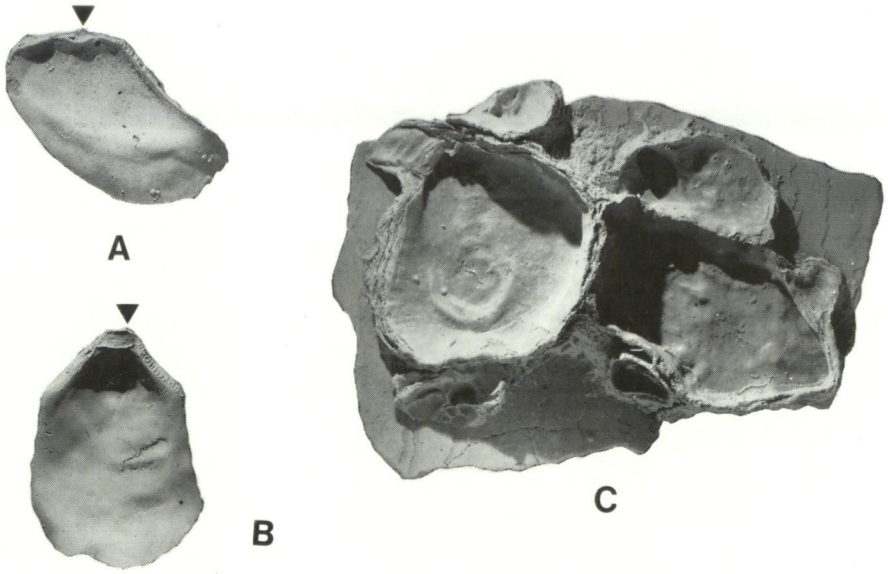

Figure 7. **A-C** *Pycnodonte vesiculare* (Lamarck). **A** WAM 88.304a. Locality 13. RV interior, x 1. **B** WAM 88.304b. Locality 13. RV interior, x 1. Both Miria Fm. **C** WAM 69.802. Locality 25. Clustered LVs attached to inoceramid fragment, x 1. Korojon Calcarenite. Triangles indicate positions of beaks. All whitened.

Compared with Miria specimens, the Santonian shells of *"ginginensis*-form" are likewise thin but attain a larger size. The attachment area, large to small, is generally present and its size and shape have influenced shell form. Truncation of the LV umbone is usual and compressed, inflated and sub-gryphaeate forms occur. In his figured material, Etheridge (ibid., pl. 4, figures 5-7) included two LV's with elevated, incurved umbones. Specimens of this form are collected occasionally (e.g., WAM 74.1187d) and may be associated with a small attachment object and area. Small clusters of shells are occasionally observed but most are single. The largest specimen known to us (WAM 77.3525a), a compressed LV, measures 92 mm (length) by 85 mm (height).

Differences in shell morphology, size and abundance between the present (Miria) material and Santonian specimens from the Western Australian chalks may have arisen from the influence on the latter of a softer substrate accumulating in a more offshore, deeper and less energised environment.

Crespin (1964) was unable to locate the type or figured material of *Pycnodonta ginginensis* Etheridge in Western Australian collections and further, recent enquiries at the Geological Survey of Western Australia and Australian Museum, Sydney, have again been unproductive and we presume that the figured specimens are lost. However, Etheridge retained for the Australian Museum a small part of the Gingin material that had been forwarded to him (Mr R. Jones, written communication, 27 July 1988),

including four specimens of *P. ginginensis* and from this we nominate Australian Museum specimen no. F 15256 as the lectotype of *Pycnodonta ginginensis* Etheridge, 1913. A specimen (UWA 48966) from "Toolonga Hill, Murchison River area" (Toolonga Calcilutite) was cited by Feldtmann (1963, pl. 5, figure 1, 1a) as a hypotype of this species.

Pycnodonta strathalbynensis Feldtmann was described (Feldtmann, 1963: 121, pl. 5, figures 4a, 4b, pl. 6, fig. 1) from a single pair of valves from the Gingin Chalk of McIntyre Gully, Gingin. It is distinguished from *P. ginginensis* by little apart from small size and its height exceeding the length and recalls Lower Cretaceous forms of *Pycnodonte* assigned to the species or subspecies *P. vesiculosa* (Sowerby) (e.g. Woods 1913, pl. 55, figures 10-14). In view of the great plasticity of form shown by shells of the *P. vesiculare* complex, we regard Feldtmann's species as an occasional morphological variant of no taxonomic validity.

Stratigraphic range

(Western Australia). Gingin Chalk, Toolonga Calcilutite, Korojon Calcarenite, Miria Formation. Santonian — Maastrichtian.

Pycnodonteine oysters from the Paleocene Cardabia Group of the Giralia Range

At least two additional pycnodonteine oysters have been collected from the study area, at times in close association with Miria and other undoubted Cretaceous fossils. Some of these oysters appear to have worked downslope into gullies or colluvial lag deposits of mixed origin. From field observations, we consider that each of the forms described hereunder has originated from overlying units of the Paleocene Cardabia Group.

(a) *Pycnodonte* sp. cf. *P. vesiculare* (Lamarck)
(Figures 8-10)

Material.

WAM 83.3068, 83.3119, 83.3122, 83.3123, 83.3124, 83.3128. Fifty three specimens. NMV P122149. Thirty six specimens.

Description.

Shell large, thick, robust, usually of gryphaeate form; vesicular microstructure present; LV strongly convex, internally capacious; umbone prominent, elevated, incurved and usually with a small or no visible attachment area; postero-ventral lobe (auricle) and sulcus prominent; commissural shelf wide, defined dorsally by a strong angulation which weakens ventrally; posterior margin concave-geniculate; chomata few or not apparent, where present, close to the ligamental area, strong and often irregular; ligamental area large, triangular, the adjacent margins (of both valves) gaping somewhat; RV concave, smaller than the LV and nestling within it; umbone small but

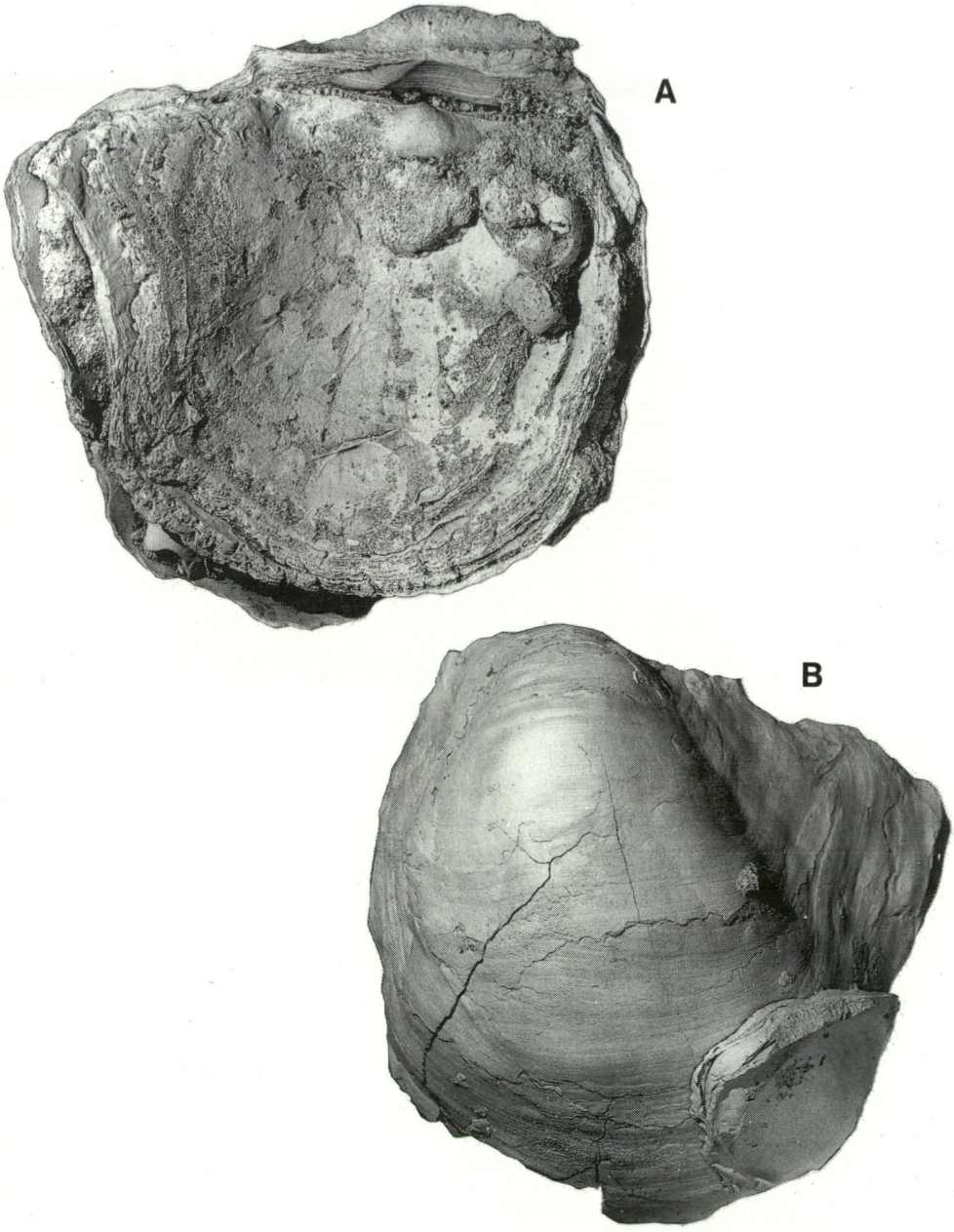

Figure 8. **A, B** *Pycnodonte* sp. cf. *P. vesiculare* (Lamarck). WAM 83.3123. Locality 34. Conjoined valves; RV exterior showing radial striae; LV exterior showing posterior auricle, x 1. Boongerooda Greensand (Paleocene). Whitened.

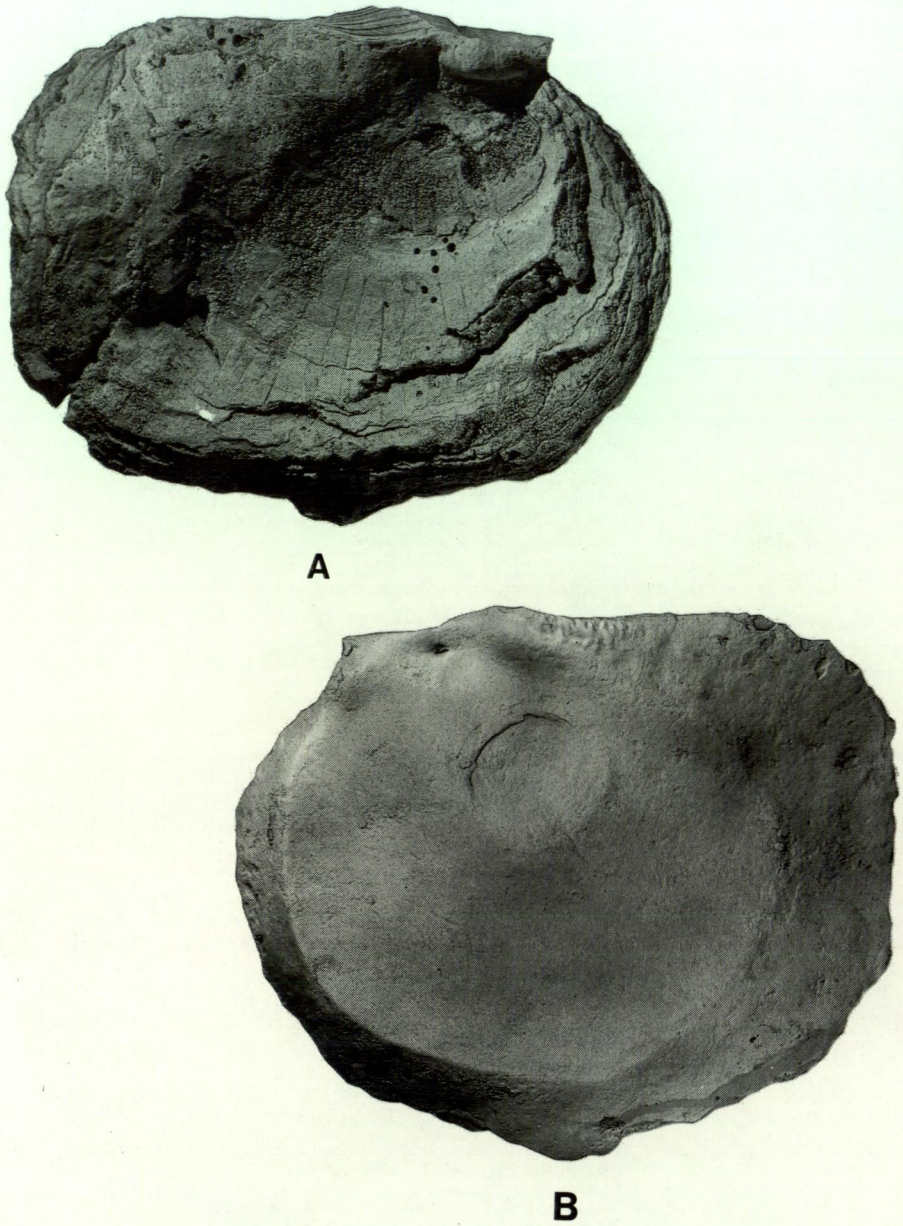

Figure 9. **A,B** *Pycnodonte* sp. cf. *P. vesiculare* (Lamarck). WAM 83.3128h. Locality 35. RV exterior showing radial striae; RV interior showing weak chomata, x 1. Boongerooda Greensand (Paleocene). Whitened.

often well differentiated from the disc; sculpture of transverse growth lamellae, sometimes crossed by distinct radial striae; commissural shelf and ligamental area both reflexed, the latter often strongly so as to be projected externally. Adductor scars (both valves) prominent, roundly subovate to subquadrate and located usually within the postero-dorsal quadrant. Most shells occur singly, occasionally in small clusters. The largest LV (WAM 83.3124b) has a length of 100+ mm, height 108+ mm, inflation 40+ mm.

Remarks.

Pycnodonte shells of gryphaeate form, such as are described above (Figure 10), resemble those assigned in the literature to the subgenus *Phygraea* Vyalov; a few specimens in the present material (e.g., WAM 83.3119, 83.3123) have truncated umbones resulting from attachment to shells, including those of heteromorph ammonites (Figures 8, 9), and have assumed a morphology more in accord with *Pycnodonte* s. str. (Stenzel, 1971: N1107, figs J81-J83). As noted by Machalski (1988: 77), these subgeneric distinctions appear to be based, in part at least, on "ecologically controlled features" (ibid.) and their taxonomic significance seems to be limited.

Henderson and McNamara (1985b: 36) report reworked Miria ammonites from the basal Boongerooda Greensand and we consider that the oyster-ammonite association in the present Paleocene material to be a further example of reworking. The age of the Boongerooda Greensand, according to McGowran (1968, 1978) is Late Thanetian, separated from that of the Miria Formation by a substantial time-break.

The present *Pycnodonte* material from the Boongerooda Greensand resembles closely many examples of *P. vesiculare* that have been figured in the literature (e.g., Stoliczka 1871, pl. 42, figure 4, pl. 43, figure 1; Woods 1913, figures 169, 171, 172, 173; Abbass 1962, pl. 10, figure 1a). Three LVs (WAM 88.479) of *P. vesiculare* from the Maastrichtian Kallankurchchi Formation ("orbitoidal limestone"), Ariyalur Group of South India are quite similar to most of our Paleocene LVs. Basse (1932: 12) records the species from the Maastrichtian and Danian of Malagasy. These records suggest that the *P. vesiculare* lineage, *sensu lato,* persisted in northwestern Australian seas until well into Paleocene time.

Machalski (1988) has redescribed *Pycnodonte simile* (Pusch) from the Danian of Poland and compared it with *P. vesiculare.* In that comparison, the present material stands substantially closer to *P. vesiculare,* differing from Pusch's species in its greater size, well-developed posterior auricular lobe and sulcus (LV), presence of radial sculpture on the RV and the presence of thick vesicular layers separated by narrow foliated layers on the RV; chomata vary in strength and distribution but no Giralia specimen has these encircling the entire valve, as may occur in *P. simile.* The range of *P. simile,* according to Machalski, is: USSR-Maastrichtian of Crimea, Danian of Georgia, Maastrichtian, Danian and Thanetian of Mangyshlak; Poland-Upper Danian. ?Austria-Thanetian.

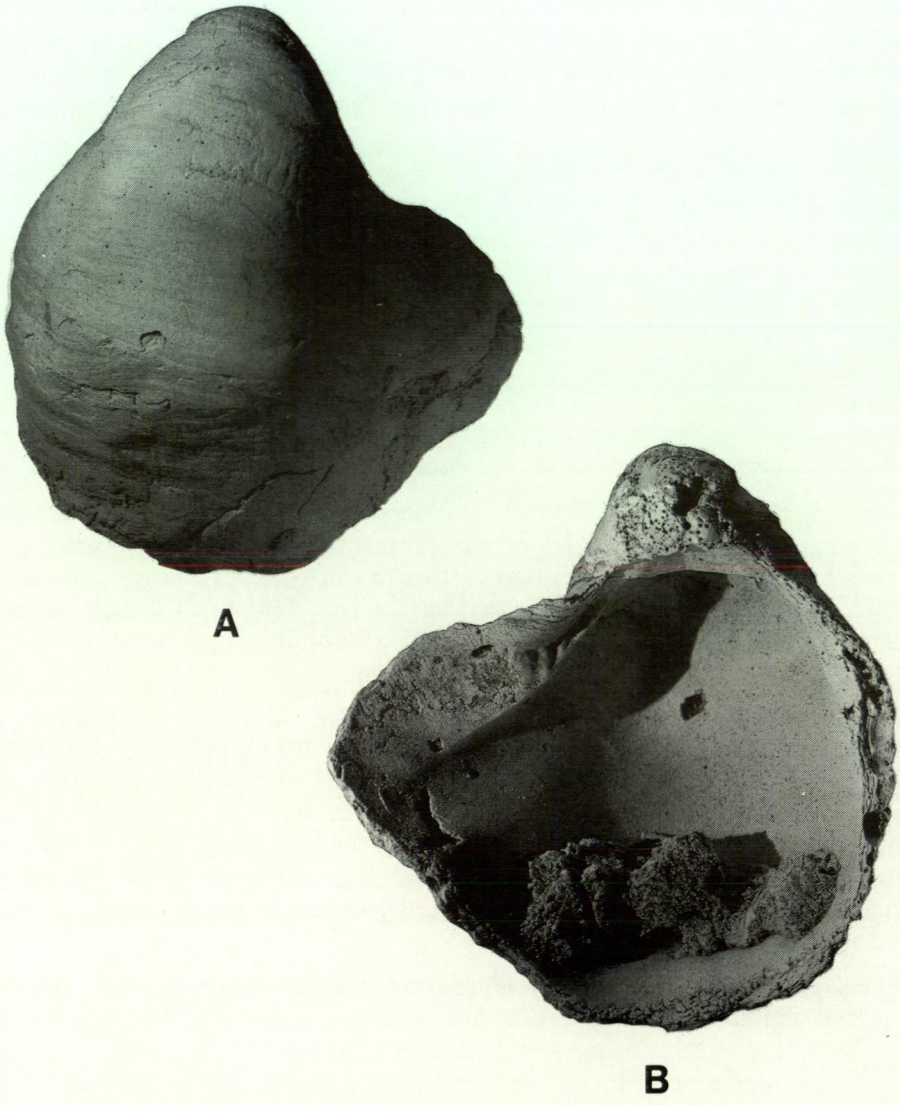

Figure 10. **A, B** *Pycnodonte* sp. cf. *P. vesiculare* (Lamarck). WAM 83.3128c. Locality 35. LV of gryphaeate form, exterior; interior, x 1. Boongerooda Greensand (Paleocene). Whitened.

Several small, robust, strongly gryphaeate LVs (WAM 60.99, 75.1218) of uncertain stratigraphic position from the Section Hill-Remarkable Hill sector of the Giralia Range may, in the absence of a continuous growth series, represent a juvenile form of the present species.

Stratigraphic range.
Boongarooda Greensand. Late Paleocene.

(b) *Labrostrea* ? sp.
(Figure 11 A-D)

Material.
WAM 60.133, 72.382, 72.391, 74.580, 80.686, 80.3027, 84.1321, 88.23, 88.27, 88.44, 88.68, 88.760. Twenty six specimens. NMV P101775-87, P119673, P122150, P122151. Fifty four specimens.

Description. Shell small, robust, LV much the larger (and more frequently encountered); vesicular structure present. LV thick, strongly convex; anteriorly short, rounded; posteriorly extended, the postero-dorsal margin concave to geniculate; umbone elevated, truncated usually by a small to minute attachment area; umbonal cavity deep, bordered by a prominent and well-defined, broad commissural shelf; ligamental area small, resilifer and bourrelets of variable sizes; adductor scar roundly subquadrate, located in the postero-dorsal quadrant; catachomata few, mostly straight, restricted to the dorsal part of the shelf which here forms a thickened ridge; catachomata more apparent on the anterior side; external sculpture of transverse, slightly foliaceous growth ridges, often worn. RV uncommon, relatively thin but robust, very slightly concave, nestling upon the commissural shelf (LV) and probably in life with a reflexed marginal flange; a strong circumpherential curb defines the cavity; adductor scar as in LV; anachomata more prominent anteriorly, where they are more or less straight; posteriorly fewer and mostly denticular; anachomata continue onto the thickened adjacent margin to form a distinct corrugation. The largest LV (WAM 83.3027) to hand has an estimated length of 43 mm, height 31 mm and inflation 14 mm.

Remarks.
The species is not uncommon in the lower units of the Cardabia Group (Boongarooda Greensand and Wadera Calcarenite) and is a regular feature of downslope lag deposits and Cretaceous erosion surfaces. It agrees well with the description and figures of *Labrostrea labrum* Vyalov, the type species of *Labrostrea* Vyalov (Stenzel 1971: N1114, fig. J87-4a-d) from the Paleogene of the Transcaspian Region, USSR and is assigned provisionally to that genus. According to Stenzel (ibid.), there is uncertainty as to the presence or otherwise of vesicular structure in *L. labrum* (an indication of pycnodonteine affinity). Positive confirmation of that character in Vyalov's species would support the relevance of that genus to the present material.

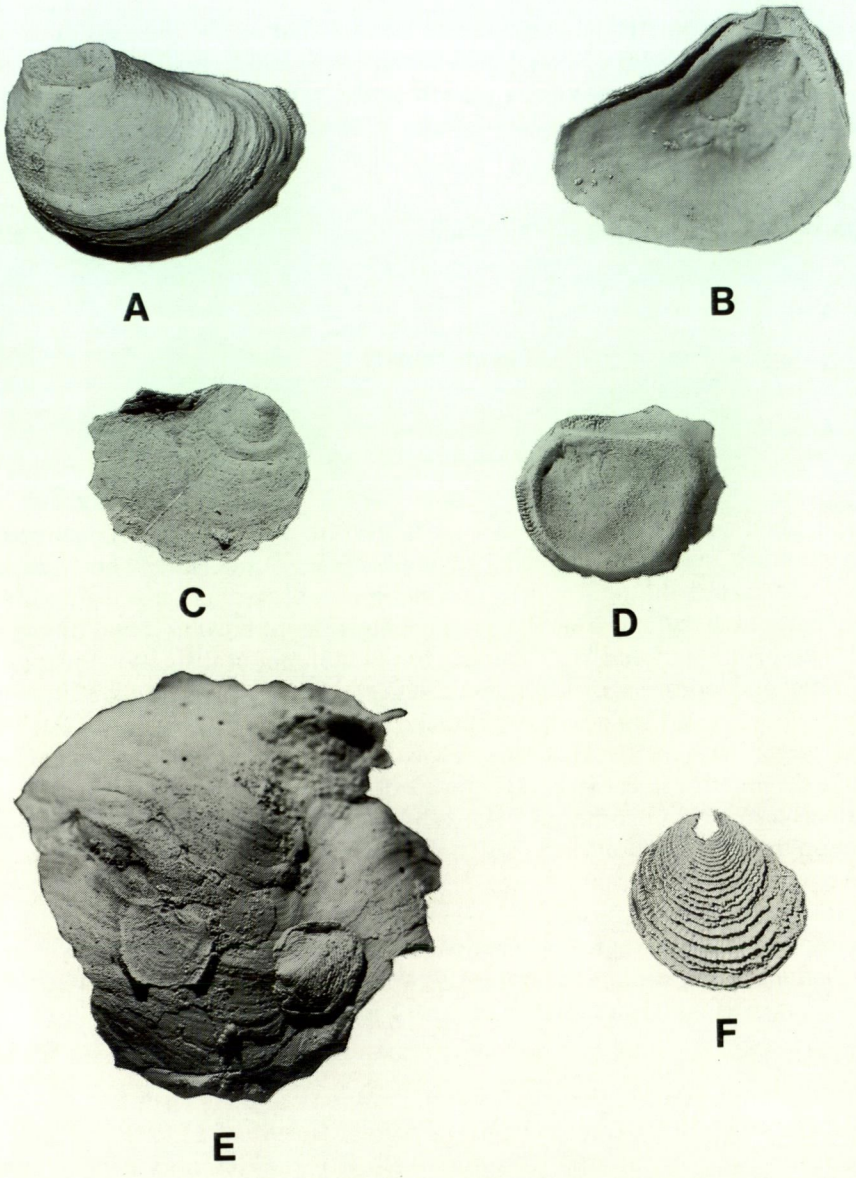

Figure 11. **A-D** *Labrostrea* (?) sp. **A, B** WAM 84.1321a. Locality 20, overlying type section of Miria Fm. LV exterior; interior, x 1.5. Boongerooda Greensand (Paleocene). **C, D** WAM 88.44a. Locality 4. RV exterior; interior, x 1.5. Probably from Wadera Calcarenite (Paleocene). **E** *Atreta* sp. cf. *A. nilssoni* (von Hagenow). WAM 86.1471. Locality 15. RV interior and LV exterior attached to LV of *Pycnodonte vesiculare* (Lamarck), x 2. Miria Fm. **F** *Dimya* sp. WAM 88.39. Locality 10. LV exterior with lamellose sculpture, x 2. Wadera Calcarenite (Paleocene). All whitened except **F.**

Our attention has been drawn (A.G. Beu, personal communication May 1987) to the resemblance of the present species to *Pycnodonte (Notostrea) tarda* (Hutton) from the Waipawan of the Chatham Islands, New Zealand (Fleming 1966, pl. 23, figures 223-233). Closer comparison of these widely dispersed but similar Paleocene oysters seems desirable.

Stratigraphic range.

Boongarooda Greensand, Wadera Calcarenite. Late Paleocene.

Superfamily Plicatulacea Watson, 1930
Family Plicatulidae Watson, 1930

Genus *Atreta* Étallon, 1862

Type species: *Ostrea blandina* d'Orbigny, 1850. By subsequent designation of Cox, 1960.

Atreta sp. cf. *A. nilssoni* (von Hagenow).

(Figure 11 E)

Ostrea nilssoni von Hagenow, 1842, pp. 546-547.

Material.

WAM 85.1407, 86.1471. Fourteen attached RVs and one conjoined pair presenting the LV exterior. NMV P119704, P126802. Two attached RVs. CPC 27833. One attached RV.

Description.

Shell small, compressed, about as long as high, inequivalve, roundly subquadrate; dorsal margin almost straight, others irregularly rounded; RV disc-shaped, with a very large attachment area and narrow, everted margin bearing fine, close-set radial costellae; LV a little smaller than the RV, nestling within it and with an everted commissure; umbone low, small, slightly anterior of centre, not transgressing the dorsal margin; sculpture (exterior) of fine, close-set, transverse lamellae generated along the everted commissure; hinge and adductor scars not seen; a row of fine, even crenulae is present internally, parallel to and well spaced from the margin; thin, widely spaced, rather weak radial costae are sometimes visible internally (RV).

Dimensions.

	Length	Height	Inflation
WAM 86.1471, pair, attached	6.5	6.2	1 (est.)

Remarks.

Internal features of the hinge and adductor scars have not been observed on the present material and some uncertainty remains as to its familial and generic affinities.

From consideration of the views of Cox (1964: 45-47) comparing the genera *Atreta* Étallon and *Dimya* Rouault, we assign the Miria species tentatively to the former, noting its close resemblance in all available characters to the Cretaceous *A. nilssoni* (von Hagenow), a widespread and long-ranging (Albian to Maastrichtian) species) of the chalks of Europe (Groenwall 1906: 203-205; Dhondt 1982: 87, pl. 2, figure 10; Cleevely and Morris 1987: 92, pl. 20, figure 11). There is also some resemblance between our material and *A. cretacea* (Conrad) from the Late Cretaceous of southwestern North America (Stephenson 1934: 273-280, pl. 38; 1935: 588-592, pl. 70). The attachment area in Conrad's species appears to be consistently smaller than in ours and its internal characters (hinge and adductor scar) appear to be unknown (Cox, 1964).

"Plicatula" glauerti Feldtmann from the Santonian Gingin Chalk of the Perth Basin (Feldtmann, 1963: 113-115, pl. 2, figures 3-7) and the Toolonga Calcilutite of the Carnarvon Basin appears to be a species of *Atreta,* which also resembles closely the present material. Feldtmann's species features a shortened dorsal margin and outlines which are "obliquely ovate to broadly piriform" (ibid. p. 113); its LV sculpture is more irregular than in the Miria material, with obscure radial elements modifying the primary transverse lamellae. Some of Feldtmann's specimens retain the crura of the hinge (for example his figure 5) but on none is the adductor scar preserved.

Feldtmann compared his species with *A. cretacea* (Conrad) and with several European plicatulids but not with *A. nilssoni.* However our material is neither adequately representative nor sufficiently well preserved for an accurate comparison to be made with these presumed congenors, including *A. glauerti.*

A record of the genus (as *Diploschiza*) from the Cenomanian of the Uttattur Group of South India is reported by Rao (1964), who compares one of his forms with *A. cretacea;* see also Chiplonkar (1987) and Tapaswi (1987).

In the Miria Formation, *Atreta* specimens have been found occasionally attached to ammonite and oyster shells. RVs predominate substantially and most show considerable wear in addition to dissolution of the cardinal area and inner shell layer, locale of the presumed single adductor scar. Specimens are uncommon and, because of small size, inconspicuous.

Small single valves (e.g., WAM 88.39, Figure 11 F) recalling *A. glauerti* in shape but with strongly lamellose LVs occur in the greensands and limestones of the Paleocene Cardabia Group in the Giralia Range and may become associated with Miria fossils by downslope drift. The adductor musculature of these specimens is likewise unknown but we assign them provisionally to *Dimya.* The LVs recall those of *D. sigillata* Tate from the Late Eocene of southern Australia (Darragh and Kendrick 1980: 16-17, figure 4C-F), differing in that most show a fine radial sculpture on the transverse lamellae.

Stratigraphic range.

Miria Formation. Maastrichtian.

Superfamily Pectinacea Rafinesque, 1815
Family Entolidae von Teppner, 1922

Genus *Entolium* Meek, 1865

Type species: *Pecten demissus* Phillips, 1829 (Quenstedt 1858) (= *Pecten disciforme* Scheubler in Zieten 1833). By original designation.

The affinities of *Entolium* have been unsettled for some time; we follow Waller (1984: 219) in assigning the genus to the family Entoliidae in association with *Syncyclonema* Meek and *Pectinella* Verrill. *Cteniopleurium* Feldtmann (1951), regarded by Newell (in Moore, 1969) and by Dhondt (1971: 7, 8) as a subgenus of *Entolium,* has not been recognized in the study material and continues to be known only from the Santonian Gingin Chalk of the Perth Basin.

Entolium sp. cf. *E. membranaceum* (Nilsson)
(Figure 12 A,B)

Pecten membranaceus Nilsson, 1827: 23, pl. 9, figure 16.
Entolium membranaceum (Nilsson): Dhondt 1971: 27-36, pl. 1, figures 2a, b (with synonymy).

Material.
UWA 91445. The posterior portion of a LV. One specimen.

Description.
Valve of medium size, robust, compressed but with a distinct posterior gape; posterior auricle small, demarcated from the disc by a linear suture; auricle bearing two strong, divergent crura, the groove separating them finely wrinkled; umbonal cavity bounded on the posterior side by a strong internal rib, bearing opposite the ventral termination of the auricle a prominent pointed tubercle; postero-ventral margin internally thickened, smooth; exterior of disc and auricle smooth except for fine, spaced growth striae; disc with remnant polish.

Dimensions

	Length	Height
UWA 91445, LV fragment.	50 (est.)	50 (est.)

Remarks.
The limited present material is consistent with the very widely distributed *E. membranaceum* (Nilsson), which during the Late Cretaceous (Turonian-Maastrichtian) has been recorded from throughout Europe, Zululand (Dhondt 1971), from New Caledonia, New Zealand, Antarctica (Freneix 1960) and from South India (Stoliczka 1871: 436, pl. 32, figure 5, pl. 41, figures 7, 8). Its occurrence in the Carnarvon Basin at this time would therefore not be unlikely. Confirmation would depend on further material becoming available. Zinsmeister & Macellari (1988) described two new species of *Entolium* from the Maastrichtian of Seymour Island but did not compare either with

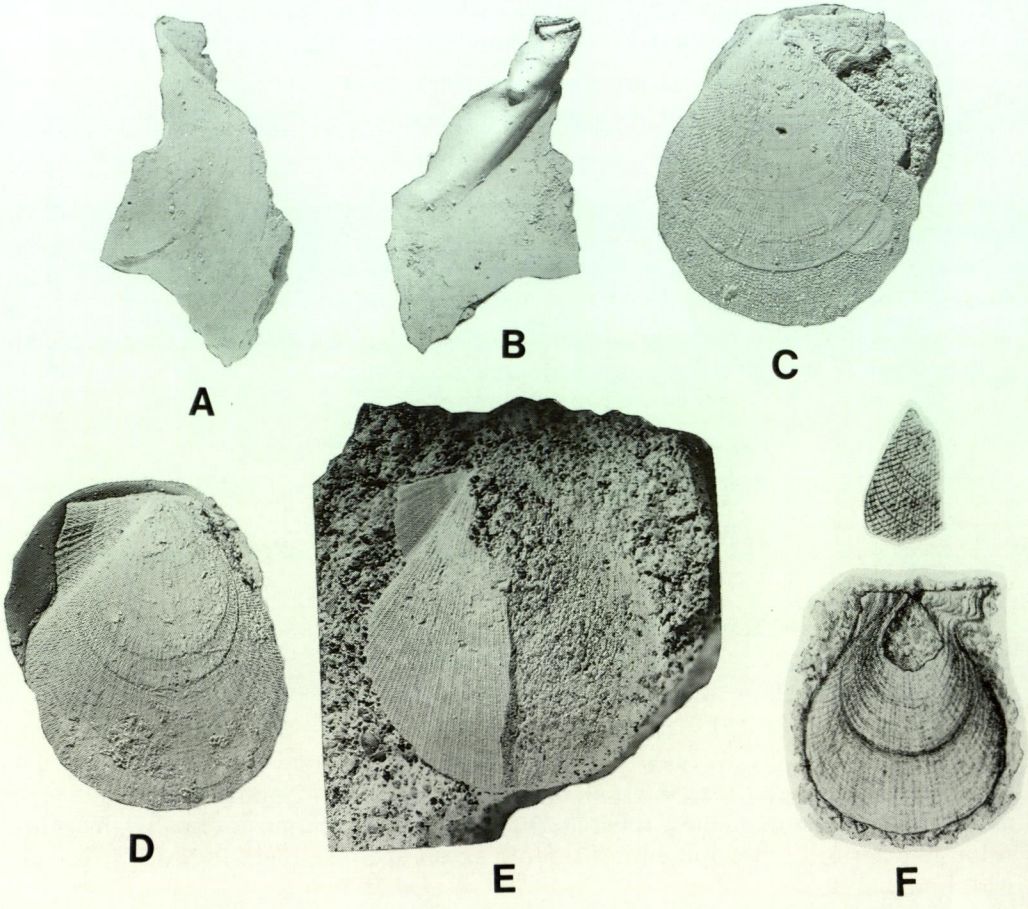

Figure 12. **A, B** *Entolium* sp. cf. *E. membranaceum* (Nilsson). UWA 91445. Locality 40. LV, posterior portion, exterior, interior, x 1. Miria Fm. **C, D** *Chlamys* (*Nipponectes*) sp. WAM 86.1225. Locality 32. Paired valves (displaced 180°); **C** RV exterior; **D** LV exterior, x 2. Miria Fm. **E** *"Camptonectes" ellipticus* Etheridge. WAM G4611. Molecap Hill, Gingin, W.A. LV anterior portion, x 2. Gingin Chalk (Santonian). **F** *Camptonectes ellipticus* Etheridge. Holotype, original figures. Dimensions of specimen 22 x 10 mm. Gingin, W.A. Gingin Chalk (Santonian). All whitened except F.

E. membranaceum. The Miria specimen has some resemblance to *E. sadleri* Zinsmeister & Macellari. The species appears to be rare in the Miria Formation.

The genus, which ranges from the Middle Triassic to Late Cretaceous according to Newell (in Moore 1969), is represented in the Albian of Queensland by *E. gradatum* (Etheridge) (Etheridge, 1902).

Stratigraphic range (Australia).

Miria Formation. Maastrichtian.

Family Pectinidae Rafinesque, 1815

Genus *Giraliapecten* gen. nov.

Diagnosis.

Pectinidae with discrepant valves; RV inflation exceeds that of LV; RV sculpture transverse with subordinate radials on flanks; LV sculpture of scaled radials unlike those of RV; byssal notch shallow; fasciole narrow; ctenolium vestigial. Distinguished from *Cyclopecten* by presence of ctenolium and by reversed valve inflation; from *Eburneopecten* by discrepant inflation/sculpture and strengths of fasciole, byssal notch and ctenolium (see Table 3).

Type species: *Giraliapecten oboloides* Darragh and Kendrick, designated herein.

Remarks.

Studies by Waller (1984) on the function and significance of the pectinacean ctenolium have led him to conclude that this structure is a family-level character, the presence of which is held to be diagnostic of the Pectinidae. Waller also recognized two forms of "pseudoctenolium", one of which is located on the RV disc along the suture demarcating the anterior auricle. Like the true ctenolium, which develops independently from the inductura, the "disc-type" of pseudoctenolium is considered to be an exclusive character of the Pectinidae.

A second form of pseudoctenolium forms along the anterior auricle of the RV on the auricular side of the suture demarcating the auricle and disc and is considered to characterize the families Propeamussiidae and Syncyclonemidae. Species of these two families lack a true ctenolium (Waller ibid.).

The present material is usually worn and incomplete but examination of all RVs to hand shows that at least nine of these retain elements of the ctenolium, located on the recurved edge of the inductura immediately anterior to the auricle and of minute size. Examples are WAM 86.1226, and NMV P119708. From the foregoing, we conclude that the new genus *Giraliapecten* should be assigned to the Pectinidae.

In the taxonomic arrangement of Hertlein (in Moore 1969: N348-N373), the affinities of *Giraliapecten* would appear to lie with elements of the "Group of *Eburneopecten*", an expedient and heterogeneous assortment of mostly smallish, thin-shelled pectens lacking internal ribs. Of these, Waller (ibid.) relocates *Pectinella* Verrill in the Entoliidae and *Cyclopecten* Verrill in the Propeamussiidae. There is a certain similarity in sculpture between *Giraliapecten* and some modern species of *Cyclopecten* (see Grau 1959) but the differences between the two genera are clear from Table 3. *Giraliapecten* appears to be an Australian endemic element; two species are recognized from the Miria Formation.

Giraliapecten oboloides sp. nov.

(Figures 13 A-F, 14 A,B)

Material.

Holotype. WAM 87.370. Paired valves, lacking the antero-ventral portion of the LV, both resilifers and the inner shell layers. From an eastward draining gully, 1 km NW of West Tank, Giralia Range, Giralia station (KV 175 883).

Table 3. Salient characters of *Eburneopecten, Syncyclonema, Cteniopleurium* (Fig. 15 A-D), *Palliolum, Cyclopecten* and *Giraliapecten.*

Characters	*Eburneopecten* after Speden (1967)	*Syncyclonema* after Speden (1967)	*Cteniopleurium* after Feldtmann (1951)	*Palliolum* after T. Abbott (1974)	*Cyclopecten* after Grau, 1959	*Giraliapecten* this paper
fasciole, RV	prominent	narrow to wide	very narrow	narrow	narrow	narrow
byssal notch, RV	strong	deep to moderate	absent or very shallow	strong	strong	shallow
ctenolium, RV	strong	absent	absent	present	weak or absent	vestigial
auricular margins	ascending slightly	straight	ascending	straight	straight or ascending slightly	straight
auricular crura	all double except LV posterior which is single	absent	double where known	?	?	all single
inflation	valves equal	valves equal	LV exceeds RV	valves equal	LV exceeds RV	RV exceeds LV
sculpture	not discrepant; divaricate	not discrepant; finely divaricate, smooth or with strong transverse striae	not discrepant; radial; beaded or spinose	discrepant or otherwise; reticulate or fine radial threads	discrepant; RV transverse; LV smooth, transverse, cancellate or with radial rows of scales or pustules	discrepant; RV transverse with radials, mainly on flanks; LV with scaled radial costae

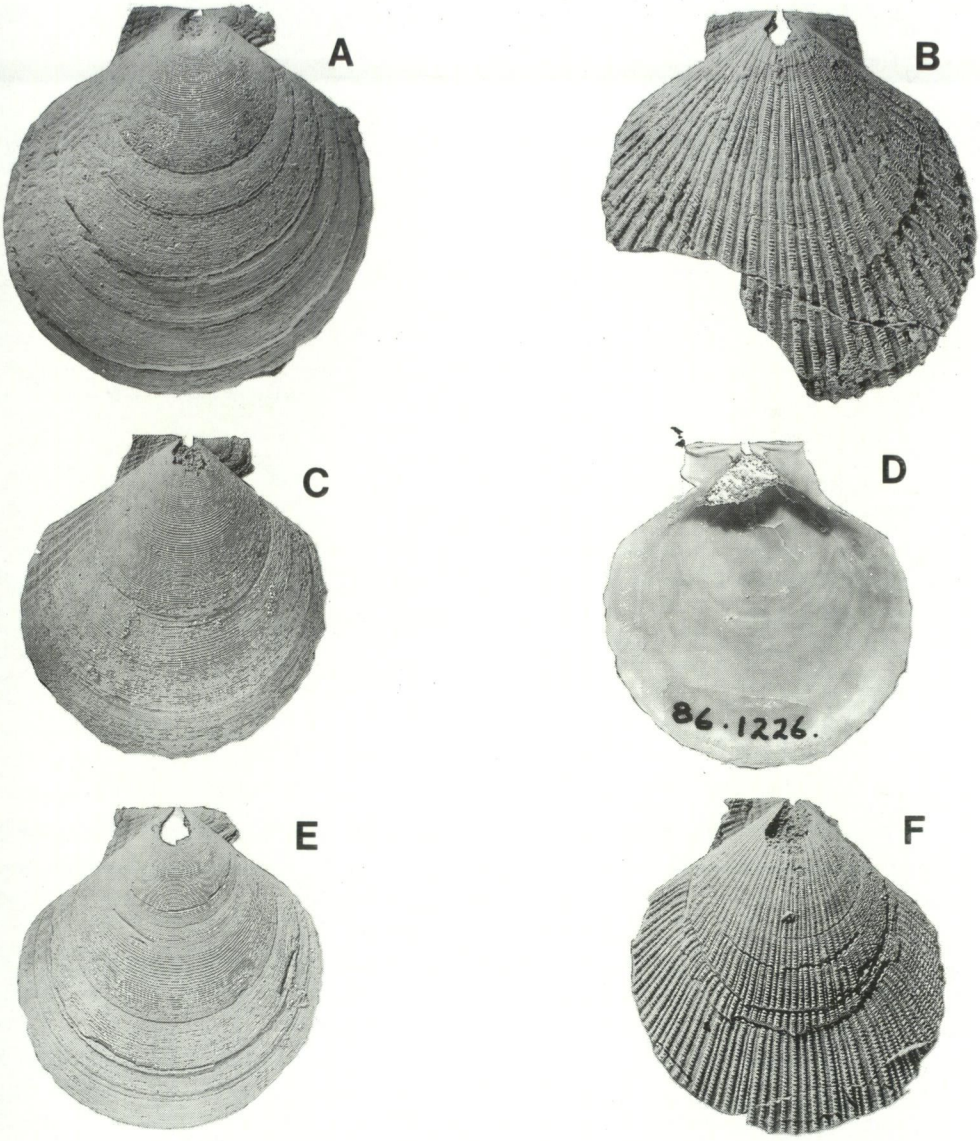

Figure 13. **A-F** *Giraliapecten oboloides* gen. et sp. nov. A, B WAM 87.370. Holotype. Locality 10. Paired valves, **A** RV, **B** LV, x 1.5. **C, D** WAM 86.1226. Paratype. Locality 32. RV exterior, interior, x 1.5. **E** WAM 86.1317. Paratype. Locality 13. RV exterior, x 1.5. **F** WAM 87.405. Paratype. Locality 3. LV exterior, x 1.5. All Miria Fm. All whitened except **D.**

Paratypes.

WAM 80.683 (pair), 83.2978 (RV), 83.3015b (RV), 86.1226 (RV), 86.1317 (RV), 86.1456 (pair), 87.405 (LV). Seven specimens. NMV P119542 (LV and internal mould), P119678-9 (pair), P102196 (LV), P102245 (RV). Four specimens. UWA 91471 (RV and internal mould). One specimen.

Other material (all fragmentary).

WAM 71.294, 74.592, 80.822, 80.853, 83.2925, 83.2964, 83.2965, 83.3015a, 83.3016, 83.3081, 83.3107, 83.3130, 86.1223, 86.1227. Fifteen specimens. NMV P101752, P119541, P119543, P119680 (part), P119708, P102253, P102274. Eighteen specimens. UWA 91444 (part). Two specimens.

Diagnosis.

As for the genus. See Table 4, below.

Dimensions.

		Max. length	Length hinge margin	Height	Inflation
WAM 87.370a*, Holotype,	RV	34.6	12.7	36.4	6.0 (est.)
WAM 87.370b*, Holotype,	LV	34.6 (est.)	12.7	36.4	4.5
WAM 80.683, Paratype,	pair	36.8	15.0 (est.)	39.0 (est.)	10.5 (est.)
WAM 86.1226, Paratype,	RV	28.4	11.5 (est.)	29.9	4.9
WAM 87.405, Paratype,	LV	29.5	12.0 (est.)	31.8 (est.)	4.0 (est.)
NMV P119678*, Paratype,	RV	35.9	?	36.1 (est.)	5.0
NMV P119679*, Paratype,	LV	35.9 (est.)	14.5 (est.)	36.1 (est.)	4.2
UWA 91471, Paratype,	RV	29.9	11.0 (est.)	30.6	4.6

*paired valves

Description.

Shell of medium size, thin, compressed, suborbicular, a little higher than long and slightly produced posteriorly; RV inflation exceeds that of LV; umbones broad, acline, the margins subtending an angle of about 115°; antero - and postero-dorsal margins straight and transversely striate; auricles short, subequal, all well-demarcated from the disc, the hinge margins thickened and transversely rugose, particularly that of the RV anterior auricle; fasciole broad; byssal notch shallow; ctenolium minute; byssal sinus small; hinge margin short; resilifer small, central, triangular (in the present material preserved rarely), bounded (RV) by two short wrinkled cardinal crura; a single, vertically wrinkled crus on each auricle, those of the RV strong, divergent from the margin but curving abruptly to join it at the extremities; anterior crus of LV prominent, attenuated, divergent, rising to join the margin a little short of the extremity; posterior crus (LV) weaker than the anterior, short, divergent; adductor scars not preserved on shells, evidently lightly impressed from the absence of evidence on internal moulds; valve interiors lacking ribs; ventral margins bevelled, smooth, lacking crenulation or folds. Sculpture discrepant: RV with very fine, close, transverse lamellae across the entire disc, with from three to ten weak radial striae confined to the anterior and posterior flanks; LV with numerous (up to 70), well-defined, low, narrow radial costellae of uneven width

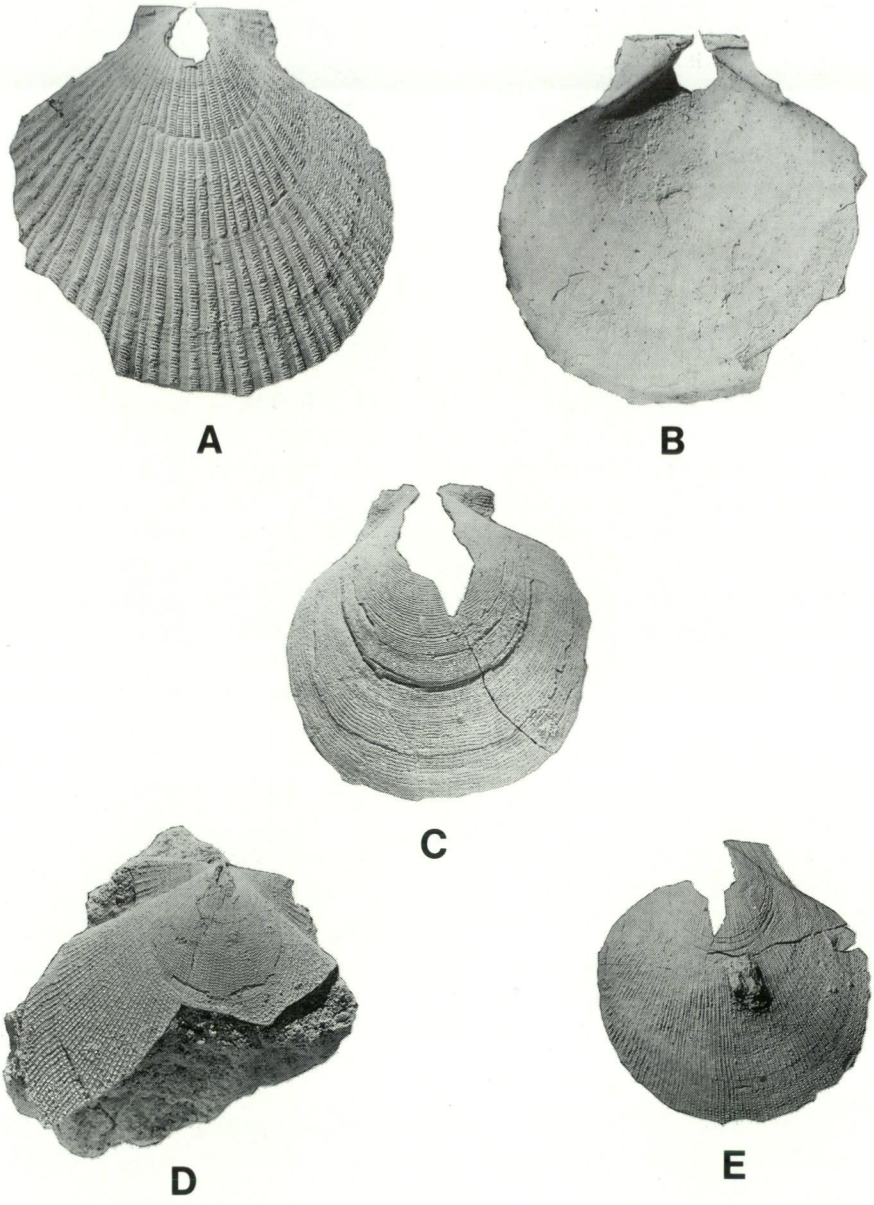

Figure 14. **A-B** *Giraliapecten oboloides* gen. et sp. nov. NMV P119679. Paratype. Locality 10. LV exterior, interior, x 1.5. **C-E** *Giraliapecten* sp. **C** UWA 91443. Locality 40. RV exterior, x 1.5. **D** WAM 83.2963. Locality 3. LV exterior, x 1.5. **E** WAM 83.2979. Locality 10. LV exterior, x 1. All Miria Fm. All whitened.

and spacing; new costellae arise independently from within the interspaces, resulting in alternating wider/narrower sequences; tops of the costellae bear fine, crowded, erect, transverse scales; intercostal spaces with very fine transverse growth striae; sculpture of beaks unknown. Auricular shape and sculpture: RV anterior, sub-alate, with from two to six fine scaled radials between the transversely rugose fasciole and hinge margin; RV posterior an isosceles triangle with four to nine scaled radials; LV anterior a scalene triangle with three to five scaled radials; LV posterior an isosceles triangle with four or five scaled radials; all auricular radials similar to the disc sculpture of the LV. The radial element on each disc is distinctive; that of the RV, striate; that of the LV, costellate.

Remarks.

Variation within the species is most evident in the radial element of the sculpture of each valve. The anterior striae (three to six) of the RV tend to be raised weakly above the transverse lamellae; the posterior striae (three to ten) tend to be incised through the lamellae. Costellae of the LV vary in number according to the size of the valve and the frequency with which new costellae arise from within the interspaces. A range of 46-70 costellae was obtained from seven of the larger, more complete specimens.

We have been unable to locate any fossil pectinid from Cretaceous or other sources that compares closely with the present species. There are however, striking but superficial sculptural similarities between this and the propeamussiids *Propeamussium (Parvamussium) davidsoni* (Dall) and *Cyclopecten benthalis* Grau, both extant species from the North Pacific (Grau, 1959, pp. 20-21, pl. 4; p. 24, pl. 5). These resemblances in systematically distant pectinacean groups appear to have arisen by homeomorphy.

Distribution of the species is general throughout the outcrop area along the Giralia Range, with most of the material to hand having come from the more northerly areas. Careful collecting from gully sections there has shown that the species, mainly as single or fragmentary valves, is not uncommon.

The specific name is derived from the Greek noun *obolos,* a coin, in view of the contrasting sculpture of the valves.

Stratigraphic range.

Miria Formation. Maastrichtian.

***Giraliapecten* sp.**

(Figure 14 C-E)

Material.

WAM 80.823 (RV), 83.2963 (LV), 83.2979 (LV), 87.383 (RV). Four specimens. NMV P101674 (RV). One specimen. UWA 91443 (RVs). Two specimens.

Description.

Shell of small to medium size, thin, compressed, suborbicular, about as high as long and slightly produced posteriorly; RV inflation exceeds that of the LV; umbones broad, acline, the margins subtending an angle of about 115°; antero - and postero - dorsal margins straight or slightly concave, sometimes transversely striate; auricles short,

sub-equal, all well-demarcated from the disc; hinge margins short, thickened internally; fasciole narrow, transversely rugose; ctenolium not seen, probably due to abrasion; byssal notch shallow; byssal sinus small; each auricle with a single, submarginal crus, finely wrinkled, that of the LV posterior rather short; ventral margins smooth, bevelled; other internal characters unknown.

Sculpture discrepant. RV predominantly with very fine, close, transverse lamellae extending over the entire disc and overriding numerous weak, close radial costellae of uneven strength and spacing, distributed across the entire disc; the lamellae form weak scales crossing the costellae and also in the interspaces (of worn specimens). LV with about 130 very fine, low, scaled, radial costellae, slightly irregular and of uneven width and spacing; new costellae arise from within the interspaces. Auricular shape and sculpture: RV anterior, broken but probably sub-alate, with six fine, scaled radials between fasciole and hinge margin; RV posterior a scalene triangle with nine very fine, scaled radials; LV anterior a scalene triangle with six very fine, scaled radials; LV posterior a scalene triangle with six very fine, scaled radials.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 83.2963, LV	37 (est.)	15.0	?	?
WAM 83.2979, LV	39 (est.)	?	40 (est.)	3.8
NMV P101674, RV	57 (est.)	?	?	7 (est.)
UWA 91443, RV	30 (est.)	11.5 (est.)	30 (est.)	4.5

Remarks.

The material to hand comprises worn and fragmentary single valves. Our correlation of left and right valves is therefore provisional, deriving from the general resemblance of each to the respective valves of *Giraliapecten oboloides,* as described above. Confirmation of this, a second species of *Giraliapecten* in the Miria Formation, would require the collection of paired valves corresponding to the present material and consistently distinct from *G. oboloides.*

The present species is distinguished, provisionally, from *G. oboloides* by sculpture, auricular characters and size according to Table 4 (page 55).

The species is uncommon; records are distributed along the outcrop area from near Remarkable Hill, Cardabia station in the south to the northern part of the Giralia Range, Giralia station.

Stratigraphic range.

Miria Formation. Maastrichtian.

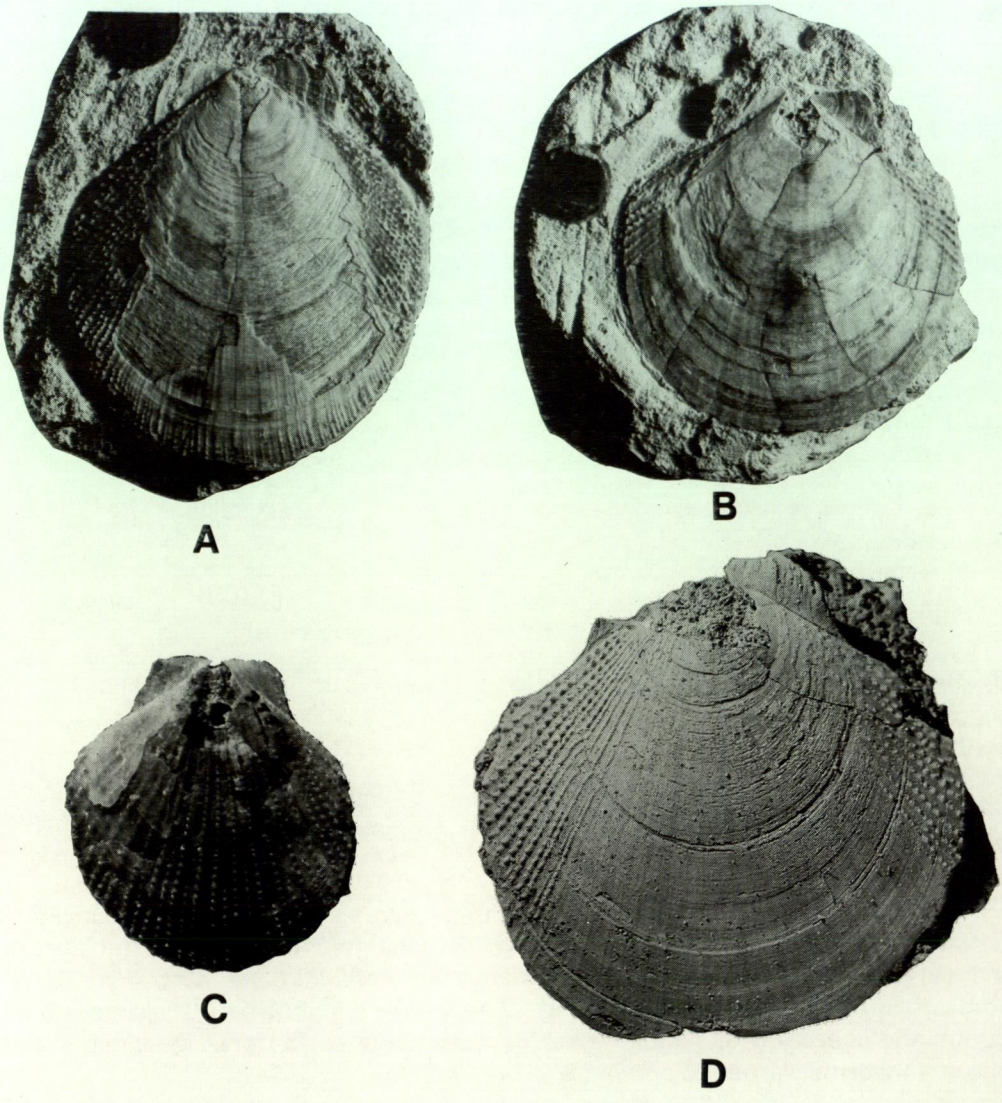

Figure 15. **A** *Syncyclonema (Cteniopleurium) subreticulatus* Feldtmann. UWA 37525. Holotype. RV, partly decorticated, x 1.8. Gingin Chalk, ca. 0.6 m below top of Marsupites subzone (Santonian). **B** *Syncyclonema (Cteniopleurium) subserratus* Feldtmann. UWA 37522. Holotype. RV, x 1.7. Gingin Chalk, near junction of the Uintacrinus and Marsupites subzones (Santonian). **C** *Syncyclonema (Cteniopleurium) perspinosus* Feldtmann. UWA 37527. Holotype. LV, x 1.8. Gingin Chalk, Marsupites subzone. (Santonian). **D** *Cteniopleurium subserratum* (Feldtmann). WAM 71.485. LV lacking antero-dorsal portion, disc not decorticated, x 2. Gingin Chalk, 0.56 m above junction of Uintacrinus and Marsupites subzones (Santonian). This specimen has 14 anterior and 12 posterior costellae. **D** only has been whitened.

Table 4. Distinguishing characters of *Giraliapecten oboloides* Darragh and Kendrick and *Giraliapecten* sp.

	Giraliapecten oboloides	*Giraliapecten sp.*
Disc		
(a) RV sculpture	Fine, close, transverse lamellae; radially striate on flanks only.	Fine, close, transverse lamellae; radially costellate over entire disc.
(b) LV sculpture	Up to 70 radial costellae bearing crowded, transverse scales.	Up to 130 very fine radial costellae bearing close, transverse scales.
(c) Max. length	40 mm	57 mm
Auricles		
(d) RV anterior	Sub-alate; fasciole broad; two to six scaled radials.	Sub-alate?; fasciole narrow; six scaled radials.
(e) RV posterior	Isosceles triangle; four to nine scaled radials*.	Scalene triangle; nine very fine scaled radials.
(f) LV anterior	Scalene triangle; three to five scaled radials*.	Scalene triangle; six very fine scaled radials.
(g) LV posterior	Isosceles triangle; four or five scaled radials*; crus extended.	Scalene triangle; six very fine scaled radials; crus short.
	* costellae like those of LV disc.	

Genus *Chlamys* Röding, 1798

Type species: *Pecten islandicus* Müller, 1776. By subsequent designation of Herrmannsen, 1847.

Subgenus *Microchlamys* Sobetski, 1977

Type species: *Pecten pulchellus* Nilsson, 1827. By original designation.

Chlamys (Microchlamys) propesalebrosa sp. nov.

(Figure 16 A-E)

Material.

Holotype. WAM 83.3000. Articulated pair with gaping valves. From eastward-draining gully, 1.8 km south of the Bullara-Giralia road, Giralia Range, Giralia station (KV 175 893).

Paratypes.

WAM 71.295 (LV), 80.852 (2 pairs, 2 LVs, 1 RV), 83.2870 (LV), 83.3055 (3 pairs), 83.3065 (LV), 83.3080a (LV), 83.3118 (pair). Thirteen specimens. NMV P101565 (pair), P119500 (RV), P126890 (pair). Three specimens. CPC 27837 (pair). One specimen.

Other material.

WAM 60.101, 68.88, 71.185, 71.256, 80.627, 80.629, 80.747, 80.875, 83.2894, 83.2912, 83.2924, 83.2941, 83.2962, 83.3014, 83.3080b-d. Twenty six specimens. NMV P98241, P98277-80, P101552, P101616-8, P101693-5, P101730-1, P101754, P101770-1, P101890, P101932, P101934, P102018-9, P102194-5, P102277-81, P119495-99, P119501-7, P119691, P119698. Fifty eight specimens.

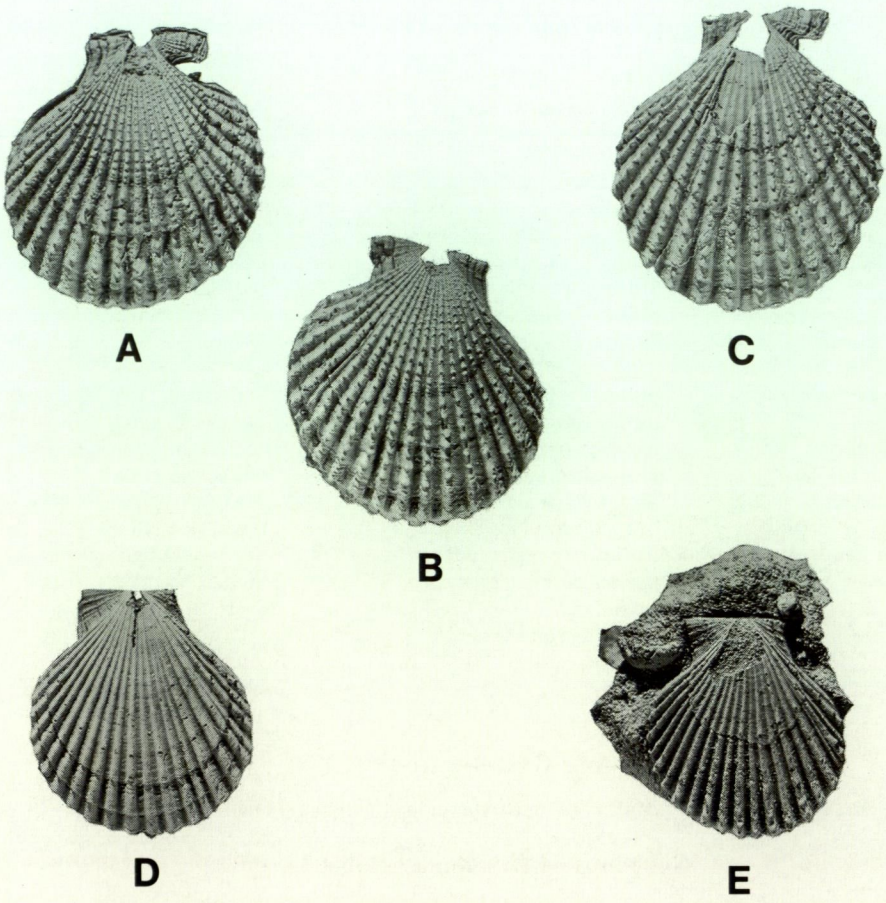

Figure 16. **A-E** *Chlamys* (*Microchlamys*) *propesalebrosa* sp. nov. **A, B** WAM 83.3000. Holotype. Locality 7. Conjoined valves; RV exterior; LV exterior; x 1.5. **C** WAM 80.852c. Paratype. Locality 18. RV exterior, x 1.5. **D** WAM 83.2870. Paratype. Locality 17. LV exterior, x 1.5. **E** WAM 83.3065. Paratype. Locality 14. LV exterior, x 1.5. All Miria Fm. All whitened.

Diagnosis.

A small *Microchlamys,* combining undivided, scaled costae, roundly triangular in cross-section, 20-24 on LV, 21-22 on RV; secondary riblets absent; microsculpture reticulate.

Description.

Shell small for the genus, robust, suborbicular, higher than long, a little produced posteriorly; LV slightly more inflated than the RV; hinge margin short, serrated, somewhat elevated; antero - and postero - dorsal slopes slightly concave, the anterior the shorter; umbonal angle of about 90^0; anterior margin roundly subtruncate, shorter and a

little higher than the posterior margin; auricles short, the anterior pair the longer; fasciole and byssal notch of the RV well developed; ctenolium very small with up to eight minute teeth; byssal sinus of the LV strong; auricular crura single on each auricle of the LV; on the RV anterior is a strong tapered crus extending the full length of the auricle with a shorter, distant divergent crus below it; RV posterior auricle with a single crus.

Sculpture of strong, spaced, simple radial costae, slightly broader on the RV and roundly triangular in cross section, wider than the interspaces, narrower toward the flanks and numbering 20-24 on the LV, 21-22 on the RV; secondary riblets absent; infrequently, new costae arise either by bifurcation or intercalation; costae bear on the crests spaced imbricating scales, which become erect-spinose toward the flanks; unworn specimens show a reticulate microsculpture on both disc and auricles; auricles bear strong, transverse growth rugae and weak radials numbering from one to seven, those on the anterior auricles exceeding those on the posterior; spaced co-marginal growth-pause lines are a feature of most specimens; cardinal area missing on all available material due presumably to the dissolution of primary aragonite; commissure strongly crenulate, interlocking, the crenulae extending onto the inner surfaces as low, rounded costae; original inner layers of valves missing and adductor scars obscure, due to dissolution of primary aragonite.

Dimensions.

	Length	Length of hinge margin	Height	Inflation
WAM 80.683, Holotype, pair	22.6	10.8	24.1	9 (est.)
WAM 80.852a, Paratype, pair	31.7	13.5 (est.)	35.3	12 (est.)
WAM 80.852c, Paratype, RV	24.0	11.4	26.5	5.0
WAM 80.852e, Paratype, pair	26.5	12.1	29.1	10.1
WAM 83.2870, Paratype, LV	19.3	8.7	21.5	3.0
WAM 83.3080a, Paratype, LV	19.0	9.7	21.2	4.4
CPC 27837, Paratype, pair	29.9	12.1	32.3	10.0 (est)

Remarks.

The present species bears a general resemblance to a widely distributed group of Late Cretaceous *Microchlamys* (Sobetski 1977: 56) species, of which it appears to be a northwest Australian representative, distinguished chiefly by its simple, scaled costae and reticulate microsculpture.

From *"Pecten (Aequipecten)" kossmati* Woods, described from a LV from the Late Cretaceous of Pondoland (Woods, 1906: 297, pl. 35, fig. 11), our species differs in its more numerous ribs (20-24 against 16) and in the absence of fine radial striation.

"Pecten" venustus Morton, from the Late Cretaceous of southeastern North America, which, from the redescription and figures of Stephenson (1941: 130-131, pl. 22, figures 3-6), appears to be a *Microchlamys,* differs from the present species in having fewer ribs

little higher than the posterior margin; auricles short, the anterior pair the longer; fasciole and byssal notch of the RV well developed; ctenolium very small with up to eight minute teeth; byssal sinus of the LV strong; auricular crura single on each auricle of the LV; on the RV anterior is a strong tapered crus extending the full length of the auricle with a shorter, distant divergent crus below it; RV posterior auricle with a single crus.

Sculpture of strong, spaced, simple radial costae, slightly broader on the RV and roundly triangular in cross section, wider than the interspaces, narrower toward the flanks and numbering 20-24 on the LV, 21-22 on the RV; secondary riblets absent; infrequently, new costae arise either by bifurcation or intercalation; costae bear on the crests spaced imbricating scales, which become erect-spinose toward the flanks; unworn specimens show a reticulate microsculpture on both disc and auricles; auricles bear strong, transverse growth rugae and weak radials numbering from one to seven, those on the anterior auricles exceeding those on the posterior; spaced co-marginal growth-pause lines are a feature of most specimens; cardinal area missing on all available material due presumably to the dissolution of primary aragonite; commissure strongly crenulate, interlocking, the crenulae extending onto the inner surfaces as low, rounded costae; original inner layers of valves missing and adductor scars obscure, due to dissolution of primary aragonite.

Dimensions.

	Length	Length of hinge margin	Height	Inflation
WAM 80.683, Holotype, pair	22.6	10.8	24.1	9 (est.)
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WAM 80.852e, Paratype, pair	26.5	12.1	29.1	10.1
WAM 83.2870, Paratype, LV	19.3	8.7	21.5	3.0
WAM 83.3080a, Paratype, LV	19.0	9.7	21.2	4.4
CPC 27837, Paratype, pair	29.9	12.1	32.3	10.0 (est)

Remarks.

The present species bears a general resemblance to a widely distributed group of Late Cretaceous *Microchlamys* (Sobetski 1977: 56) species, of which it appears to be a northwest Australian representative, distinguished chiefly by its simple, scaled costae and reticulate microsculpture.

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(LV 17-20; RV 15), in having smaller ribs intercalated between the larger ribs, and in its much longer hinge margin. Other broadly comparable species include *"Pecten" campaniensis* d'Orbigny from the Turonian to Maastrichtian of Europe and *"Pecten" acuteplicatus* Alth from the Maastrichtian of Europe, Egypt and the Levant, both redescribed (within the genus *Lyropecten* Conrad) and figured by Dhondt (1972). D'Orbigny's species appears to be rather variable in sculpture, which includes transverse elements and also a tendency for the costae to divide; it lacks reticulate microsculpture. A LV from Maastricht figured by Dhondt (ibid., pl. 1, figure 1a) is not unlike the present species. *"Pecten" acutiplicatus* Alth differs from our species in its more discrepant primary sculpture on which occur secondary riblets and "globular structures" (Dhondt, ibid., p. 29, pl. 1, figures 3a, b). *Chlamys teicherti* Feldtmann, described from a fragmentary LV and an internal mould from the Santonian Gingin Chalk of the Perth Basin (Feldtmann, 1951), recalls the present species in sculpture and proportions, differing in that the costae appear to be alternately stronger and weaker. The affinities of Feldtmann's species will become clarified with the collection of further, better material. *Chlamys (Microchlamys) propesalebrosa* is the most common pectinid species of the Miria Formation, occurring regularly throughout the area of outcrop in the Giralia Range. Articulated specimens, some gaping, are not uncommon. In the material to hand, four specimens (WAM 60.101, 71.295, 80.852e, CPC 27837) are enclosed within hard, grey, phosphatic nodules, suggesting an origin in the nodule bed at the contact of the Korojon Calcarenite and Miria Formation.

The specific name *propesalebrosa* derives from the Latin *prope* meaning near, and *salebrosa,* a rough, uneven road, in recognition of the tracks of the Giralia Range in the type area.

Stratigraphic range.

Nodule bed at contact of Korojon Calcarenite and Miria Formation; Miria Formation. Maastrichtian.

Subgenus *Nipponectes* Tashiro, 1982

Type species: *Chlamys* (s.l.) *tamurai* Tashiro, 1976. By original designation.

Chlamys (Nipponectes) sp.
(Figure 12 C, D)

Material

WAM 71.279 (RV juvenile), 86.1225 (paired valves, rotated 180° so that the ventral margin of each adjoins the dorsal margin of the other), 87.409 (LV, juvenile). Three specimens.

Description

Shell small, thin, compressed, higher than long, inequivalve, the LV more inflated than the RV; umbones slightly prosogyrate, the margins subtending an angle of about 80°; hinge margin straight, elevated; antero-dorsal slopes slightly concave; postero-dorsal slopes almost straight; anterior and posterior margins roundly subtruncate;

rounded ventrally; auricles markedly unequal, the anterior pair much the larger; RV anterior auricle produced, wing-like, thickened and transversely rugose; byssal notch prominent; ctenolium weak with up to seven minute, bead-like teeth; RV posterior auricle small, narrowly truncated like a scalene triangle; both auricles of the RV sharply demarcated from the disc; anterior auricle of the LV large, an isosceles triangle; byssal sinus present; posterior auricle (LV) very short, like that of the RV; demarcation of the LV posterior auricle sharp, of the anterior auricle, concavely rounded; auricular crura all single, submarginal, stronger on the RV; cardinal area not preserved.

Sculpture discrepant, weak, that of the RV of fine, close, flattened, divaricate costellae, stronger on the posterior flank; costellae are non-punctate and occasionally divide and anastomose; at about 17 mm from the beak, the costellae develop low, transverse scales, their absence elsewhere probably due to wear; divarication is continuous over the posterior auricle but is absent from the anterior auricle, which bears several obscure radials above the fasciole; RV generally lacks radial sculpture (non-divaricate) but under magnification with oblique light, several obscure radials may be seen on the anterior flank. Sculpture of the LV of two orders: (a) about 30 fine radial costellae of variable prominence and spacing, dispersed across the entire disc, with a further seven on the anterior auricle; (b) first-order radials and interspaces crossed by very fine, close, flattened costellae, increasing occasionally by division, divaricate about the median axis and lacking punctation; divaricate sculpture continuous from the disc over the anterior auricle, weak on the posterior auricle; divarication strongest on the anterior flank and becoming obsolete medially after about 17 mm of growth from the beak; both valves show stepped, co-marginal growth pauses. Ventral margins internally smooth; other internal characters not seen.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 71.297, RV	11.2 (est.)	6.4	13.5	1.3
WAM 86.1225, RV	18.2 (est.)	10.4 (est.)	21.5	1.5 (est.)
WAM 86.1225, LV	18.2	10.4 (est.)	21.5	2.5 (est.)
WAM 87.409, LV	8.3	4.8	10.0	1.7

Remarks

The salient feature of this species lies in its combination, on both valves, of fine, close, divaricate sculpture and weakly developed radial costellae, the latter more numerous on the LV. Micropunctation is absent from the divaricate sculpture and this, together with the presence of macrosculpture that does not follow the microsculpture, preclude assignment of the species to the genus *Camptonectes* Agassiz in Meek, 1864, after the generic diagnosis of Dhondt (1972: 5).

In sculptural and other features, the present species resembles and is probably related to *Chlamys* (s.l.) *tamurai* Tashiro from the Campanian Himenoura group and

Maastrichtian Izumi group of SW Japan, which is the type species of *Nipponectes* (Tashiro, 1982). The genus (or subgenus) was erected to encompass a group of four species from the Lower Aptian to Maastrichtian of Japan. For the present, we assign this to subgeneric rank within the genus *Chlamys* (s.l.), Tashiro's (1982) paper reached us late in the course of the present study.

The Miria species differs in sculpture from *Chlamys tamurai* in that the RV has much weaker radial ribbing while the divarication is wider, flatter and fewer in number; the LV has fewer and weaker radial costellae and the divarication is rather more prominent. These differences occur within a wider subgeneric similarity.

Dr A.V. Dhondt (in litt.) has drawn our attention to the presence in varying degrees of divaricate secondary sculpture on some European Cretaceous species belonging to *Chlamys* s.l., for example *C. robinaldinus* d'Orbigny; they are visible also on *C. fissicosta* (Etheridge) (see Woods, 1902, pl. 30, 34, 35) and occasionally on *C. cretosa* (Defrance). Though similar in proportions, outline, auricular shape and inflation, these species have much stronger radial sculpture than ours and the Japanese species of *Nipponectes.*

We note a close similarity between the present species and *Camptonectes ellipticus* Etheridge from the Santonian Gingin Chalk of the Perth Basin (Etheridge, 1913: 19-20, pl. 1, figures 16, 16a). *C. ellipticus* is known in the literature only from the type material, a single RV. Efforts to locate Etheridge's type in the collections of the Geological Survey of Western Australia, Western Australian Museum and Australian Museum have been unsuccessful and it appears to be lost. However a second specimen of *C. ellipticus,* the anterior portion of a LV (WAM G4611), collected at Molecap Hill, Gingin by Mr L. Glauert in 1926, has been examined by us and confirms similarity with the Miria species. Figures of the two known specimens of *C. ellipticus* are included here (Figure 12 E, F).

Comparison of *C. ellipticus* with the present species shows them to be of similar size and also that in both species the inflation of the LV exceeds that of the RV; a sculpture of fine radials and a divaricate microsculpture characterizes each. Etheridge (ibid.) refers to "the appearance of shell pitting" at the intersections of the two types of sculpture on his type but we have not observed this on any of the material to hand, possibly a consequence of abrasion. The hinge margin (RV) is said to be nearly half the maximum length in *C. ellipticus* but in the Miria material this dimension clearly exceeds half the length. Comparison of the RV sculptures suggest that radials are a little stronger on *C. ellipticus,* whereas the divarication is both stronger and more general across the entire disc in the Miria material. On the LV of *C. ellipticus,* the radials are narrower and more sharply defined; radials of the anterior auricle are more prominent on the Miria species.

The material to hand at present is not adequeate to determine whether one or more species is represented but clearly the two forms, one Santonian, the other Maastrichtian, are related closely.

There appears to be a close but probably superficial resemblance in sculpture between that of the LV of the present species and of both valves of *"Pecten" filosus* Hauer from the Triassic of Europe and SW Asia and type species of the genus *Filopecten* Allasinaz (Allasinaz, 1972: 301-4, pl. 40, figures 1-7, pl. 41, figures 1-4). Cox (1924: 69-70) has

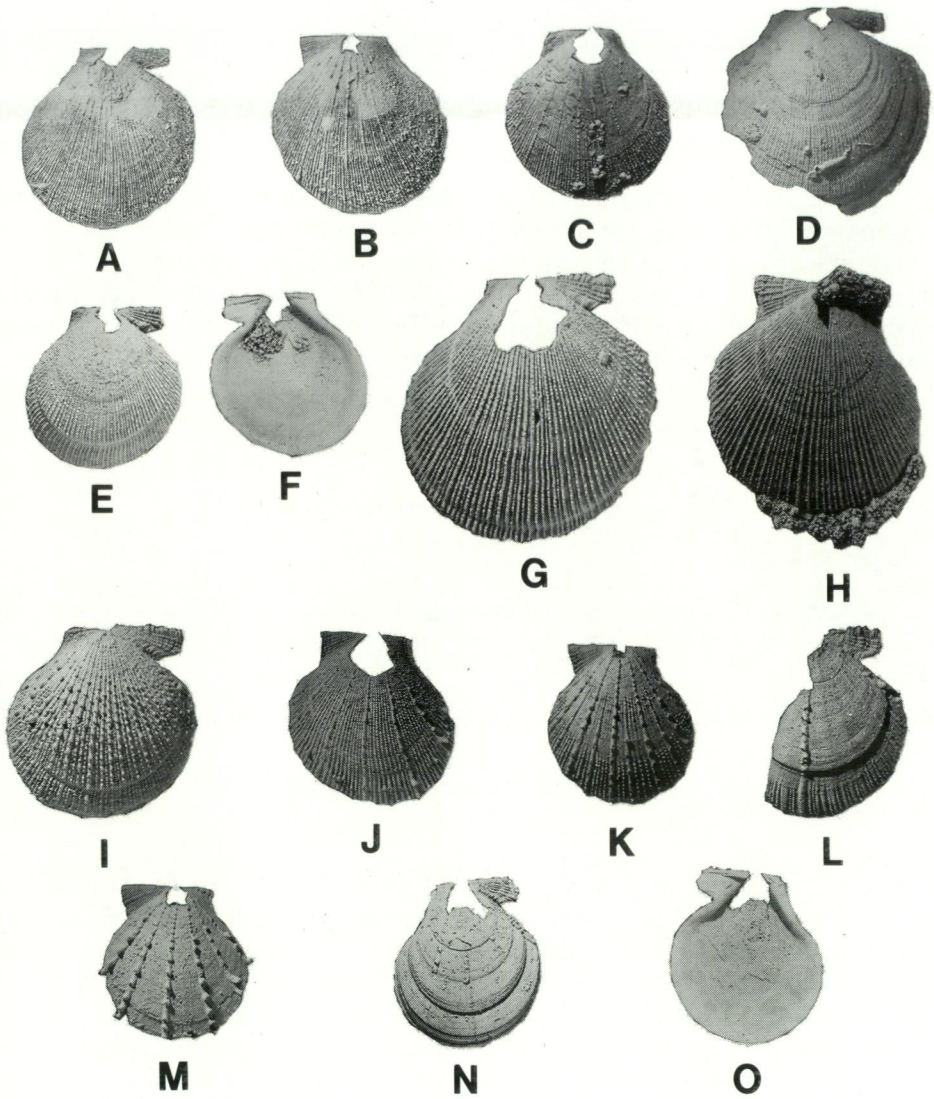

Figure 17. **A-O** *Chlamys* (s.l.) *cracenticostata* sp. nov. **A, B** WAM 83.2871. Holotype. Locality 17. Paired valves; RV exterior; LV exterior; x 1.5. Form A. **C** WAM 83.3169. Paratype. Locality 3. LV exterior, x 2. Form A. **D** WAM 87.407. Locality 3. RV exterior, x 2. Form B. **E, F** WAM 86.1228. Paratype. Locality 32. RV exterior, interior, x 2. Form B. **G** WAM 87.371. Paratype. Locality 10. RV exterior, x 2. Form B. **H** WAM 87.372. Locality 10. LV exterior (with phosphatic encrustation), x 2. Form C. **I** WAM 87.406. Locality 3. RV exterior, x 2. Form D. **J** WAM 71.309. Locality 20. LV exterior, x 2. Form D. **K** WAM 87.377. Locality 10. LV exterior, x 2. Form D. **L** WAM 87.378. Locality 10. RV anterior portion, x 2. Form D. **M** WAM 87.376. Locality 10. LV exterior, x 2. Form E. **N, O** NMV P101651. Locality 27. RV, exterior, interior, x 2. Form E. All Miria Fm. All whitened.

shown that the distinctive sculpture of *"P." filosus* is derived from the internal structure of the shell but we see no evidence of this in the present species. Other differences from *Filopecten* include (on the present species) the unequal inflation and sculpture, the strongly unequal auricles, the height's exceeding the length and the presence of a byssal sinus.

The presence of *filosus*-type sculpture, combining radial and non-punctate, divaricate ribbing, in such widely disparate elements of the Pectinidae appears to be the result of homeomorphy and not necessarily indicative of any systematic relationship.

The present species, evidently close to *Camptonectes ellipticus* Etheridge, is widely distributed but rare in the Miria Formation More positive determination is deferred until further material becomes available.

Stratigraphic range.

Miria Formation. Maastrichtian.

Chlamys, sensu lato, *cracenticostata* sp. nov.

(Figure 17 A-O)

Holotype

Holotype WAM 83.2871. Paired valves, complete but for the cardinal areas. From gullies draining south, 0.4 km south of the north boundary of Bungarra Paddock, Giralia Range, Giralia station (KV 160870).

Paratypes.

WAM 83.3169 (LV), 86.1228 (RV), 87.371 (RV). Three specimens.

Other Material.

WAM 71.296, 80.626, 87.372-82, 87.406-8, 88.20. Eighteen specimens. NMV P101651, P119534-6, P119587, P119692. Thirteen specimens.

Diagnosis.

A small, suborbicular, moderately inflated *Chlamys,* a little higher than long; LV inflation exceeding that of the RV: umbonal angle about 100°; byssal notch (RV) well developed; fasciole broad; ctenolium small with up to seven minute teeth; byssal sinus (LV) small; auricles unequal, each with a single crus; margins bevelled, internally smooth, without crenulation; sculpture slightly discrepant, extremely variable in combinations of few to many radial costellae of variable strength and spacing, with or without scales, spines or beading; costellae tend to be accentuated and spinose on anterior area of RV; anterior auricle of RV with three to five scaled or beaded radials between the fasciole and thickened hinge margin, both of which are transversely rugose; other auricles with or without weakly scaled radials.

Description.

Shell small, thin, suborbicular, height exceeding the length, slightly produced posteriorly; moderately inflated, the LV more so than the RV; umbones slightly prosocline, the margins subtending an angle of about 100°; auricles unequal, the anterior pair the larger; RV anterior auricle demarcated sharply from the disc, the others less so; byssal notch (RV) well developed; fasciole broad, transversely rugose; ctenolium small,

with up to seven minute teeth; byssal sinus (LV) small; hinge margin short, straight; antero-dorsal slope short, straight to slightly concave; postero-dorsal slope longer, slightly concave; other margins evenly rounded; auricles each with a single, submarginal, slightly divergent, finely wrinkled crus; cardinal crura not preserved; at the base (internal) of each anterior auricle is a small broad tubercle, that on the LV projecting into the byssal notch of the RV; margins bevelled, internally smooth without crenulation; other internal characters not preserved. Sculpture slightly discrepant, radial, highly diverse.

Sculpture.

Form A. RV with about 122 very fine, close, slightly irregular costellae of uneven strength and spacing; about nine of these are stronger, and distributed unevenly over the disc but particularly on the median and anterior areas; costellae bear fine, crowded, transverse scales, reduced or absent on the umbone (abrasion?); the nine stronger costellae bear low spines on the umbone and anterior area, elsewhere scales; anterior auricle with four fine, close, scaled radials between the transversely rugose hinge margin and fasciole; posterior auricle with three weak scaled radials. LV with about 130 very fine, close radial costellae, of which about ten are stronger. Otherwise sculptured like the RV; auricles with weak, scaled costellae, nine on the anterior, 12 on the posterior.

The holotype and paratype WAM 83.3169 are of Form A.

Form B. Disc of the RV with about 83 narrow, slightly irregular costellae, narrower than the interspaces, beaded or bearing low scales (fewer than in Form A) and which are more prominent and sometimes spinose on the anterior area, weaker posteriorly; auricular sculpture similar to Form A, but radials on the anterior auricle may be three or four. LV not known. WAM 87.407 is a worn, gerontic RV with about 134 very fine costellae on the disc, generally without scales except on the anterior area, where costellae and scales are more prominent; anterior auricle with three scaled radials; posterior auricle with transverse growth striae only.

Paratypes WAM 86.1228 and 87.371 are of Form B. WAM 87.407, included here notwithstanding its high rib count, could be seen to connect Forms A and B.

Form C. RV with about 77 well defined radial costellae of irregular width and spacing; new costellae arise independently from within the interspaces; erect, hollow scales of variable strength rise from the crests of the costellae, becoming prominent spines on the costellae of the anterior flank; about ten larger costellae of variable prominence are distributed unevenly across the disc, bearing proportionately stronger scales or spines; anterior auricle not seen; posterior auricle with about five weak, scaled radials. LV with about 80 fine, well defined radial costellae of irregular width (new costellae arising from the interspaces), mostly narrower than the interspaces; costellae with slight or no scale development; anterior auricle with seven to nine fine radials with few or no scales; posterior auricle with a few faint or no radials; the area between the disc and the auricles may show a strong to weak transverse striation (e.g., WAM 87.373).

Assigned to Form C are WAM 80.626, 87.372, 87.373, 87.374, 87.380 and 87.408; NMV P119587, P119692 (part).

Form D. RV with about eight to twelve relatively prominent costellae of uneven distribution, bearing erect scales and low spines, the latter particularly on the anterior flank; additionally across the disc are about 51 to 83 fine to very fine costellae, appearing at various stages of growth up to 10 mm from the beak; umbone usually smooth except for the stronger costellae; transverse scales, crowded or spaced, present on the fine costellae; anterior auricle with three or four scaled radials between fasciole and hinge margin (both transversely rugose); posterior auricle with or without several obscure radials. LV with about seven to eleven stronger costellae, bearing low spines and distributed unevenly among about 60 to 80 fine to very fine costellae, with or without transverse scales; umbones bear only the stronger costellae for the first 4 mm of growth, after which the finer radials develop; anterior auricle with seven or ten fine, scaled costellae; posterior auricle with three or four very weak radials.

Assigned to Form D are WAM 71.296, 71.309, 87.375, 87.377, 87.378, 87.381, 87.406; NMV P119534, P119536, P119692 (part).

Form E. Disc of the RV similar to that of Form D, differing in the near or total absence of the finer, second-order costellae. Specimen NMV P101651 bears two of the stronger spaced radials (one medially, one posterior to it) and on the anterior flank three spinose costellae; otherwise smooth except for prominent, stepped growth pauses; anterior auricle with five scaled radials between the rugose fasciole and dorsal margin; posterior auricle without radials. Specimen WAM 88.20a has three of the stronger spaced radials in the posterior quarter, three spinose costellae on the anterior flank and some weak to obscure fine costellae on the anterior third; otherwise smooth except for stepped growth pauses; anterior auricle with four weak radials. LV also sculptured as in Form D but lacking the finer radials; bearing up to six stronger costellae, of which the posterior two bear erect spines, the others erect scales; otherwise smooth; anterior auricle with several obscure radials; posterior auricle with a single row of submarginal scales.

To this form are assigned WAM 87.376, 87.379, 87.382, 88.20 and NMV P101651.

Dimensions.

	Length	Length of hinge margin	Height	Inflation
WAM 83.2871, Holotype, RV	15.2	8.0	16.3	3.2
WAM 83.2871, Holotype, LV	15.2	7.7	16.3	3.5
WAM 87.371, Paratype, RV	17.0 (est.)	8.5 (est.)	17.8	3.5
WAM 87.372, LV	15.5 (est.)	8.0 (est.)	16.5	3.1
WAM 87.376, RV	10.3	16.5	11.1	2.1
WAM 87.406, LV	13.0	7.9	13.2	2.9
NMV P101651, RV	10.2	6.0 (est.)	11.5	2.1
NMV P119534, LV	11.8	6.6	12.7	2.9

Remarks.

The material assigned to this species combines a broadly similar chlamydoid form, outline and auricular configuration with a highly variable but intergrading sculpture, which cannot be subdivided consistently. The above groupings (Forms A-E) are not

sharply differentiated and represent parts of a more or less continuous range of variability. Some specimens could be assigned as easily to one form as to another or to a separate group and we therefore regard this as a single variable species. The type series is restricted to relatively similar forms, characterized by numerous very fine, scaled or beaded. radial costellae.

Despite the diversity of sculpture, two features appear to be near-constant throughout. One is the prominent, spinose radials on the anterior areas of RVs. The other is the sculpture of the RV anterior auricle, which seems to vary only within narrow limits. These and other factors noted above encourage the view that our material represents a single, polymorphic species. The material to hand includes only one pair of valves, the holotype (Form A), and it should be noted that our arrangement of dissociated left and right valves into "Forms" according to sculptural similarities is subject to confirmation as more paired specimens become known.

We have been unable to locate any Cretaceous pectinid species with close resemblance to *C. cracenticostata.* There seems to be a degree of similarity with *"Pecten" raduloides* Stoliczka from the Campanian-Maastrichtian Ariyalur Group of South India (Stoliczka, 1871: 431, pl. 31, figure 20, pl. 32, figures 2, 3, pl. 42, figure 6). Stoliczka's species is equivalve, smooth-ribbed and differs in auricular configuration from ours.

The subgeneric position of *Chlamys cracenticostata* is uncertain; none of the taxa listed by Hertlein (in Moore, 1969) seems appropriate. Of these, *Mixtipecten* Marwick, 1928 (type species *"Pecten (Aequipecten)" amuriensis* Woods, Upper Cretaceous of New Zealand) comes closest, differing from the present species in its strongly discrepant valve inflation and sculpture.

Dhondt (1975: 4-6) has redescribed the subgenus (of *Chlamys*) *Merklinia* Sobetzki, 1960 (type species *"Pecten" asper* Lamarck, Albian-Turonian, N. Europe), the characters of which include a distinct, transverse striation on the "lunulate areas", as illustrated by a specimen of *C. (M.) perornata* (Cottreau) from the Senonian of Malagasy (Cottreaux, 1922, pl. 2, figure 2B). One of our specimens (WAM 87.373, Form C) shows similar striation but the significance of this, while unclear, does not seem great. The species of *Merklinia* are larger than *C. cracenticostata,* with equivalve, strongly-ribbed and marginally crenulate shells.

The present species is distributed generally along the outcrop of the Miria Formation in the Giralia Range on Cardabia and Giralia stations. Because of its small size, it is easily overlooked but careful collecting of gully sections in the northern area of the Range has shown it to be not uncommon there.

The specific name derives from the Latin *cracentis,* slender, and *costata,* ribbed, with reference to the very fine ribbing of the type series.

Stratigraphic range.

Miria Formation. Maastrichtian.

Chlamys (sensu lato) sp. A

(Figure 18 A,B)

Material.

WAM 83.3035 (LV). One specimen. NMV P101579 (LV with internal mould), P119529 (LV), P102202 (LV). Three specimens.

Description.

Shell of medium size, robust, compressed, suborbicular, a little higher than long and slightly produced posteriorly; inflation of the LV exceeding slightly that of the RV; umbone (LV) acline, gently inflated, the margins well-demarcated from the auricles and subtending an angle of about 100°; byssal sinus present, weak; auricles (LV) damaged but apparently small, subequal, the posterior an isosceles triangle; auricular crura (LV) single, submarginal, divergent from the hinge margin, finely wrinkled. Sculpture (LV) radial, of two orders; stronger costae, estimated to number about 20 are spaced unevenly across the disc, stronger in the median area and bearing spaced, erect, hollow spines and scales, of which the strongly concave aspect is directed ventrally; between each pair of first order costae are from one to three finer, scaled costellae, new ones of which arise frequently from within the interspaces, so that the number of costellae increases with growth; auricles of the LV bear weak, lightly scaled radials, about four on the anterior, four to six on the posterior; internal margin smooth, lacking crenulation and folds; the umbonal margin on the posterior side (LV) supports an oblique, divergent rib, terminating near the ventral apex of the auricle; other internal characters unknown. Right valve known only from the internal mould.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 83.3035, LV	47 (est.)	?	44	5.5 (est.)
NMV P101579, LV	22.5 (est.)	11 (est.)	23.2	7 (est., both valve

Remarks.

The limited material to hand of this highly distinctive pectinid suggests an affinity with the genus *Chlamys,* to which it is assigned provisionally.

A Cretaceous pecten with similar shape and comparable sculpture is *"Syncyclonema" (Cteniopleurium) perspinosus* Feldtmann from the Santonian Gingin Chalk (Marsupites Zone) of the Perth Basin (Feldtmann, 1951: 13-15, pl. 1, figures 6-8). Feldtmann's species, which (after Speden 1967) does not appear to be a *Syncyclonema,* is known only from the LV, and its generic and familial locations are uncertain. It differs from the present species in having 25 first-order costae and only eight weaker costellae; the scales are flat or slightly concave (strongly concave on the present species) and are lower in profile; it is a much more fragile species; a close relationship seems unlikely.

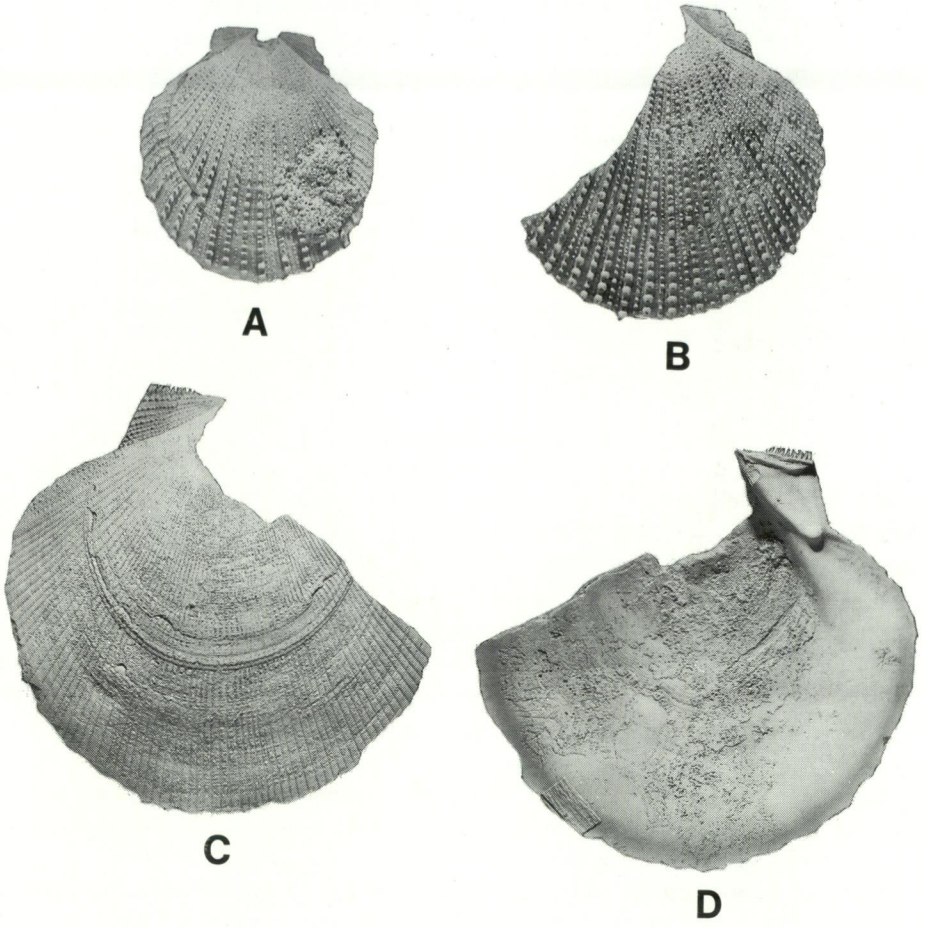

Figure 18. **A, B** *Chlamys* (s.l.) sp. **A.** A NMV P101579. Locality 33. LV with internal mould, x 1.5. **B** WAM 83.3035. Locality 11. LV (part), exterior, x 1. **C-D** *Chlamys* (s.l.) sp. B. UWA 91470. Locality 40. RV (part), exterior, interior, x 1. All Miria Fm. All whitened.

In sculpture, our species is not unlike that of a RV of *Chlamys (Granulochlamys) margaritifera* (Bittner) from the Upper Triassic (Carnian) of Hungary, figured by Allasinaz (1972: 363, tau. 48, figure 5). The subgenus was erected (ibid., pp. 361-2) for a group of Triassic species (type species *Pecten tubulifera* Münster, 1841) characterized by prominent tubercles and nodules on the radial costae, frequently tegulate, protruding and imbricating. In the species *C. (G.) margaritifera,* the strong radials bear a succession of elongated, protruding nodules which, as in the present species, are neither tegulate nor imbricating; radials are more numerous than on our species.

In the absence of the RV, the affinities of the Miria species remain uncertain. The species is uncommon but distributed widely along the Giralia Range on Cardabia and Giralia stations.

The Miria specimen is not unlike a RV figured by Stoliczka (1871: 423, pl. 42, figure 7) as *"Pecten" verdachellensis* Forbes from the Albian-Turonian Uttattur Group of South India. The ribs on Forbes' species are said to be "often subdivided", a feature which on the Miria specimen is apparent only on a few ribs on the posterior flank. A further distinction is the row of erect scales along the (posterior) auricular margin. The LV of *"P." verdachellensis* has fewer, wider ribs than the RV; that of the Miria form remains unknown.

Stratigraphic range.

Miria Formation. Maastrichtian.

Chlamys (sensu lato) sp. B

(Figure 18 C,D)

Material.

UWA 91470. (RV, incomplete). One specimen.

Description.

Shell of medium size, lacking the antero-dorsal portion, robust, suborbicular, longer than high; umbone broad (angle indeterminable), moderately inflated; postero-dorsal slope slightly concave and gaping slightly; posterior margin roundly subacuminate; ventral margin broadly and evenly rounded; posterior auricle large, an isosceles triangle, well-demarcated from the disc and forming an angle with the margin of 140°; auricle with a single, strong, submarginal crus, wrinkled vertically; on the posterior margin of the umbonal cavity, adjacent to the base of the auricle is a rounded tubercle; margin smooth, without crenulation or folds; other internal characters unknown. Sculpture of numerous flat radial costellae, numbering 80 on the specimen (estimated total 90 on the complete RV); costellae of uneven width, occasionally bifurcating and with narrower, incised interspaces; remnants of weak transverse threads or scales persist on the tops of some costellae and in some interspaces in the median area; on the posterior flank, the costellae become smoother and lower, with narrow scales confined to the interspaces; toward the posterior extremity, the scaled interspaces enlarge into narrow scaled costellae and the corresponding primary costellae become flattened interspaces; posterior auricle with eight, fine, scaled radials; hinge margin thickened, with 13 strong, erect, transverse scales.

Dimensions.

	Length	Height	Inflation
UWA 91470, RV	63 (est.)	60	8.8

Remarks.

This unique specimen represents the largest pectinid species discovered to date in the Miria Formation. Most of the finer, second order sculpture appears to have been lost

due to abrasion and/or corrosion but the available characters, e.g., the fine radial sculpture and the shape of the posterior auricle, are consistent with a species of *Chlamys*. Confirmation of this and subgeneric determination would require the collection of further material of both valves.

Genus *Neithea* Drouet, 1825

Type species: *Pecten aequicostatus* Lamarck, 1819. By subsequent designation of Chenu 1862.

Neithea sp.

(Figure 19 A)

Material.

WAM 88.21. (RV, juvenile). One specimen.

Description.

Shell small, robust, subtriangular, higher than long, plane of greatest length in the ventral half, moderately inflated; umbone prominent, gibbous, narrowly extended and projecting above the hinge margin; umbonal margins subtending an angle of 40°; distorted near the beak due to compaction and/or shell dissolution in the cardinal area, resulting in an opisthogyrate inclination; beak incurved; hinge margin short; anterior and posterior slopes extended, slightly concave; ventral margin angulate, slightly asymmetric; auricles short, subequal, the anterior damaged but probably slightly the larger; anterior auricle sharply demarcated from the disc, the posterior auricle less so; byssal notch weak; ctenolium not apparent.

Sculpture of six spaced principal radial costae, lacking radial striation, the first and sixth weaker than the other four; costae of slightly asymmetric disposition, the longest and strongest being the fourth; the third rib is bifid; the five intercostal spaces bear fine, regular, radial costellae, which are slightly wider than their interspaces; counts of the costellae in each of the five intercostal segments are four-five-five-four-five; both areas bear additional fine costellae, the anterior seven, the posterior ten; radial sculpture of the posterior area continuous with that of the auricle which bears a further six radials; anterior auricle with several obscure radials; entire disc and auricles overlain by fine, close, transverse growth striae and low ridges, more prominent medially; cardinal area poorly preserved; margins crenulated in accord with the external ribbing; other internal characters unknown.

Dimensions.

	Length	Length hinge margin	Height	Inflation
WAM 88.21, RV	8.7	3.5 (est.)	11.6	4.0 (est.)

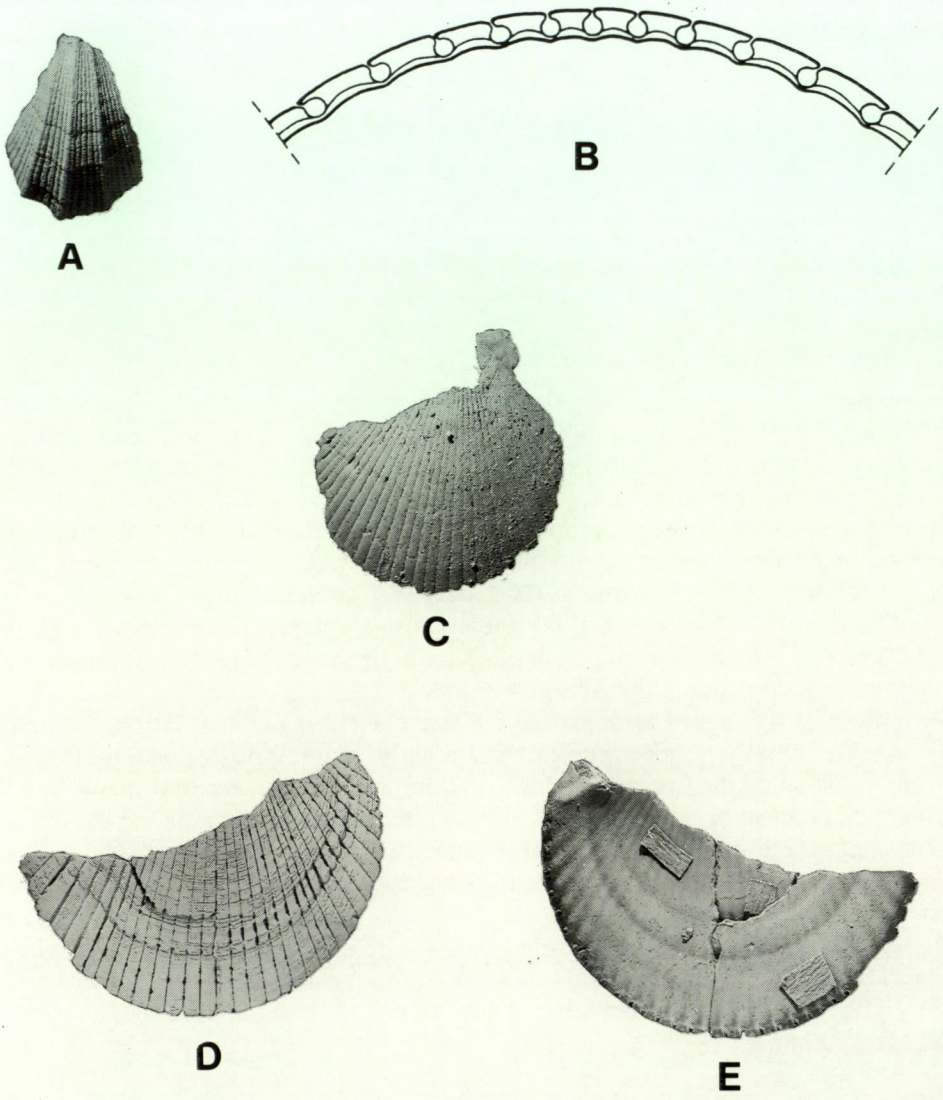

Figure 19. **A** *Neithea* sp. WAM 88.21. Locality 13. RV (juvenile) exterior, x 2. **B-E** Pectinid, genus and species undetermined. **C** WAM 87.384. Locality 10. LV exterior, x 2. **D, E** UWA 91444. Locality 40. Fragment of uncertain orientation, exterior, interior, x 1. **B** marginal cross section of UWA 91444 showing rib structure, x 1.6. All Miria Fm. All whitened.

Remarks

The limited material to hand resembles the long-ranging and widely distributed *N. quinquecostata* (J. Sowerby) in the absence of secondary radial riblets on the principal costae but differs in the disposition of these riblets across the intercostal spaces. Discussing *N. quinquecostata,* Dhondt (1973: 33) noted that "If the number of intercalaries is higher than 4 then it is found in the outer principal intervals, if it is lower than 4 then it is in the middle principal intervals." This disposition of the intercostal riblets is not matched in the present material, on which segments or "principal intervals" two, three and five have five riblets each and segments one and four have four.

Dhondt (in litt.) has advised us that there is a close resemblance between the Miria specimen and *N. sexcostata* (Woodward) (see Woods 1903: 40 and Dhondt 1973: 44-48). We note however that Woodward's species has fine secondary riblets along the principal costae (of the RV), a feature which is not apparent on the present specimen, and therefore defer positive determination until more and better material comes to hand. *N. sexcostata* is widespread in the Late Cretaceous (Cenomanian-Maastrichtian) of Europe and is present in the Senonian of Iran and "Upper Cretaceous" of Mozambique and Natal (Dhondt, ibid.).

The genus is among Kauffman's cosmopolitan Cretaceous element (Kauffman 1973: 359). It appears not to have survived the Cretaceous. A species of *Neithea,* from the Neocomian of the Northern Territory is recorded by Skwarko (1966: 88, pl. 4, figures 1-3) and compared with the North American *N. occidentalis* (Conrad).

The present species appears to be rare in the Miria Formation. Matrix associated with the specimen represents the lower, calcarenite unit of the formation.

Stratigraphic range.

Miria Formation. Maastrichtian.

Pectinid, genus and species undetermined
(Figure 19 B-E)

Material.

WAM 87.384 (LV, incomplete juvenile). One specimen. UWA 91444 (fragment of uncertain orientation). One specimen.

Description.

This is limited due to the fragmentary nature of the material. Shell of up to medium size, robust, suborbicular, about as high as long, compressed; postero-dorsal slope (LV) short, straight or very slightly concave; posterior and ventral margins rounded; posterior auricle (LV) small, well-demarcated from the disc and with a single short, divergent crus; umbonal cavity bounded on the posterior side by a short, thickened rib, bearing a low tubercle near the base of the auricle and a larger, terminal tubercle below it; internal margin bevelled, crenulate; weak radial costae extend from the marginal crenulations across the interior of the valve but appear to reflect more the external sculpture, in the

absence of the original inner layers.

Sculpture of smooth, almost flat radial costae, estimated to number about 40 on the complete valve, broader in the median area and separated by deep, almost closed, incised grooves; on juveniles, the intercostal incisions are all but closed; along the ventral margin, where the intercostal grooves are seen in cross-section, the grooves enlarge with depth, forming minute tubular cavities within the disc beneath each surface groove; in the median area, the cavities lie directly beneath each groove; towards each flank, the cavities lie to the side of each groove nearer the median area (Figure 19 B). The posterior flank of the LV is devoid of sculpture for an area equal in width to that of about three costae.

Dimensions.

	Length	Height	Inflation
WAM 87.384, LV	17 (est.)	17 (est.)	2.5 (est.)
UWA 91444, ?	54 (est.)	54 (est.)	5 (est.)

Remarks

With its unusual sculpture and limited representation, we have been unable to establish a generic identity for this rare species. The known localities are well-separated, near the northern and southern areas of outcrop in the Giralia Range.

A specimen (WAM 87.612) of what appears to be a closely related, probably conspecific pectinid, has been collected recently from the Toolonga Calcilutite (Santonian) of the Shark Bay district. It comprises the posterior half of a juvenile LV, similar to but a little less worn than WAM 87.384. The auricle is sculptured only with faint growth striae (no radials); crura are double, the upper submarginal, narrow, the lower more divergent, stronger, both short; two short internal ribs margin the umbonal cavity, of which the more dorsal one terminates in a tubercle; the postero-dorsal margin of the disc is transversely striate.

Clarification of the identity of this species would require the collection of further material.

Stratigraphic range.

Toolonga Calcilutite (?). Miria Formation. Santonian(?) — Maastrichtian.

Family Spondylidae Gray, 1826

Genus *Spondylus* Linnaeus, 1758

Type species: *Spondylus gaderopus* Linnaeus, 1758. By subsequent designation of Schmidt 1818.

Subgenus *Spondylus* sensu stricto

***Spondylus (Spondylus) schekkermanae* sp. nov.**

(Figures 20 A-E, 21 A-D)

Material.

Holotype. WAM 86.1398. Paired valves, from large gully draining eastward, 1 km WNW of West Tank, Giralia Range, Giralia station (KV 174 880).

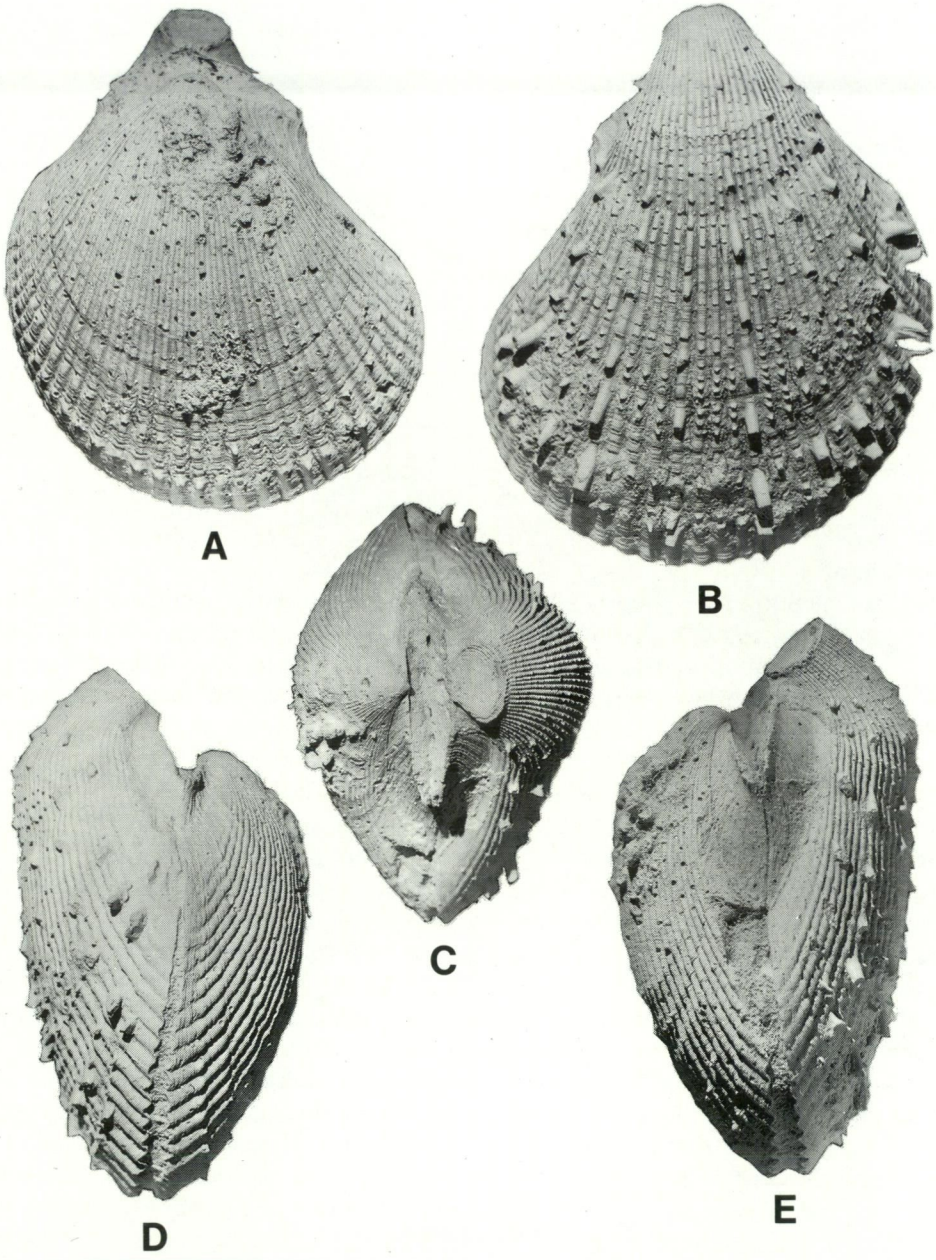

Figure 20. **A-E** *Spondylus schekkermanae* sp. nov. WAM 86.1398. Holotype. Locality 13. Conjoined valves: **A** LV, **B** RV, **C** dorsal aspect, **D** anterior aspect, **E** posterior aspect, all x 1. Corals visible on umbone of LV. Miria Fm. All whitened.

Paratypes.

WAM G10586 (pair), 60.103 (int. mould), 71.184a (RV and int. mould), 71.184b (int. mould), 80.854a (RV), 80.854d (pair), 83.2872a, b (two pairs), 83.2966a, e (two pairs), 83.3042b (LV), 87.472a, b (two pairs). Thirteen specimens. NMV P98295 (pair), P101907 (LV). Two specimens.

Other material.

WAM 60.35, 60.36, 60.67, 60.83, 60,85, 60.115, 71.191, 76.1757, 80.628, 80.684, 80.748, 80.824, 80.854b,c,e-h, 80.876, 80.888, 83.2872c,d, 83.2881, 83.2889, 83.2895, 83.2913, 83.2966, 83.2980, 83.3002, 83.3018, 83.3030, 83.3042a, 83.3056, 83.3066, 83.3082, 83.3112, 86.1459. Sixty one specimens. NMV P97597, P98230-4, P98270, P98296, P98302, P101537-9, P101548-9, P101571-2, P101578, P101602-3, P101615, P101625-7, P101635-6, P101641-5, P101675-7, P101698-9, P101724-5, P101741-5, P101763-6, P101944-5, P101980, P102093, P102197-201, P102044-50, P102249, P102254-63, P102303-5, P102352, P102385-9, P119526, P119702. Eighty-four specimens. UWA NW184. One specimen. GSWA F9388, 30083. Twelve specimens.

Diagnosis.

An inflated *Spondylus* with a small attachment area, valves with about 38 (32-46) radial costae, of two orders of prominence on RV, one on LV; bifid and intercalated costate rare. Differs from *S. spinosus* (J. Sowerby) in its more numerous ribs, weaker first-order spinosity (RV) and larger auricles.

Description.

Shell of medium size, robust, higher than long, moderately produced posteriorly; plane of greatest length located in the ventral half; valves discrepant, strongly inflated, RV the larger; umbones orthogyrate to slightly opisthogyrate, that of the RV gibbous and projecting slightly to strongly above that of the LV; attachment area small, truncating the umbone of the RV and apparently functional only in the juvenile; ligamental area of medium length, recessed, amphidetic, finely striate normal to the hinge axis, triangular on each valve, separated from the auricles by a raised rim; auricles prominent, the posterior pair the larger, each demarcated from the disc by a sulcus, which is bounded by a thin radial rib; hinge usually not preserved but, where observed, typically spondyloid with two crural teeth on each valve about a deep resilifer; adductor scars large, sub-circular to ovoid, weakly impressed, centred in the postero-dorsal quadrant; scars not apparent on shells due to dissolution of internal layers but sometimes discernible on internal moulds; commissure serrate with interlocking valve margins; marginal crenulations extend to form short, low, internal costae, visible on internal moulds. Sculpture slightly discrepant: RV with about 39 (32-46) radial costae, about as wide as or wider than the interspaces, with rounded to roundly triangular crests, medially strong and becoming slightly weaker toward the flanks; seven to ten of the costae distributed across the disc bear prominent raised spines (often broken), grooved along the ventral surface; spines on the median area directed parallel to the costae and becoming increasingly divergent, often flattened, toward the flanks; other costae with spaced, imbricating, short scales and spines; fine, close, transverse growth striae and ridges cross costae and interspaces as well as the auricles; LV with about 38 (32-42) radial costae, similar to those of the RV but bearing only short, spaced imbricating scales and spines, the latter less prominent than those of the RV; costae, interspaces and auricles

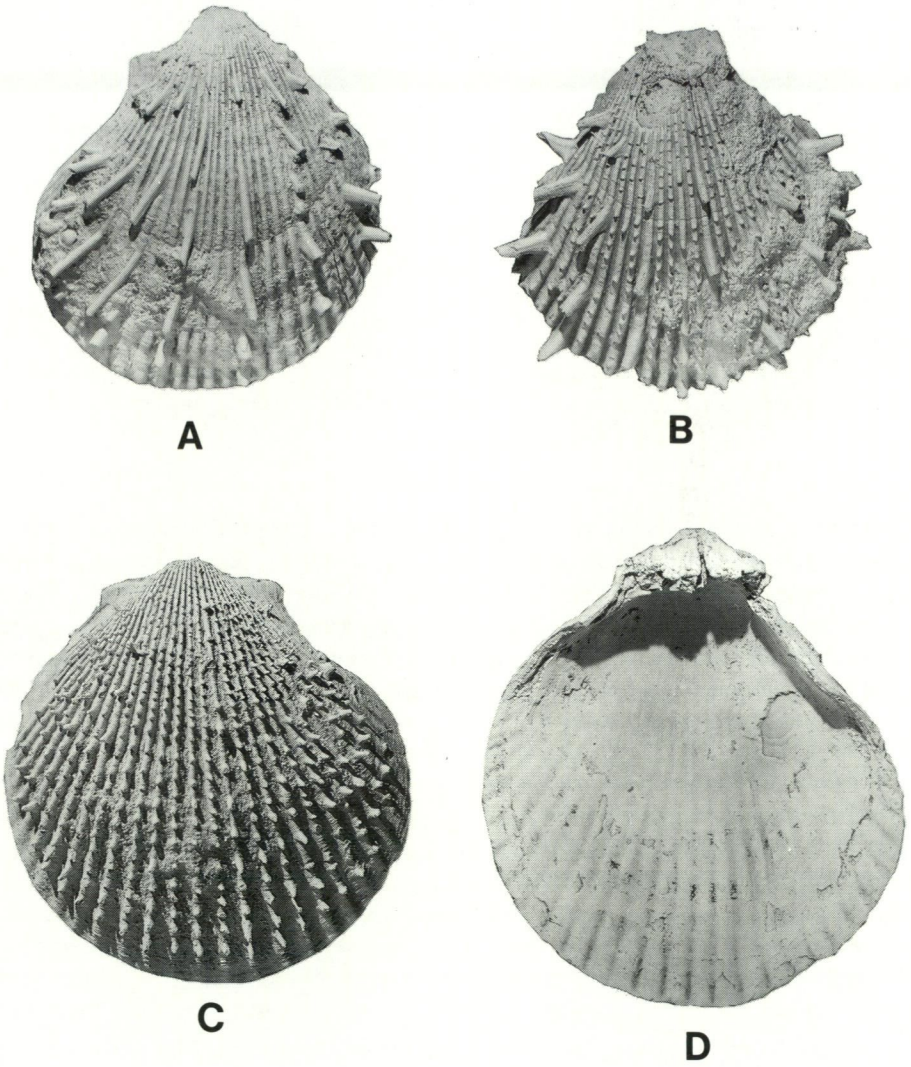

Figure 21. **A-D** *Spondylus schekkermanae* sp. nov. **A** WAM 80.854d. Paratype. Locality 18. RV exterior, x 1. **B** WAM 83.3042b. Paratype. Locality 1. RV exterior, x 1. **C** WAM 87.472b. Paratype. Locality 7. LV exterior, x 1. **D** WAM 80. 854a. Paratype. Locality 18. RV interior, x 1. All Miria Formation. All whitened.

with fine, close transverse growth striae and low ridges. Costae may be of equal number on each valve of paired specimens, but the RV often bears one or two ribs more than the LV; the reverse is uncommon (see Table 5, below). In arriving at the above rib counts, obscure and poorly preserved costae on the flanks have been included but not the thin rib adjacent to the auricular sulcus.

Dimensions.

	Length	Length hinge margin	Height RV	Height LV	Inflation
WAM 86.1398, Holotype, pair	62	32	65	76	40 (est.)
WAM 80.854d, Paratype, pair	50	25	50	55	30 (est.)
WAM 83.2872a, Paratype, pair	69	30 (est.)	74	82	42
WAM 83.2966d, Paratype, pair	59	27	58	59	30 (est.)
WAM 83.2966e, Paratype, pair	37	17	38	41	23 (est.)
WAM 87.472a, Paratype, pair	67	33	72	78	43
WAM 87.472b, Paratype, pair	57	25	60	61	33

Estimated inflations are from paired valves with small marginal gapes.

Remarks.

Variation in *S. schekkermanae* is apparent mainly in proportions and sculpture. The RV of the holotype has a narrowly extended umbone which, despite its truncation at the attachment area, extends 11 mm beyond the dorsal extremity of the LV. The same specimen has a well developed posterior extension and correspondingly long postero-dorsal slope; both valves, particularly the LV, show reduced spinosity compared with most other specimens to hand. By contrast, paratypes WAM 83.2966d and 87.472b show height differences between LVs and RVs of only one mm; these are both less produced posteriorly than the holotype with shorter postero-dorsal slopes and both valves of each are more strongly spinose than the holotype. Other combinations of these characters are observed in the material to hand. The largest attachment area sighted (WAM 83.3030b) has a diameter of 19mm, from contact with a probable *Eubaculites* shell; that of the holotype has a diameter of 11 mm and others are smaller.

Attached to the umbone of the LV of the holotype are about 15 small caryophylliid corals, similar to *Caryophyllia gracilis* Stoliczka, 1873 from the Late Cretaceous of South India (P. Jell, written communication, March, 1989).

The present species appears to be an Australian representative of a group of Tethyan — Late Cretaceous species of which the most similar is *S. spinosus* (J. Sowerby, 1814) from the Turonian-Maastrichtian chalks of Western Europe. *S. spinosus* is a highly variable species, as Woods (1901: 127-131, pl. 23, figs 6-11, pl. 24, figs 1-7) demonstrates, in which two principal forms of rib ornament occur: (a) undivided ribs on the RV are associated with relatively few, stout ribs of uniform size on the LV, and (b) bifid ribs on the RV are associated with the development of intercalated ribs among those of the LV. Woods' data (ibid., p. 130) are taken from 60 LVs of *S. spinosus,* of which 12 lack small intercalated ribs; these 12 specimens have rib counts of between 26 and 32 (mean of 28.3).

Table 5. Rib counts of 13 paired valves of *Spondylus schekkermanae:* * includes a single intercalated rib; ** includes a bifurcate rib counted as two. Rib counts of the RV exceed those of the LV on seven specimens; RV-LV counts are equal on five specimens; LV counts exceeds that of RV on one specimen. The thin radial riblet adjacent to each auricular sulcus (two per valve) has been excluded from the above counts.

WAM specimens	83.3056a	83.2895a	83.2872b	87.472b	83.2872a	87.472a	G10586	76.1757	83.2966d	80.876b	83.2966e	86.1398 HOLOTYPE	80.854d	Means of 13 pairs
LV	32	34	37	37	37	38	39	39	39	41	41*	41	42	38.2
RV	32	34	38	38	39	37**	40	40	41	41	41	42	42	38.8

As shown by Table 5, the present species differs from both of these sculptural forms of *S. spinosus* in the substantial absence on either valve of bifid and intercalated ribs and in the higher and wider range of rib numbers. A single RV of the present species (WAM 83.2980) has 46 ribs, the highest total so far observed. Other differences from *S. spinosus* are: spinosity of the LV of the present species varies, with many specimens being densely crowded with short, erect spines to a degree not observed in *S. spinosus;* though often broken, it is clear that the major, first-order spines on the RV of the present species do not attain the length of their counterparts on Sowerby's species (Carter 1972, pl. 3); additionally, our species develops a stronger posterior extension and more prominent auricles.

Carter (ibid., p. 335) interprets the growth of larger spines on the RV of European Late Cretaceous *Spondylus,* in particular *S. spinosus,* as an adaptive response to direct contact with the very fine, soft substrates of the Chalk. If so, then the more modest first-order spinosity on the RV of the present species may reflect the relatively coarser lithofacies of the Miria Formation. Examination of sediment associated with the material to hand of *S. schekkermanae* indicates that the species occurs in the calcarenite constituting the lower part of the formation (Hocking *et al.* 1987: 160); its presence in the upper calcisiltite unit at present lacks confirmation.

In general form, the present species resembles the specimen from "grey sandstones" of the Santonian Upper Trichinopoly Group of South India figured by Stoliczka (1871, pl. 33, figure 10) as *Spondylus calcaratus* Forbes. The main differences appear to concern the sculpture. On Stoliczka's specimen, a LV, there is both first and second order ribbing, which on our species is a feature of the RV only. Lakshminarayana and Roy (1978: 212) have contended that the name *Spondylus calcaratus* Forbes, 1846 should, by page priority, pass into the synonymy of *Spondylus subsquamosus* Forbes, 1846 and question

the correctness of Stoliczka's use of the former. We note, however, that Stoliczka's choice of *S. calcaratus,* that of "first revisor" under Article 24 of the *International Code of Zoological Nomenclature,* is not limited by any question of page priority and is therefore valid and not subject to alteration. Lakshminarayana and Roy (ibid.) suggest that the specimens represented by Stoliczka's (ibid.) pl. 13, figures 6, 7 and 9 correspond to *S. sulcatellus* Stoliczka and not *S. calcaratus.*

Compared with *Spondylus douvillei* Basse, from the Upper Campanian — Lower Maastrichtian "Calcaire de Trangahy", Malagasy (Basse, 1931), the present species is rather higher relative to width and has a stronger, more spinose sculpture.

Spondylus ginginensis Feldtmann from the Santonian Gingin Chalk of the Perth Basin (Feldtmann, 1963) and Toolonga Calcilutite of the Carnarvon Basin (WAM 75.12) differs markedly from the present species in its smaller, thinner and more inflated shell, with fine, slightly irregular and weakly spinose ribbing and medium-sized attachment area. The limited material to hand suggests that *S. ginginensis* lived attached to firm bioclastic substrates, such as noted by Stoliczka (ibid., p. 448, pl. 34, figure 1) for the somewhat similar *S. sulcatellus* Stoliczka from the Campanian Ariyalur Group of South India.

Spondylus schekkermanae is common, often well-preserved and widely distributed throughout the outcrop area of the Miria Formation in the Giralia Range. It is named after Mrs L.C. Schekkerman, Honorary Associate of the Western Australian Museum, who collected the holotype and kindly presented it for inclusion in this study.

Stratigraphic range.

Miria Formation (calcarenite lithofacies). Maastrichtian.

Spondylus sp. cf. *S. latus* (J. Sowerby)

(Figure 22 A-H)

Dianchora lata J. Sowerby, 1815, p. 184, pl. 80, figure 2.

Material.

WAM 71.186. The antero-ventral portion of a RV. One specimen.

Description.

A small, thin-shelled, compressed species of *Spondylus,* the attachment area of which occupies most of the external surface of the RV; attachment area where visible transversely and rugosely foliate; a strong everted flange extends around the margins and is cemented at one edge to the substrate (in this instance, a fragment of a thin-shelled inoceramid); external surface of the flange bears fine radial costae in two series, that adjoining the commissure comprising close, rounded costae, wider than the interspaces and bearing low scales and spines; that adjoining the attachment area and substrate, of narrow, spaced costae, devoid of scales and spines and aligned with the interspaces of the other series; internal surface (RV) bears fine, close, slightly irregular radial costae.

Dimensions.

WAM 71.186. Estimated length 30, height 35.

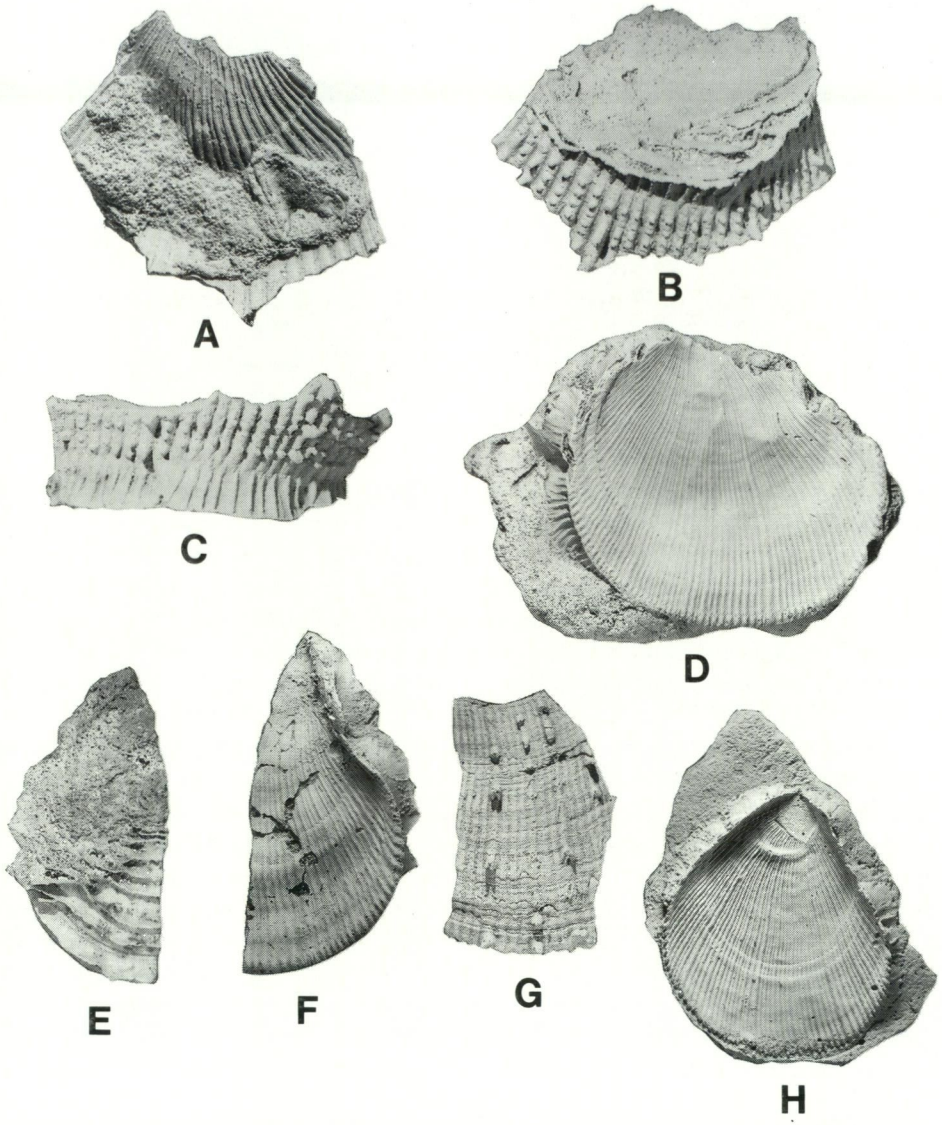

Figure 22. **A-H** *Spondylus* sp. cf. *S. latus* (J. Sowerby) **A, C** WAM 71.186. Locality 24. RV fragment; **A** interior with phospatic encrustation; **B** exterior, attachment area and ribbed flange; **C** exterior, exposed side of attachment area and flange, x 2. Miria Fm. **D** WAM 73.43. Locality 2. RV (part) attached to nodule, interior, x 1. Probably from Boongerooda Greensand (Paleocene). **E, F** UWA 91442. Locality 40. RV (part), exterior showing attachment area, interior, x 1. Boongerooda Greensand or Wadera Calcarenite (Paleocene). **G** WAM 71.167a. Locality 21. LV (part) exterior, x 1.5. Boongerooda Greensand (Paleocene). **H** WAM 74.1182a. Meanarra Hill, Kalbarri, W.A. RV attached to inoceramid fragment, interior, x 1.5. Toolonga Calcilutite (Santonian). All whitened.

Remarks.

The above limited description is from the sole specimen to hand (a fragment) which, from the associated calcarenite matrix, may be assigned with confidence to the Miria Formation. Other material (WAM 73.43, 83.3125, 86.1465; NMV P119646-9, P119666, P119670-1; UWA 91442; total of 20 specimens) from Giralia Range localities is similar to the single Miria Formation specimen but is considered, from lithological or direct field evidence, to have originated either from the Paleocene Boongerooda Greensand or Wadera Calcarenite.

We have in addition examined a range of *Spondylus* material from the Santonian Toolonga Calcilutite of the Lower Murchison district (WAM G7203, 74.1128, 75.13, 79.2907, 88.195, 88.202; total 17 specimens) and from the Santonian Gingin Chalk of Dandaragan, Perth Basin (WAM 78.4213, 78.4374, 79.2259; total six specimens), all of which resemble the foregoing.

The above mentioned Santonian, Maastrichtian and Paleocene material comprises 45 RVs and fragments thereof and a single articulated pair (WAM 86.1465), the latter distorted, worn and incomplete. Taken together it suggests a species of *Spondylus* small for the genus, of irregular shape, higher than long, a little produced posteriorly and with the plane of greatest length lying in the ventral half. The RV may be flat or irregularly contoured, according to the character of the substrate; the attachment area occupies the greater part of the RV exterior; umbone prosogyrate to opisthogyrate, the margins subtending an angle of around 80^0-90^0; auricles not usually apparent but probably small; cardinal area not preserved; dorsal margin very short, acuminate; other margins of variable configuration but generally broadly rounded ventrally; margin usually on a raised rim formed by the more or less continuous attachment flange; rim may be reduced in elevation ventrally; internal surface (RV) with up to 70 close, low, slightly irregular radial costae, of which some five to nine are more prominent than the others; new costae arise by intercalation, so that width is variable and the number increases with growth; costae crenulate the margins and extend beyond them onto the commissural flange; on each side of the cardinal area, the inner surface of the marginal rim is devoid of radials and here bears a weak transverse sculpture; inner layer of the valve, bearing the adductor scar, not preserved. The attachment area, where visible, is seen to be transversely and rugosely foliate; these structures are formed sequentially from the substrate-contact of the marginal flange; sculpture of the flange variable in prominence but generally similar to that of the Miria Formation specimen, described above, though lacking scales and spines.

The LV is poorly represented in the Santonian-Paleocene material. It appears to be thin-shelled and perhaps a little more inflated than the RV; sculpture of numerous fine, close, low, irregular radial costae, some of which (like the interior of the RV) are more prominent than the others.

Two large specimens (both RVs) have the following estimated dimensions: WAM 83.3125b, Boongerooda Greensand, Length 60, Height 65; WAM 88.195, Toolonga Calcilutite, Length 35, Height 40.

Specimens from the Toolonga Calcilutite and Gingin Chalk are usually attached to fragments of inoceramid or oyster shell. Those from the Paleocene of the Giralia Range are often attached to oyster shells or to phosphatic nodules; some show no evidence of attachment.

The present material from various Western Australian sources resembles closely *Spondylus latus* (J. Sowerby) from the Cenomanian to Late Maastrichtian of Europe (Dhondt 1982), Campanian of Egypt (Abbass 1962)and from the Turonian Deola-Chirakhan Marl (Bagh Beds) of the Narmada Valley, Madhya Pradesh (Chiplonkar and Badve 1973). One of our specimens (WAM 74.1182a) from the Toolonga Calcilutite of Meanarra Hill, Murchison River district, shows (Figure 22 H) a strong resemblance to a specimen of *S. latus* from "Chalk, Gravesend" (England) figured by Carter (1972, pl. 2, figure 5).

Because of its fragmentary nature, the precise identity of the sole Miria Formation specimen remains subject to confirmation.

Stratigraphic range.

Miria Formation. Gingin Chalk?, Toolonga Calcilutite?, Boongerooda Greensand?, Wadera Calcarenite? Maastrichtian. Santonian?, Paleocene?.

Subclass Palaeoheterodonta Newell, 1965
Order Trigonoida Dall, 1889
Superfamily Trigonacea Lamarck, 1819
Family Trigoniidae Lamarck, 1819

Genus Trigonia Bruguière, 1789

Type species: *Venus sulcata* Hermann, 1781 (ICZN Opinion 327, 1955).

***Trigonia miriana* Skwarko, 1963**
(Figure 23 A-E)

Trigonia (?) *miriana* Skwarko, 1963: 14, pl. 1, figures 2, 3.
Trigonia miriana: Darragh, 1986: 7-8, figures 4M, 5D.

Material.

WAM 60.33 (hypotype), 60.37, 60.64, 60.88, 60.100, 71.188, 75.1207, 75.1208 (hypotype), 80.687, 80.855, 80.877, 83.2883, 83.2896, 83.2915, 83.2952, 83.2968, 83.3003, 83.3044, 83.3057, 83.3069, 86.1219, 87.307. Twenty six specimens. NMV P41761, P41763, P41764, P98273, P101584, P101700-1, P101726, P101748-9, P101903, P101983-4, P102056-7, P102094, P102096, P102287, P102324, P102342-4, P102360, P102378-9. Fifty one specimens. UWA NW144. Three specimens.

Diagnosis.

Trigonia miriana has been redescribed by Darragh (1986: 7-8, figs 4M, 5D). Further material to hand indicates that the sulci are discrepant in both sculpture and width, that of the LV being broader than that of the RV (Figure 23 A,B); anterior pedal retractor, anterior pedal protractor and posterior pedal retractor scars are all present.

Dimensions.

	Length	Height	Inflation
WAM 60.33, Hypotype, (pair)	44	47	36.7 (gaping)
WAM 75.1208, Hypotype, (LV)	42	40	17
WAM 83.3003, — (pair)	47	44.5	35
WAM 86.1219, — (pair)	44	42.5	35

Remarks.

Darragh (1986: 7-8, figures 4M, 5D) concluded that *Trigonia miriana* appeared to be an intermediate representative of a broad evolutionary trend connecting "the classical costate group of *Trigonia* from Europe and Asia" with the Paleocene-Miocene *Eotrigonia* of Australia. Ancestral *Trigonia* characters include the relatively large size, the strong serrate carina, broad sulcus and well developed escutcheon. Others considered to anticipate *Eotrigonia* include the quadrate outline, thin shell, radial folds on the internal surface of the area, crenulate posterior margin, discrepant width and sculpture of the sulci, radial sculpture of the escutcheon and the radial alignment of the secondary sculpture on the flank adjacent to the sulcus. Additional well preserved specimens (e.g., Figure 23 A-C) collected recently are in accord with Darragh's conclusions.

We are aware of no closely comparable Cretaceous congenor of *Trigonia miriana* and regard it provisionally as part of an endemic Australian lineage, the other elements of which are unknown. Darragh (ibid. p. 2) has suggested that the Middle Jurassic *Trigonia moorei* Lycett (Skwarko 1974: 92-3, pl. 33, figures 1-7) from the Champion Bay Group of Western Australia may represent an appropriate ancestral group. In this context, the report by Cox (1961: 21, pl. 3, figures 6-8) of two species of *Trigonia* s. str. in the Neocomian-Aptian Nanutarra Formation of northwestern Australia (Skwarko 1966: 67-68) is of interest.

Trigonia miriana is common along the entire outcrop area of the Miria Formation in the Giralia Range, usually as phosphatic internal moulds. Well preserved specimens retaining the shell are rare.

Infilled moulds of clionid sponge borings, similar to those attributed to *Entobia cretacea* Portlock by Henderson and McNamara (1985a: 310, figure 3A, B), cover the exterior of WAM 87.307, a LV of *T. miriana*.

Stratigraphic range.

Miria Formation. Maastrichtian.

Genus *Linotrigonia* van Hoepen, 1929

Type species: *Linotrigonia linifera* van Hoepen. 1929. By original designation.

Subgenus *Oistotrigonia* Cox, 1952

Type species: *Trigonia spinosa* Parkinson, 1811. By original designation.

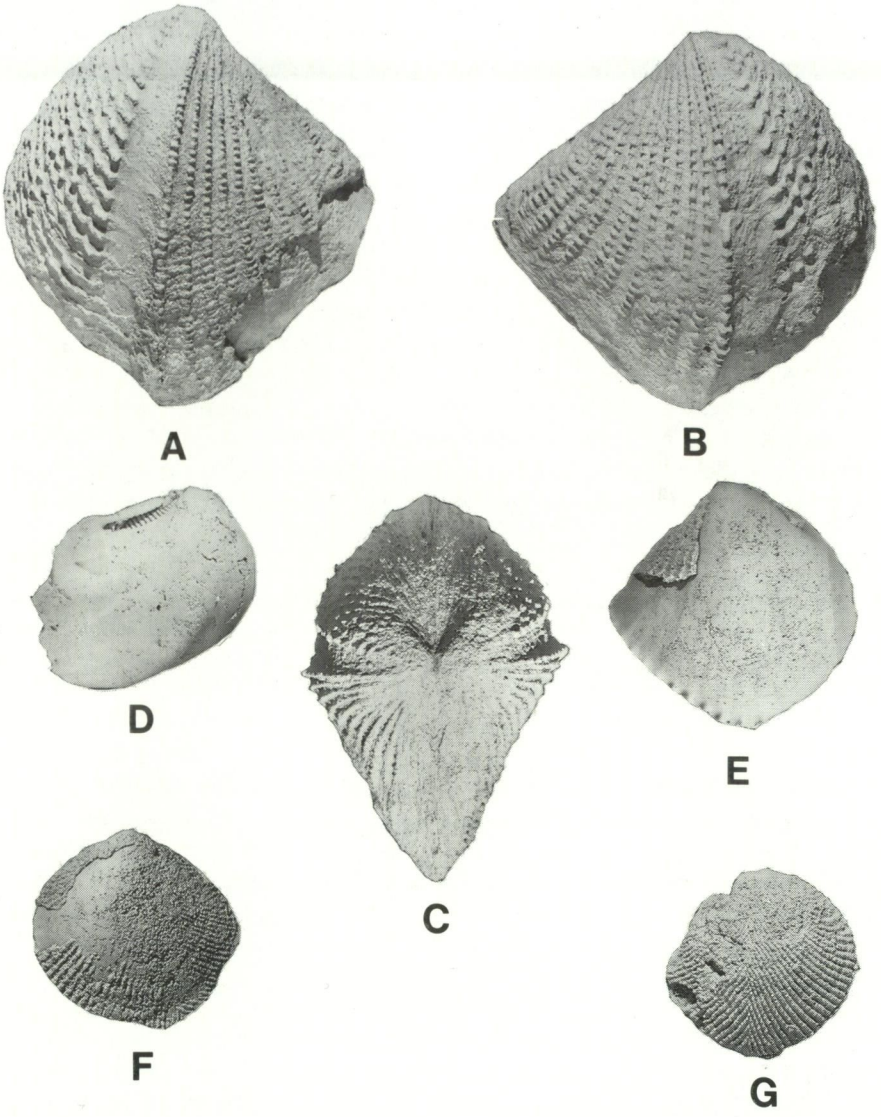

Figure 23. **A-E** *Trigonia miriana* Skwarko. **A-C** WAM 86.1219. Locality 6. Conjoined valves: LV exterior, RV exterior and dorsal aspect, x 1.2. **D** WAM 80.855. Locality 18. RV internal mould showing impression of posterior adductor scar, radial groove on area and hinge detail, x 1. **E** WAM 80.687. Locality 28. Internal mould of conjoined valves showing (RV) postero-ventral crenulation, x 1.5. **F, G** *Linotrigonia (Oistotrigonia)* sp. **F** NMV P102319. Locality 23. Conjoined valves, LV exterior, x 1.5. **G** WAM 86.1230. Locality 32. Conjoined valves, RV exterior, x 1.5. All Miria Fm. All whitened.

Linotrigonia (Oistotrigonia) sp.
(Figure 23 F,G)

Material.
WAM 71.259, 86.1230, 87.320. Three specimens. MNV P101607, P102319. Two specimens.

Description.
Shell small for the subgenus, thin, subquadrate, moderately inflated; umbone broad, slightly prosogyrate, raised a little above the margin; postero-dorsal and posterior margins almost straight, together subtending an approximate right angle; anterior and ventral margins gently rounded; area wide, weakly defined, comprising almost half of the valve; area and flank bear fine, closely set, tuberculate radial costae, of which the number on each part is about equal; costae of the area and flank join together along a very weak, submedian carina, forming a regular, chevron-like sculpture; escutcheon carina poorly defined (much worn on the available material); escutcheon costae continuous with those of the area; commissural margins finely crenulate, corresponding to the external sculpture; a weak radial groove, indicated by a low ridge on the mould, is present on the internal-median surface of the area; other internal characters unknown.

Dimensions.

	Length	Height	Inflation
WAM 87.320, pair	13.1	13.0	7.2
NMV P102319, pair	19.0	18.1	10.5

Remarks.
Our generic and subgeneric usage follows that of Cox (in Moore 1969: N483). *Oistotrigonia* developed extensively throughout the Cretaceous but we have located no species to which the Miria representatives could be assigned. Somewhat comparable is *"Trigonia" crenifera* Stoliczka from the Campanian-Maastrichtian Ariyalur Group of South India (Stoliczka 1871: 318, pl. 15, figure 13) and Cretaceous of Malagasy (Cottreau 1922: 41, pl. 4, figure 3), which appears to be an *Oistotrigonia.* Judging from the figures, the present species has more numerous, finer ribs and a weaker marginal carina than Stoliczka's. *Linotrigonia (Oistotrigonia) lima* Glaessner from "probable Cenomanian" beds of Papua (Glaessner 1958: 205-7, pl. 25, figures 7-9) is a larger species with an elliptical rather than quadrate outline, fewer, stronger and tuberculate ribs and a distinct carina, all points of distinction from the Miria species. None of the three New Zealand species assigned to *Oistotrigonia* (one Campanian, two Maastrichtian) by Fleming (1987: 51, 52, pl. 7, figures 23-33) is comparable in shape and sculpture with the present species; in each of these, the posterior area is much smaller than the flank and the sculpture is not as fine. Likewise, *"Trigonia" antarctica* Wilckens (also an *Oistotrigonia*) from the Campanian of Snow Hill Island (Wilckens 1910: 35-39, pl. 2, figs 16-20) has fewer, stronger, more granulated ribs than the Miria species, with a different outline and small area; also distinct is the related Maastrichtian *"T." pygoscelium* Wilckens from

Seymour Island (see Zinsmeister and Macellari 1988: 273, figure 12, 10-17) and *L. (O.) saunali* (Freneix) from the Senonian of New Caledonia (Freneix 1980: 100-101, pl. IV, figure 2).

The limited available material of this probable new species is not adequate in preservation for full description and specific determination. It is rare but widely distributed along the outcrop area of the Miria Formation in the Giralia Range.

Stratigraphic range.

Miria Formation. Maastrichtian.

Subclass Heterodonta Neumayr, 1884
Order Veneroida H. and A. Adams, 1856
Family Carditidae Fleming, 1828

Carditid, genus undetermined, Species A
(Figure 24 A)

Material.

WAM 75.1212. One specimen. UWA 91487. Two specimens.

Description.

Internal moulds of a small, equivalve, heterodont bivalve, ovately subtrigonal, a little higher than long, inflated; umbones prominent, elevated, prosogyrate; beaks incurved, proximate, located anterior of midline; anterior, ventral and posterior margins more or less evenly rounded; antero-dorsal margin shorter than the postero-dorsal margin; internal margins crenulate, matching weak internal ribs (shown on the mould) which probably correspond to the external (radial) sculpture; adductor scars lightly impressed, large, subequal, ovate; pallial line obscure; hinge details not retained.

Dimensions.

	Length	Height	Inflation
WAM 75.1212, pair	17.9	18.6	13.1

Remarks.

All specimens available are phosphatized internal moulds without shell. Their stratigraphic origin is uncertain, none having been collected from *situ,* whilst UWA 91487a shows glauconitic grains in the matrix, suggesting an origin for that specimen in the Paleocene Boongerooda Greensand. The other specimens, apparently without glauconite, are accepted with reservation as possible Miria Formation material. The species is consistent with a small carditid of form resembling that of the genus *Ludbrookia* Chavan, 1951 from the Cretaceous of Europe and North America. It may be distingusihed from the following species by its smaller size, reduced length relative to height and to inflation, its more convex ventral margin and the presence of fine, internal radial ribs (as impressions on the mould). Positive determination would require better-preserved material of confirmed stratigraphic position.

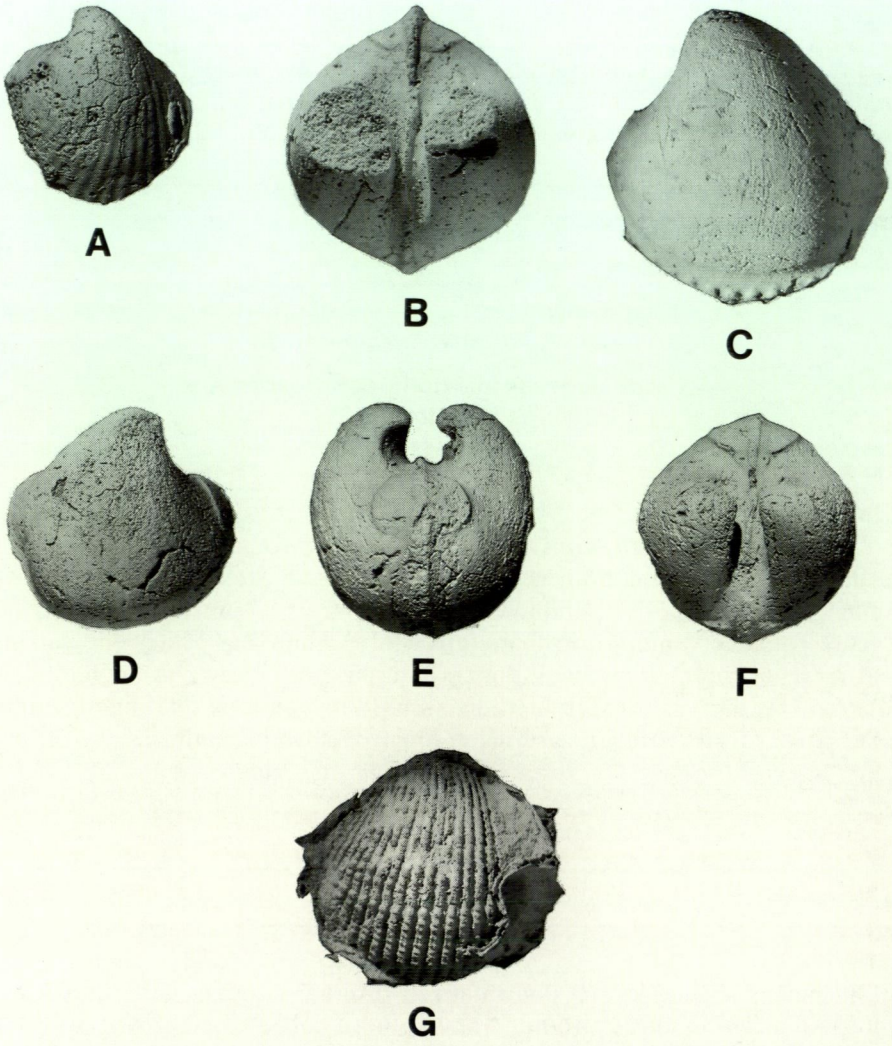

Figure 24. **A** Carditid, genus undetermined, sp. **A.** WAM 75.1212. Locality 30. Internal mould of conjoined valves, LV, x 1.5. Probably Miria Fm. **B-G** Carditid, genus undetermined, sp. B. **B** WAM 60.80. Locality 39. Internal mould of conjoined valves, dorsal aspect showing anterior adductor scars (umbonal extremities broken), x 1.5. Probably Miria Fm. **C** WAM 83.2880. Locality 17. Internal mould of conjoined valves, LV showing marginal crenulation, x 1.5. Probably Boongerooda Greensand (Paleocene). **D-F** WAM 89.843. Precise locality unknown; probably from northern Giralia Range. Internal mould of conjoined valves; **D** RV; **E** anterior aspect, **F** dorsal aspect, x 1.5. Probably from Wadera Calcarenite (Paleocene). **G** WAM 83.3104d. Locality 13. Latex cast of external mould, probably of LV, x 1.5. Boongerooda Greensand (Paleocene). All whitened.

Stratigraphic range.

Miria Formation — Boongerooda Greensand. Maastrichtian-Paleocene.

Carditid, genus undetermined, Species B

(Figure 24 B-G)

Material.

WAM 60.80, 88.1139. Two specimens.

Description.

Internal moulds of a small, very strongly inflated heterodont bivalve, about as long as high, with prominent, elevated, strongly prosogyrate umbones and incurved beaks; the shell probably higher than long; margins rounded, crenulate, the posterior a little more produced than the anterior; anterior adductor scars close to the hinge area, recessed, well defined, lobate; posterior adductor scars a little more distant from the hinge area, lightly impressed, elliptical; pallial line well defined, entire, parallel to and well above the ventral margin; hinge details not retained.

Dimensions.

	Length	Height	Inflation
WAM 60.80, pair	22.8	23 (est.)	21.1
WAM 88.1139, pair	19 (est.)	20.0	21.6

Remarks.

The material resembles that of the preceeding species in its comprising internal moulds devoid of shell. WAM 60.80 is a clean, brown, phosphatized mould without visible glauconite; 88.1139 is composed of a soft, pale brown, calcareous siltstone containing a few glauconitic grains. Provisionally, both specimens are accepted as being derived from the Miria Formation but the record requires confirmation from further, stratigraphically-localized material.

Internal moulds of similar form and apparently conspecific are not uncommon in the Boongerooda Greensand, which has a matrix rich in glauconite grains. Examples to hand are WAM 60.32, 60.118, 75.1213, 80.633, 83.2880, 83.2940, 83.3104 and NMV P101629, P101788-9 and P119669. One of these (WAM 83.3104d) is an external mould showing fine radial ribs and interspaces, the former lightly scaled on what seems to represent the anterior flank (Figure 24 G).

In shape and sculpture, this species bears a slight resemblance to *Baluchicardia beaumonti* (d'Archiac and Haime) from the "Danian" (Lower Paleocene) of Sind and Baluchistan (Kumar 1986: 202).

From the present indications, both this and the preceeding species may have straddled the Cretaceous-Tertiary boundary.

Stratigraphic range.

Miria Formation, Boongerooda Greensand. Maastrichtian-Paleocene.

Order Myoida Stoliczka, 1870
Superfamily Hiatellacea Gray, 1824
Family Hiatellidae Gray, 1824

Genus *Panopea* Menard de la Groye, 1807

Type species: *Panopea aldrovandi* Menard de la Groye, 1807 = *Mya glycymeris* Born, 1778. By subsequent designation of Children, 1823 (I.C.Z.N. Opinion 1414, 1986).

Panopea stenopleura sp. nov.
(Figure 25 A-F)

Material.

Holotype. WAM 83.2884a. Internal mould of an articulated pair retaining shell remnants. From small hill ca. 2 km SSW of Remarkable Hill, Giralia Range, Cardabia station (KV 005485).

Paratypes.

WAM 60.98a, 71.478, 71.482, 74.581, 80.878a, 83.2884b, 83.3058, 86.1231, 86.1238. Eleven specimens. NMV P101581-3. Three specimens. UWA 91426a, b. Two specimens.

Other material.

WAM 60.65, 60.82, 60.98b, c, 71.192, 71.301, 71.479, 71.480, 75.1215, 75.1217, 76.1756, 80.688, 80.857, 80.878b, 80.956, 83.2909, 83.2916, 83.2927, 83.2953, 83.2982, 83.3019, 83.3031, 83.3045, 83.3070, 83.3084, 83.3120, 84.941. Thirty six specimens. NMV P97594-5, P98251-3, P98255, P101531, P101560, P101567, P101619-22, P101650, P101709-10, P101729, P101750-1, P101977-8, P101880, P102013, P102098, P102193, P102247, P102250, P102295-302, P102322-3, P102353, P102375-6, P119510-2, P119696. Forty seven specimens. UWA 91426, 91467, NW147, NW176. Fifty six specimens. GSWA F9388. One specimen.

Diagnosis.

A medium sized, transversely subrectangular *Panopea* with compressed posterior flanks and microsculpture of radially aligned tubercles. Differs from *P. clausa* Wilckens in its greater length relative to height and its posterior compression.

Description.

Shell of medium size for the genus, very thin, transversely subrectangular, inflated anteriorly and usually tapered to varying degrees posteriorly; umbones broad, low, prosogyrate; beaks incurved, almost touching and located at the anterior third to fourth; anterior margin short, bluntly rounded; ventral margin broadly convex to almost straight and sub-parallel to the postero-dorsal margin; posterior margin rounded; each valve with a broad, saddle-like radial depression posterior to the umbonal ridge; each end usually gaping but either may be closed (thus accentuating the gape of the other) according to the degree of *post-mortem* valve displacement; primary sculpture of broadly rounded, irregular, anastomosing transverse costae over the entire disc, crowded on the beaks, becoming broader and more spaced ventrally and replicated on the internal mould; microsculpture of very fine, close-set tubercles, radially aligned and discernible only on infrequently preserved shell; each valve with a single, strong, conical tooth immediately anterior of the beak, the tooth of the RV located anterior to that of the LV; nymph not observed but indicated on the mould by a marginal depression posterior to the beak; adductor scars, pallial line and other internal characters not seen.

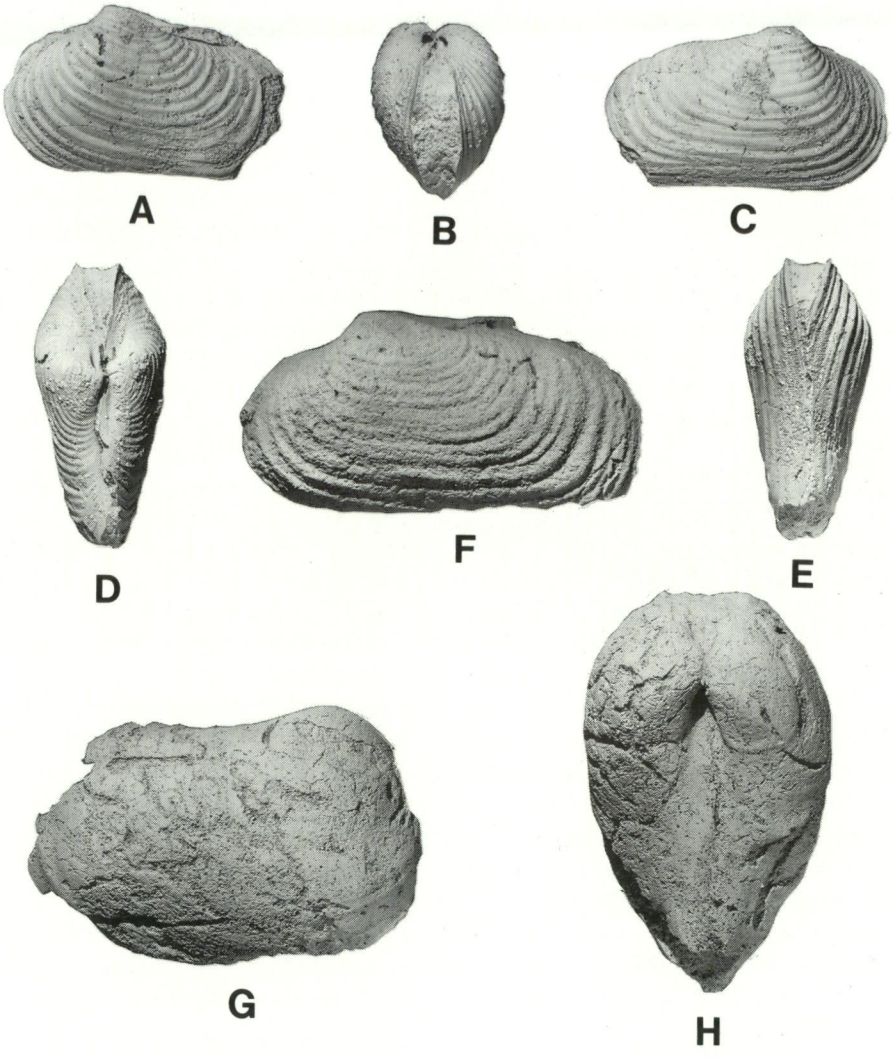

Figure 25. **A-F** *Panopea stenopleura* sp. nov. **A-E** WAM 83.2884a. Holotype. Locality 33. Internal mould of conjoined valves with shell remnants; **A** LV; **B** anterior aspect; **C** RV; **D** dorsal aspect; **E** ventral aspect, x 1. **F** WAM 74.581. Locality 30. Internal mould of conjoined valves; LV, x 1. **G, H** *Pholadomya* sp. WAM 60.102. Locality 31. Internal mould of conjoined valves; RV and dorsal aspect, x 1. All Miria Fm. All whitened.

Dimensions.

	Length	Height	Inflation
WAM 83.2884a, Holotype, pair	40+	23.6	18.5
WAM 60.98a, Paratype, pair	52.5	30.0	23.5
WAM 71.482b, Paratype, pair	55.0	25.4	19.5
WAM 74.581, Paratype, pair	58.1+	29.1	21.8
UWA 91426b, Paratype, pair	43.4+	25.1	19.2

Remarks.

The present species resembles and appears to be related to a group of ribbed, transversely subrectangular *Panopea* possessing a fine, radially aligned, tuberculate microsculpture. Examples of this group are *P. gurgitis* (Brongniart) from the Aptian-Albian of Europe (Woods 1909: 222-7, pl. 38, figure 2), *P. plicata* (Sowerby) from the Neocomian-Albian of Europe and Japan (Hayami 1966: 153-5, pl. 22, figures 1-7), *P. subplicata* Shumard from the Campanian-Maastrichtian Navarro Group of Texas (Stephenson 1941: 241-2, pl. 45, figures 3-6) and *P. clausa* Wilckens from the Campanian of Snow Hill and Seymour Islands, Antarctica (Wilckens 1910: 68, pl. 3, figure 10; Zinsmeister and Macellari 1988: 280-2, figure 16, 1-3). Wilckens' species has been recorded subsequently from the Piripauan (Campanian) Amuri Group of New Zealand (Woods 1917: 33, pl. 18, figures 6-7) and from the Senonian of New Caledonia (Freneix 1960: 43, pl. 3, figure 6; Freneix 1980: 51). Of the above, our species most resembles *P. clausa.*

Comparison of the Miria material with specimens of *P. clausa* from Seymour Island shows similarity in the form of the beaks and anterior ends, in the degree of inflation and sculpture. Consistent differences are the greater length relative to height and compressed posterior flanks in *P. stenopleura.* Specimens of *P. clausa* from Amuri Bluff, New Zealand vary somewhat in their length : height ratios, one approaching the Mira form, but differ consistently in the absence of compressed flanks.

Panopea orientalis Forbes from the Trichinopoly and Ariyalur Groups (Coniacian-Maastrichtian) of South India (Stoliczka 1871: 89, pl. 2, figures 1-4) is a much longer and more inflated species than ours, with more elevated umbones, a different outline and lacking tuberculate microsculpture. It appears to share no close affinity with *P. stenopleura.*

Compared with P. maccoyi (Moore) from the Aptian of Queensland and South Australia (Ludbrook 1966: 170, pl. 21, figure 3, pl. 22, figures 1-5), the Miria species is much smaller, less inflated and has narrower costae over the entire disc; the compressed flanks and microsculpture also distinguish our species from Moore's. In shape and primary sculpture, *P. stenopleura* approaches *P. aramacensis* (Etheridge, jnr) from the Albian of Queensland and South Australia (Ludbrook 1966: 169, pl. 22, figure 7) but differs in microsculpture. *P. glaessneri* Cox from the Neocomian-Aptian Nanutarra Formation of the Carnarvon Basin (Cox 1961: 28-9, pl. 5, figure 7, pl. 6, figure 4) differs

considerably in shape from the Miria species. Other Australian Cretaceous *Panopea* species in Skwarko (1966: 113-6, pl. 12, figures 1-12) and Skwarko (1967: 22, pl. 3, figures 8-15) show little resemblance to *P. stenopleura.*

The preservation of our material is generally poor, all specimens being internal moulds, a few of which retain vestiges of the shell. Most represent conjoined valves, consistent with the deep-burrowing habit attributed to the group. The best-preserved specimens have been collected from localities in the type area.

Variation in the degrees of anterior and posterior gape appears to be due to variable *post-mortem* valve displacement. Truncation of the primary sculpture along the ventral margin of some specimens may have a similar cause.

The specific name derives from the Greek *stenos,* narrow and *pleura,* side, in reference to the compressed posterior flanks of the species.

Panopea stenopleura is common throughout the outcrop area of the Miria Formation in the Giralia Range.

Stratigraphic range.

Miria Formation. Maastrichtian.

Subclass Anomalodesmata Dall, 1889
Order Pholadomyoida Newell, 1965
Superfamily Pholadomyacea, Gray, 1847
Family Pholadomyidae Gray, 1847

Genus *Pholadomya* G.B. Sowerby, 1823

Type species: *Pholadomya candida* G.B. Sowerby, 1823. By subsequent designation of Gray, 1847.

Subgenus *Pholadomya* s. str.

Pholadomya (Pholadomya) sp.

(Figure 25 G,H)

Material.

WAM 60.102 (internal mould). One specimen.

Description.

Shell of medium size, equivalve, transversely oblong-subtrigonal, strongly inequilateral; anteriorly short, ventricose; maximum inflation a little posterior of beaks; posteriorly extended, tapered; umbones prosogyrate, broad, moderately elevated; beaks incurved, probably touching, located at the anterior fifth; anterior margin descending, bluntly rounded and merging with the broadly convex ventral margin, which rises posteriorly; postero-dorsal margin slightly concave, sinuate, recessed, the RV margin apparently overlying that of LV; posterior margin and posterior part of the dorsal margin poorly indicated, the former possibly obliquely truncate, the latter possibly elevated and parallel with the postero-ventral margin; other characters indeterminable.

Dimensions.

	Length	Height	Inflation
WAM 60.102, pair	57 (est.)	38	33.5

Remarks.

The only specimen is a single, imperfect internal mould, devoid of shell and indicating little more than the general proportions of the genus and subgenus. The species appears to have been notably shortened anterior of the beaks, probably more so than any of the South Indian species in Stoliczka (1871: 79-81).

Specific determination of this rarity must await the collection of further material.

Stratigraphic range.

Miria Formation. Maastrichtian.

Superfamily Pandoracea Rafinesque, 1815
Family Periplomatidae Dall, 1895
Genus *Periploma* Schumacher, 1817

Type species: *Periploma inaequivalvis* Schumacher, 1817 (= *Corbula margaritacea* Lamarck, 1801). By monotypy.

***"Periploma"* sp.**
(Figure 26 A-H)

Material.

WAM 80.634, 80.955, 83.2928, 87.391 (internal moulds). Four specimens.

Description.

Shell of medium size, angularly and irregularly subovate, thin, longer than high, inequivalve, the margins without apparent gape or overlap; LV slightly more inflated than RV; moderately inflated anteriorly; compressed, subrostrate and flexed to the right posteriorly; umbones broad, low; beaks submedian, very small, slightly prosogyrate, without visible slit; anterior and ventral margins broadly and evenly rounded; dorsal margin arched and more or less subacuminate at its junction with the short, flexed posterior margin; dorsal and ventral commissures sinuate; hinge poorly indicated but apparently edentulous; chondrophores socket-like, oblique, directed posteriorly and buttressed postero-ventrally on each valve by a strong internal rib (indicated on the mould by a radial groove); posterior adductor scar, of LV lightly impressed, sub-triangular (?), located at the termination of the internal rib; others not seen; pallial line weakly indicated, possibly with a shallow sinus (80.634); sculpture poorly indicated, obscure dorsally, weakly transverse ventrally; no indication of granulose microsculpture; within the umbonal cavity is a suggestion of several obscure radial striae.

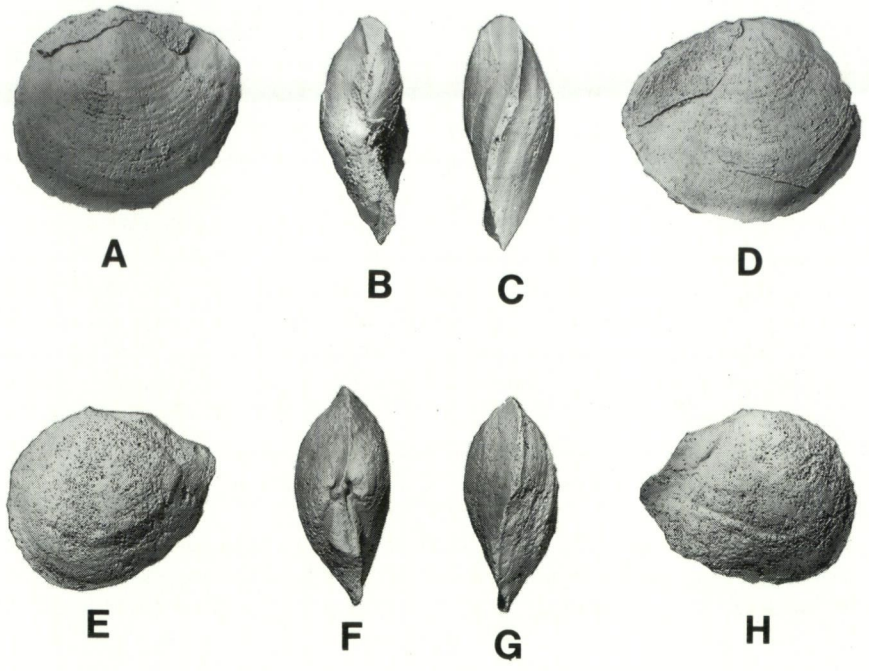

Figure 26. **A-H** *"Periploma"* sp. **A-D** WAM 80.634. Locality 26. Internal mould of conjoined valves with shell remnants; **A** LV; **B** dorsal aspect; **C** ventral aspect; **D** RV, x 1. **E-H** WAM 80.955. Locality 19. Internal mould of conjoined valves; **E** LV; **F** dorsal aspect; **G** ventral aspect; **H** RV, x 1. All Miria Fm. All whitened.

Dimensions.

	Length	Height	Inflation
WAM 80.634, pair	32.5	28.4	12.9
WAM 80.955, pair	30.4	24.3	13.7
WAM 83.2928, pair	26.3	21.6	11.7
WAM 87.391, pair	26.8	21.3	11.8

Remarks.

All specimens are internal moulds, one of which retains, as calcite replacements, a few "shell" remnants; three show a little *post-mortem* valve displacement and on one the LV beak is intact. The species is assigned to the Pandoracea from its combination of unequal valves, edentulous hinge and strong, oblique chondrophores, each buttressed by a strong internal rib.

Other characters suggestive of the Periplomatidae include the descending, socket-shaped chondrophores, the strong flexure and sinuate commissure (a feature of some species of *Periploma*), a possible shallow pallial sinus and an outline similar to that of some species of the genus, e.g., *P. lagartilla* Olsson and *P. carpenteri* Dall, figured in Olsson (1961 pl. 82, figures 1a, 5, 5a and 7a). Other features less consistent with the Periplomatidae as presently defined are the LV's inflation exceeding that of the RV, the slightly prosogyrate beak, the slight though distinct posterior inclination of the chondrophores and the absence of a slit on the beaks.

Posteriorly directed chondrophores and beaks without slits are shared by the present species and the pandoracean family Thraciidae but discrepancies are substantial. The stronger LV inflation and internal ligament with ribs buttressing the chondrophores appear to discount any thraciid affinity for our material. Comparable objections apply to other pandoracean families and for the present, the Periplomatidae seems the most appropriate of these. Our material may represent a new generic or subgeneric entity of that family, but additional, better-preserved specimens would be needed for that to be determined.

The genus *Aelga* Slodkevich, 1937 is very similar in shape to *Periploma* and there seems little if anything to differentiate between the two. The internal characters of the only described species of *Aelga* are not known with certainty to differ from those of *Periploma* (see figures in Kamada 1962, pl. 6).

The Late Cretaceous *P. subgracile* (Whitfield) from the Fox Hills Formation of South Dakota (Speden 1970: 149-150, pl. 38, figures 6-8) is more elongate and inflated than the Miria specimens and seems also to be less sinuate. *P. ambigua* Tashiro (1976: 75, pl. 11, figures 18, 19) from the Maastrichtian Himenoura Group of Kyushu seems to be more elongate and to have a more prominent umbone than the Miria specimens.

Stratigraphic range.

Miria Formation. Maastrichtian.

LOCALITIES

Fossil localities that have yielded study material are covered by the Mia Mia (Sheet 1751) and Giralia (Sheet 1752) 1: 100,000 topographic series; grid references have been calculated from the 1st edition, 1974.

Localities listed hereunder relate to type and figured specimens only. Most represent estimated median positions of linear outcrops or lag deposits of various extents, in some cases exceeding 1 km in length. Referenced localities are arranged from north to south; those for which no map reference is available are listed separately.

Locality 1. Creek sides and bed near northern extremity of anticline, Giralia station. KV 180 945.

Locality 2. Creek bed 10.8 km west from Giralia homestead on Bullara-Giralia road, Giralia station. KV 189 914.

Locality 3. Gully draining east, 0.3 km southwest of grid on Bullara-Giralia road (12 km west of Giralia homestead), Giralia station. KV 180 910.

Locality 4. One km south of Bullara-Giralia road, Giralia station. KV 175 903.

Locality 5. Gully draining east, 1.5 km south of Bullara-Giralia road, Giralia station. KV 168 898.

Locality 6. Gully draining east, 3 km northwest of West Tank, Giralia station. KV 160 895.

Locality 7. Gully draining southeast, ca. 2 km south of Bullara-Giralia road, Giralia station. KV 176 893.

Locality 8. Giralia station. KV 145 890.

Locality 9. Gully draining east, 3.1 km south of Bullara-Giralia road, Giralia station. KV 159 883.

Locality 10. Gully draining east in Wallatharra Paddock, ca. 1 km northwest of West Tank, Giralia station. KV 175 883.

Locality 11. Gully draining east in Wallatharra Paddock, ca. 3.1 km south of Bullara-Giralia road, Giralia station. KV 175 881.

Locality 12. Right bank of creek, draining northwest, Giralia station. KV 145 880.

Locality 13. Gully draining east, 1 km westnorthwest of West Tank, Giralia station. KV 174 880.

Locality 14. Gully draining east, 2.9 km south of Bullara-Giralia road, Giralia station. KV 177 884.

Locality 15. Gully draining east, 2.7 km south of Bullara-Giralia road, Giralia station. KV 163 877.

Locality 16. Gully draining northwest, 4.0 km south of Bullara-Giralia road, Giralia station. KV 143 873.

Locality 17. Gullies draining south, 0.4 km south of the northern boundary of Bungarra Paddock, Giralia station. KV 160 870.

Locality 18. Float from head and left bank of gully (which drains down to Coronation Bore), 3-6 km north northwest of Whitlock Dam, Giralia station. Approx. KV 115 820.

Locality 19. Toothawarra Creek, 0.2 km upstream from Miria Fm type section, Cardabia station. KV 071 726.

Locality 20. Toothawarra Creek, at Miria Fm type section, Cardabia station. KV 069 726.

Locality 21. Southern tributary of Toothawarra Creek, ca. 0.4 km south of Miria Fm type section, Cardabia station. KV 069 722.

Locality 22. Southern tributary of Toothawarra Creek, ca. 0.8 km south of Miria Fm type section, Cardabia station. KV 067 720.

Locality 23. Float from right bank of gully on north side of northern tributary of CY Creek, Cardabia station; ca. 1.5 km upstream from fence-line across creek. KV 070 708.

Locality 24. CY Creek, Cardabia station, 2.8-3.2 km east of No. 37 bore. Approx. KV 038 679.

Locality 25. CY Creek, Cardabia station. KV 039 677.

Locality 26. Junction of main CY Creek and southern tributary, Cardabia station. KV 046 670.

Locality 27. Above a prominent cliff of Korojon Calcarenite in north-south tributary of CY Creek on east side of fence, about 3/4 mile south along fence from where it crosses creek, Cardabia station. KV 043 660.

Locality 28. Right bank of unnamed creek south of CY Creek (incorrectly designated "Toothawarra Creek" on Giralia 1 : 100 000 sheet 1752, 1st ed., 1974). Within 2 km of KV 026 630.

Locality 29. Near Junction of two gullies, Cardabia station. KV 997 579.

Locality 30. Section Hill, Cardabia station. KV 011 544.

Locality 31. About 0.4 km southwest from Remarkable Hill, Cardabia station. KV 001 499.

Locality 32. Float 0.9 km westsouthwest from Remarkable Hill, Cardabia station. KV 004 498.

Locality 33. Small hill ca. 2 km south-southwest from Remarkable Hill, Cardabia station. KV 005 485.

Locality 34. Colluvial surface derived from Boongerooda Greensand near southwest corner of Wier Paddock, Cardabia station. JV 973 183.

Locality 35. 1.0-1.5 km east to northeast of Round Knob Hill, Mia Mia station; colluvial surface. JV 975 175.

Localities without map references

Locality 36. East side of Wallatharra Paddock, south of Bullara-Giralia road, Giralia station.

Locality 37. Toothawarra Creek, Cardabia station.

Locality 38. Outcrop in CY Creek, Cardabia station.

Locality 39. Central Pirie Paddock, Cardabia station.

Locality 40. Twin Hill-Remarkable Hill, Cardabia station.

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The Director, Geological Survey of Western Australia approved the loan of study material and our reproducing the figure of the type of *Camptonectes ellipticus* Etheridge.

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The Director, Australian Museum, consented to our borrowing Etheridge's specimens of *Pycnodonte ginginensis* (Etheridge). Mr R. Jones at our request kindly searched the Museum's collections and records concerning Etheridge's Gingin material.

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