COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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PERMIAN PELECYPODS AND GASTROPODS FROM WESTERN AUSTRALIA

BY

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SUMMARY

In the first part are presented identifications of more than 150 species of pelecypods and 60 species of gastropods from the Lower and Upper Permian of Western Australia—from the Irwin River area of the Perth Basin, from the Carnarvon Basin, and from the Canning Basin, including its north-eastern part, the Fitzroy Basin.

The Holmwood Shale, the Lyons Group, and the Carrandibby Shale are considered to be of Sakmarian age. The Fossil Cliff Formation, the Callytharra Formation, the Cuncudgerie Sandstone, Nura Nura Member, and the marine horizon at the base of the Poole Sandstone in the St George Range are all thought to be of the same age, and are referred to the upper part of the Sakmarian or the lower part of the Artinskian of the standard Ural sequence. The fauna of the High Cliff Sandstone and the Wooramel Group is similar to the underlying faunas but is probably of Lower Artinskian age. The main part of the Byro Group and all the Noonkanbah Formation are of Artinskian age. The upper part of the Byro Group, the bottom part of the Kennedy Group, and the Lower Liveringa marine beds include beds of Kungurian and probably also of Upper Artinskian age. The Upper Liveringa marine beds are of Upper Permian age. The oldest Permian beds in the Port Keats area (Bonaparte Gulf Basin) in the Northern Territory are of Upper Artinskian to Kungurian age and the higher beds are equivalent to the Upper Liveringa marine beds.

On a faunal basis, the strata can be assigned to six 'Stages', four in the Lower Permian and two in the Upper Permian. These are not formally named.

This study and other recent information suggest that the lowermost Permian faunas of the southern continents (South Africa, India, Australia, and South America) may have been derived from a widely distributed Upper Carboniferous fauna which is not well known because of the widespread withdrawal of the seas from the present continents in the Upper Carboniferous. In Western Australia the Lower and Upper Permian faunas have few species in common. This is partly because of a hiatus and partly because the faunas of the Lower Permian are less like those of Asia and Europe than those of the Upper Permian, indicating an important change in palaeogeographical conditions.

In the second part of this work, 43 species of pelecypods assigned to 34 genera and 20 species of gastropods assigned to 14 genera are described from the Holmwood Shale, the Fossil Cliff Formation, the High Cliff Sandstone, the Carrandibby Shale, the Callytharra Formation, the Cuncudgerie Sandstone, the Nura Nura Member, and the basal marine horizon of the Poole Sandstone of the St George Range. Twenty-one new specific names of pelecypods and two new generic names (*Quadratonucula* and *Elimata*) and fourteen new specific names of gastropods and two new subgeneric names (*Pseudobaylea* and *Woolnoughia*) are proposed.

Culunana Lintz Jnr. 1958 is regarded as a synonym of *Phestia* Chernyshev 1951, and *Polidevcia* Chernyshev 1951 as hardly more than a subgenus of *Phestia*. *Anthraconeilopsis* Tasch 1953 is considered to be a synonym of *Anthraconeilo* Girty 1911. A classification at the subgeneric level of the *Atomodesma*-like pelecypods and the *Mourlonia*-like gastropods forms is presented. One of Etheridge's original two figured specimens and a plaster cast of the other and topotype specimens of *Oriocrassatella stokesi* Etheridge Jnr 1907, the type species of *Oriocrassatella*, are figured.

The large group referred to the Grammysiacea was adapted for burrowing and certain of the aviculopectinids were already free-living. Confirmatory evidence is presented that the Mesozoic pseudomonotid and aviculopectinid forms that have been referred to the Pteriidae and therefore the Pteriacea belong to the Pectinacea. The shell structure of the Pectinacea is used to trace their evolutionary and taxonomic relationship. Discordance in left and right valves is ascribed to unequal calcification of the shell. A definition restricting *Limipecten* to Upper Carboniferous shells on the basis of external ornament is proposed. In '*Solemya*' *holmwoodensis* sp. nov., which is related to the Grammysiacea, the internal structure of the shell is similar to that found in living *Solemya*. *Retispira*-like external ornament is described in asymmetrical bellerophontids referred to *Stachella*. *Warthia* is shown to possess a slit and a slit-band; in most specimens the slit-band is covered by a smooth outer shell layer.

INTRODUCTION

Since 1948, concurrent with a great expansion in geological work, our knowledge of the Permian of the western part of Australia has greatly increased. Published work is listed in the references cited in the following section. Especially useful is the work of McWhae, Playford, Lindner, Glenister, & Balme (1958); and Teichert (1958) gives a brief review of the faunas.

The present work has been undertaken as part of a long-term project of describing the Permian pelecypod and gastropod faunas of Western Australia and western Northern Territory and of assessing their stratigraphical significance. Two portions have already appeared (Dickins, 1956; 1957). In the first paper pelecypods from earlier collections obtained from various parts of the sequence in the Carnarvon Basin were described; and in the second the earliest Permian (Sakmarian) pelecypod and gastropod fauna from the Lyons Group and the Carrandibby Formation.

Other current work in palaeontology is being undertaken by B. E. Balme (pollen and microplankton), B. F. Glenister (ammonoids), G. M. Philip (crinoids and blastoids), June R. P. Ross (bryozoans), and G. A. Thomas (brachiopods).

For faunal studies, the Permian rocks of the western part of Australia have the merit that the Lower Permian* has a complex of changing marine faunas which

* As explained elsewhere (Dickins, 1961c), a twofold division of the Permian is used—the Lower Permian consisting of the Sakmarian, Artinskian, and Kungurian Stages and the Upper Permian of the Kazanian and Tatarian Stages. For the Permian of the world, a twofold division (based on the standard Ural sequence) seems more satisfactory than a threefold, and is readily applicable in Western Australia. Middle Permian is used mainly in North America, but even here it does not have a great deal of merit, as a threefold division is not readily apparent, and Newell (1955, p. 8) and the United States Geological Survey (Cohee, 1960) have recently proposed recognition of the standard twofold division. Use of the Middle Permian in the North American sense outside that continent is to be deprecated, and a satisfactory threefold subdivision is not readily recognizable in Australia.

Ruzhencev (1956), although he indicates that the beds referred to the Kungurian Stage overlie those of the Artinskian in the Urals area, does not recognize the Kungurian as a separate stage because it does not contain a distinctive ammonite fauna. This proposal has not been followed by many Russian workers, apparently because the other groups of fossils are distinctive.

Stepanov (1957) has proposed the new name Svalbard Stage for the distinctly marine deposits of Svalbard (Spitzbergen), which he considered correlatable with the Kungurian, but these are so far distant from the Ural area where the standard Permian scale is based that it appears to be less satisfactory for a general scale than the Kungurian, whose relationship to other adjacent Permian rocks in the Ural area can be investigated. Harker & Thorsteinsson's (1960) work emphasizes the need for a subdivision of the Lower Permian which has a fauna distinguishable from the Artinskian and lies above it.

In some recent papers from the U.S.S.R., the Ufimian Stage has been used in the standard scale, placed apparently between the Kungurian and the Kazanian Stages (see U.S.S.R. Stratigraphic Lexicon). Licharew (1959) has reviewed the boundaries and subdivisions of the Permian and has proposed use of the name Kamian Stage for the Ufimian and Kazanian Stages together. If, however, the Ufimian should be included in the standard scale it would seem better to add it as it stands, rather than to introduce an additional name. The relationship between the Ufimian and Kungurian or Kazanian is not clear and some Russian workers consider that at least in part it may be equivalent to one or other.

allow a detailed study of their phylogeny and range. The value of this sequence is enhanced by the presence of marine Upper Permian in the Fitzroy and Bonaparte Gulf Basins. It represents as complete a marine Permian sequence as any in Australia, if not the most complete, and is rivalled only by that of the Hunter Valley of New South Wales.

The collections used have been mainly from the Geology Department of the University of Western Australia and from the Museum of the Geological Branch of the Bureau of Mineral Resources, Geology and Geophysics, Canberra. The Bureau of Mineral Resources collections include material from West Australian Petroleum Pty Limited.

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The loan of specimens or the gift of casts is acknowledged from the Department of Geology, University of Western Australia, the British Museum (Natural History), London, the U.S. National Museum, Washington D.C., the Department of Geology, University of Iowa, the South Australian Museum, Adelaide, the Australian Museum, Sydney, the Geological Surveys of Queensland and New Zealand, and the Queensland Museum, Brisbane. In the loan of specimens, I am especially grateful to Professor R. T. Prider of the Department of Geology of the University of Western Australia and Dr B. F. Glenister, formerly of the University of Western Australia and now at the State University of Iowa, through whom arrangements were made to borrow the large Western Australian collections, and to Messrs J. M. Lindsay and D. Rhodes, successive Curators in Western Australia, who have spent much time making locality and specimen information available. Mr S. P. Willmott guided me to localities in the Irwin River area and gratitude is expressed to him and to the management of West Australian Petroleum Pty Limited who made these arrangements possible.

I am most grateful to colleagues in the Bureau of Mineral Resources, in other parts of Australia, and in many overseas countries, who have helped through personal discussion, by letter, or in other ways. Where possible I have tried to acknowledge this in the appropriate parts of the text. Their help and co-operation has been one of the most gratifying aspects of this work.

REVIEW OF FAUNAS FROM WESTERN AUSTRALIA

It is not proposed to review the areal distribution of the Permian rocks and the details of the stratigraphy. These are available in other publications, which include those of Clarke, Prendergast, Teichert, & Fairbridge, 1951; G. Playford, 1959 (Irwin River area); Condon, 1954, 1955, 1962; Dickins, 1956, 1957, 1961a; Konecki, Dickins, & Quinlan, 1958 (Carnarvon Basin); Guppy, Lindner, Rattigan, & Casey, 1958; Traves, Casey, & Wells, 1956; Veevers & Wells, 1961 (Canning Basin); Coleman, 1957 (Irwin River area, Carnarvon and Canning Basins); Thomas, 1958 (Carnarvon and Canning Basins); Traves, 1955; Thomas, 1957 (Port Keats area of Bonaparte Gulf Basin). A valuable detailed review of all these areas, except the Port Keats area, is contained in McWhae et al. (1958).

For convenience, however, and in order to show the latest information published, areal distribution and generalized stratigraphical columns are shown in Figures 1 and 2. Some comments and additional information on the stratigraphy and the occurrence of the fossils, based on the author's field observations, are contained in the appendix.

The identifications of the faunas are shown in the accompanying charts (Figures 3-5), and these are now discussed in detail. Many of the species shown in Figure 5 are undescribed, and their identification will be subject to review when their description is undertaken.

Faunas from the Irwin River Area

Except for the ammonoids in the lower part, marine fossils are poorly represented in the Holmwood Shale; in this respect it differs faunally from the overlying Fossil Cliff Formation. Of the three species identified one and possibly two are found in the Fossil Cliff Formation, but except for the ammonoids, which are not discussed here, the fauna is not of much value for correlation: it cannot be shown that the fauna of the Holmwood Shale differs distinctly from the Fossil Cliff Formation as does that of the Lyons Group from the Callytharra Formation.

As a result of the present work, the identifications of the pelecypods and gastropods from near the base of the High Cliff Sandstone at Woolaga Creek given by me (*in* Playford, 1959, p. 17), are revised as follows:

Pelecypods

- *Parallelodon* cf. *bimodoliratus* sp. nov.
- *Astartila*? sp.
- *Atomodesma* cf. *mytiloides* Beyrich 1864.
- *Aviculopecten* cf. *tenuicollis* (Dana) 1847.
- *Streblopteria* sp.
- *Stutchburia* cf. *variabilis* Dickins 1957.
- *Cypricardinia*? sp.
- *Schizodus* cf. *fitzroyensis* sp. nov.
- *Oriocrassatella* sp.

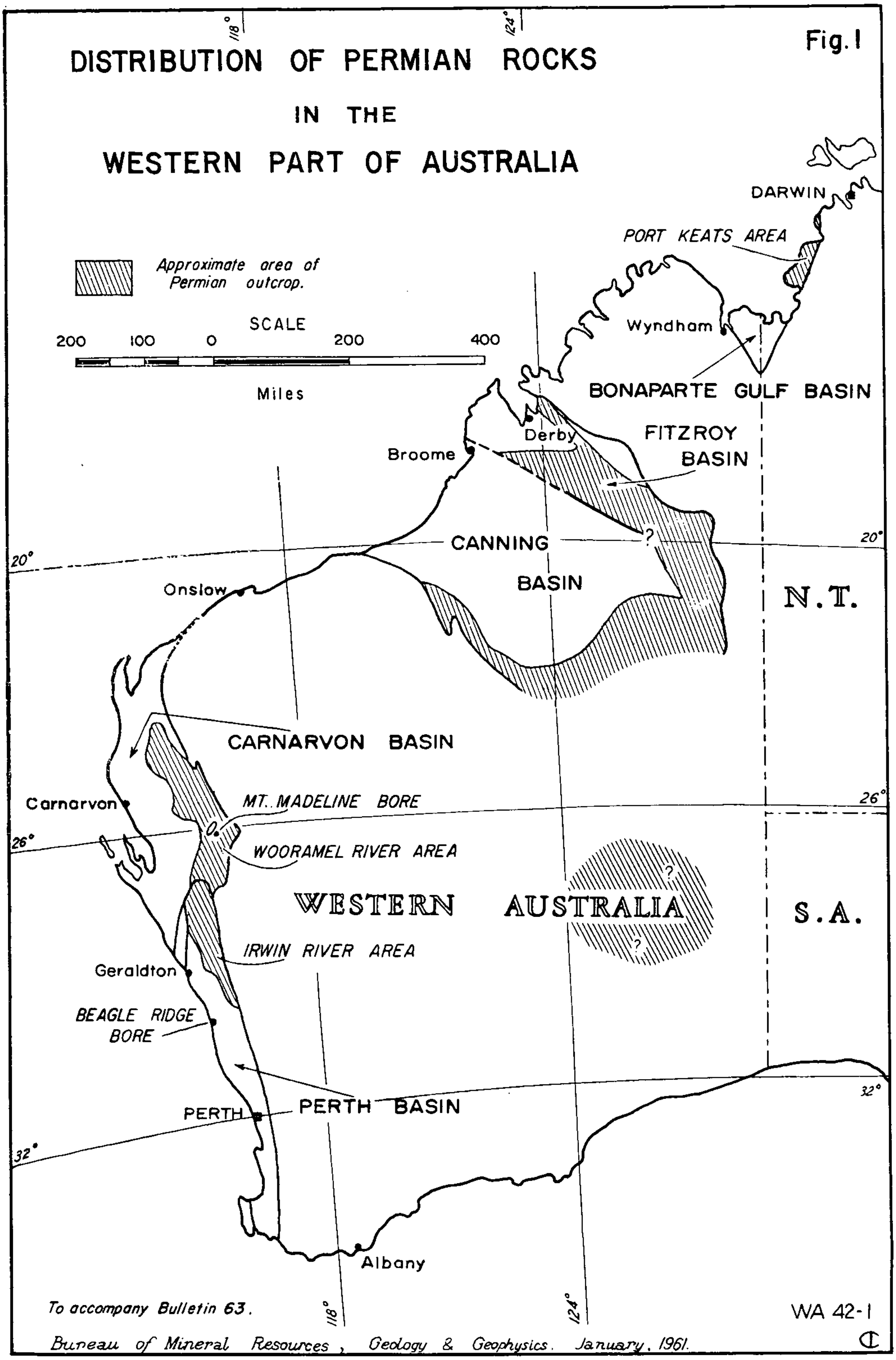
Fig. I
DISTRIBUTION OF PERMIAN ROCKS
IN THE
WESTERN PART OF AUSTRALIA
Approximate area of Permian outcrop.
SCALE
200 100 0 200 400
Miles
118°
124°
20°
26°
32°
DARWIN
PORT KEATS AREA
Wyndham
BONAPARTE GULF BASIN
Derby
FITZROY BASIN
Broome
CANNING BASIN
Onslow
N.T.
CARNARVON BASIN
Carnarvon
MT. MADELINE BORE
WOORAMEL RIVER AREA
WESTERN AUSTRALIA
S.A.
IRWIN RIVER AREA
Geraldton
BEAGLE RIDGE BORE
PERTH
PERTH BASIN
Albany
To accompany Bulletin 63.
WA 42-1
Bureau of Mineral Resources, Geology & Geophysics. January, 1961.

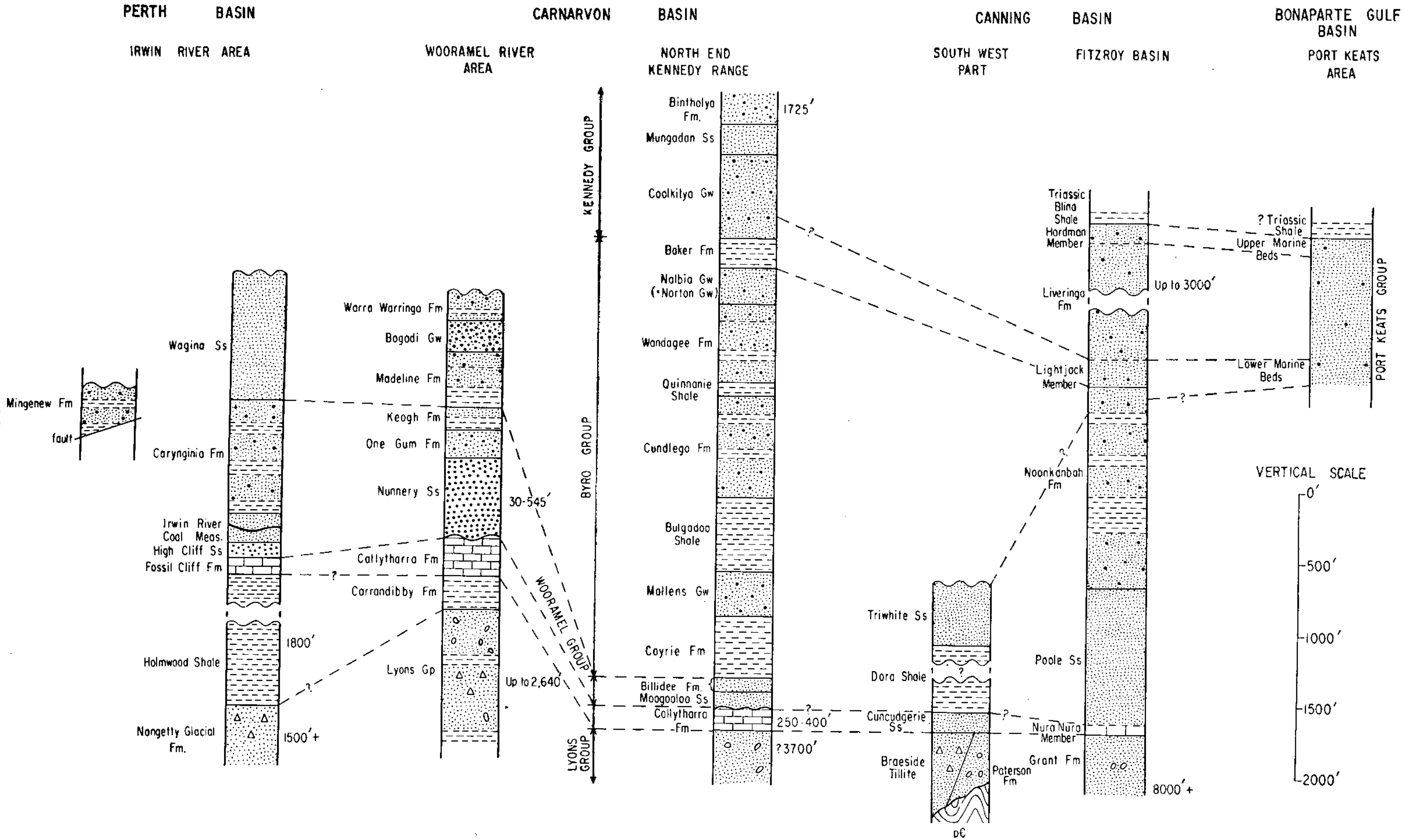
PERTH BASIN
IRWIN RIVER AREA
Mingenew Fm
fault
Wagina Ss
Carynginia Fm
Irwin River Coal Meas.
High Cliff Ss
Fossil Cliff Fm
Holmwood Shale
1800′
Nangetty Glacial Fm.
1500′+
WOORAMEL RIVER AREA
Warra Warringa Fm
Bogadi Gw
Madeline Fm
Keogh Fm
One Gum Fm
Nunnery Ss
30-545′
Callytharra Fm
Carrandibby Fm
Lyons Gp
Up to 2,640′
WOORAMEL GROUP
CARNARVON BASIN
KENNEDY GROUP
BYRO GROUP
LYONS GROUP
NORTH END KENNEDY RANGE
Binthalya Fm.
1725′
Mungadan Ss
Coolkilya Gw
Baker Fm
Nalbia Gw (=Norton Gw)
Wandagee Fm
Quinnanie Shale
Cundlego Fm
Bulgadoo Shale
Mallens Gw
Coyrie Fm
Billidee Fm.
Moogooloo Ss
Callytharra Fm
250-400′
?3700′
CANNING BASIN
SOUTH WEST PART
Triwhite Ss
Dora Shale
Cuncudgerie Ss
Braeside Tillite
Paterson Fm
pC
FITZROY BASIN
Triassic
Blina Shale
Hardman Member
Liveringa Fm
Up to 3000′
Lightjack Member
Noonkanbah Fm
Poole Ss
Nura Nura Member
Grant Fm
8000′+
BONAPARTE GULF BASIN
PORT KEATS AREA
? Triassic Shale
Upper Marine Beds
Lower Marine Beds
PORT KEATS GROUP
VERTICAL SCALE
0′
500′
1000′
1500′
2000′

Fig. 2

Gastropods

Bellerophon cf. *formani* sp. nov.
Pseudobaylea cf. *freneyensis* sp. nov.
Naticopsis? sp.

The following additional forms are also present—

Pelecypods

Palaeosolen? sp.
Edmondia sp.

Although this fauna is perhaps closer to that of the Fossil Cliff Formation than I had thought earlier (*in* Playford, 1959), there seems no reason to change the conclusion made then that, in this fauna, there are forms younger than in the Fossil Cliff Formation. Playford (1959, p. 18) presents evidence showing that marine fossils occur in the basal part of the High Cliff Sandstone, and additional information on this problem is considered in the appendix.

The Fossil Cliff Formation, although containing many similar species to the Callytharra Formation, differs in having a greater proportion of pelecypods and gastropods relative to brachiopods and bryozoans. Of the 44 species of pelecypods and gastropods positively identified from the Fossil Cliff Formation, 27 species occur in the Callytharra Formation and the Nura Nura Member (19 in the Callytharra and 16 in the Nura Nura); and of the remaining 17 species all but one, which occurs also in the Holmwood Shale, are known only from the Fossil Cliff Formation. If the species about whose identification there is some doubt are also taken into account, the likeness of the faunas is even more striking, especially when the distance between the outcrops of the Fossil Cliff and the Nura Nura Member—about 11° of latitude (about 750 statute miles)—is taken into consideration.

No doubt the number of species confined to the Fossil Cliff Formation is in part the result of the specially favourable conditions for the development and preservation of pelecypods and gastropods in the Irwin River area.

The fauna of the Mingenew Formation, as has been indicated elsewhere (Dickins *in* McTavish, 1961), is of the 'Byro type' and appears to be close to that of the Madeline Formation of the Wooramel River area.

Faunas from the Carnarvon Basin

Dickins (1957) and Dickins & Thomas (1959) concluded that although the Lyons Group (including the Carrandibby Formation) had some species in common with the Callytharra Formation and its equivalents (the Fossil Cliff Formation, the Cuncudgerie Sandstone, the Nura Nura Member and possibly the marine horizon at the base of the Poole Sandstone in the St George Range), the two faunas have distinctive features. This is confirmed in the present study, as shown in the distribution table. Notable amongst forms confined to the Lyons Group are *Deltopecten lyonsensis* Dickins 1957, *Eurydesma,* and *Keeneia.* Forms not occurring below the Callytharra Formation and its equivalents are *Deltopecten waterfordi* sp. nov., *Edmondia prichardi* sp. nov., *Astartella obliqua* sp. nov., *Atomodesma, Pseudomyalina, Cypricardinia*?, and *Oriocrassatella.* The Callytharra and its equivalents are also characterized by the large number of genera and species and the rich development of pectinid pelecypods. Important changes also occur among the brachiopods (see Dickins & Thomas, 1959).

Chaenomya? *besselensis* sp. nov., previously known only from the Carrandibby Formation, is now recorded from the Nura Nura Member, and *Mourlonia* (*Mourlonia*) *lyndonensis* is recorded from the Carrandibby Formation; previously it was known only from the Lyons Group elsewhere.

Of the 23 species of pelecypod and gastropod positively identified in the Callytharra Formation, 19 are known to occur in the Fossil Cliff Formation and 10 in the Nura Nura Member. In addition three species which occur in the Lyons Group (including the Carrandibby Formation) but not in the Callytharra Formation are found in the Nura Nura Member, and one of these, *Phestia lyonsensis* (Dickins) 1956, also occurs in the Fossil Cliff Formation.

The Wooramel Group in outcrop contains, in the main, marginal-deltaic arenitic deposits, unfavourable for the development of marine faunas. The best fauna is found in about 20 feet of leached siltstone outcrops, probably originally with limestone lenses or beds (Konecki et al., 1958, p. 33), and in about 100 feet of limestone in the Mount Madeline Bore (BMR 8) (Lat. 25°46'S., Long. 115°34'E., about 10 miles north-west of Bogadi Outcamp), at the base of the One Gum Formation of the Wooramel River area. The material is rather unsatisfactory, but the pelecypods (and the brachiopods) appear to be closer to the older Fossil Cliff/Nura Nura assemblage than to the younger fauna of the Byro Group. According to the thickness of the strata, these beds are about in the middle part of the Wooramel Group. In a few places in the Wooramel River area, a small marine fauna is found in the topmost beds of the Wooramel Group (Konecki et al., 1958, p. 37), which is identical with that found in the immediately overlying Byro Group, reflecting, apparently, the deepening of the basin and the initial development of more definite off-shore marine conditions in these places.

The lower part of the Byro Group is marked by the incoming of a distinctive fauna. Although many genera and some of the species from the older beds carry over, new genera and many new species appear. Especially outstanding is the absence of *Deltopecten, Edmondia,* and *Myonia,* and the appearance of *Heteropecten* and the first definite *Glyptoleda.* Similar changes are found in the brachiopods and calceolispongiid crinoids. The Byro, as a whole, contains an evolving complex of assemblages in which no very marked faunal subdivisions are apparent. A change, however, is associated with the Nalbia (= Norton)—Baker boundary, which is marked by the disappearance of a number of species and the appearance of others. Despite the differences in the sedimentary environment a similar change takes place at the Noonkanbah-Liveringa boundary in the Canning Basin. This change, which was recorded in Thomas & Dickins (1954) and is confirmed by the present study, is discussed in more detail in the section on the faunas of the Canning Basin. The faunas from the Bulgadoo Shale and the Cundlego Formation are not well represented in the collections, at least partly because these formations are less fossiliferous than others.

SPECIES DISTRIBUTION CHART

Fig. 3

Determinations regarded as reliable.

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SPECIES \ FORMATION	HOLMWOOD SHALE	LYONS GROUP	CARRANDIBBY FM.	CALLYTHARRA FM.	FOSSIL CLIFF FM.	NURA NURA MEMBER	CUNCUDGERIE SST.	POOLE SST. (ST. GEORGE RA.)	HIGH CLIFF SST.	ONE GUM FM.
"Solemya" holmwoodensis	●									
Baylea perthensis	●				●					
Streblopteria sp.	●			●	●		●	●	●	
Schizodus crespinae		●								
Platyschisma? sp.		●								
Megadesmus sp.		●								
Astartila condoni		●	●							
Eurydesma playfordi		●	●							
Peruvispira umariensis		●	●							
Keeneia carnarvonensis		●	●							
M. (Mourlonia) lyndonensis		●	●							
Deltopecten lyonsensis		●	●							
Stutchburia variabilis		●	●	●						
Phestia lyonsensis		●			●	●		●		
Aviculopecten tenuicollis		●	●	●	●	●				
Astartila? obscura			●							
Pachymyonia occidentalis			●							
Praeundulomya elongata			●							
Leiopteria? carrandibbiensis			●							
Chaenomya? nuraensis			●			●				
Phestia darwini			●			●	●	●		
M. (Mourlonia) sp. nov.				●						
Platyceras sp. nov.				●						
Deltopecten waterfordi				●						
Myonia sp. nov.				●	●					
Cypricardinia? elegantula				●	●					
Plagiostoma? sp. nov.				●	●					
Acanthopecten? sp.				●	●					
Girtypecten ovalis				●	●					
Parallelodon bimodoliratus				●	●					
Edmondia pritchardi				●	●	●				
Euchondria callytharraensis				●	●	●				
Chaenomya sp.				●	●	●				
Platyceras cf. abundans				●	●		●			
Modiolus koneckii				●	●			●		
Schizodus sandimanensis				●	●	●		●		
Astartella obliqua				●	●	●		●		
Oriocrassatella sp.				●		●		●	●	
Atomodesma mytiloides				●	●	●		●		
Atomodesma cf. timorense				●		●				
N. (Nuculanella) bangarraensis					●					
Quadratonucula australiensis					●					
Anthraconeilo sp. nov.					●					
Stutchburia hoskingae					●					
Astartila? tumida					●					
Praeundulomya subelongata					●					
Conocardium sp.					●					
Palaeolina sp. nov.					●					
Stachella crucilirata					●					
Ptychomphalina talboti					●					
Retispira irwinensis					●					
"Retispira" clarkei					●					
Bellerophon sp. nov.					●					
S. (Leptomphalus) sp. nov.					●					
Macrochilina winensis					●					
Woolnoughia angulata					●					
Palaeocosmomya sp.					●	●				
Stachella crucilirata					●	●				
Mourlonia? obscura					●	●				
N. (Nuculopsis) darlingensis					●	●	●			
Myonia subarbitrata					●	●	●			
Palaeosolen? badgeraensis					●	●		●		
Pseudobaylea freneyensis					●	●		●		
Euphemites wynnensis						●				
Warthia? carinata						●				
S. (Leptomphalus) Besselensis						●				
Warthia intermedia						●				
Schizodus fitzroyensis						●		●		
Lithophaga? sp.								●		
Aviculopecten? sp.								●		
Elimata guppyi								●		
Bellerophon formani								●		
Deltopecten sp.										●

Fig. 4

SPECIES DISTRIBUTION CHART

Determinations regarded as less reliable

SPECIES \ FORMATION	CALLYTHARRA FM.	FOSSIL CLIFF FM.	NURA NURA MEMBER	CUNCUDGERIE SST.	POOLE SST. (ST. GEORGE RA.)	HIGH CLIFF SST.	ONE GUM FM.
Megadesmus sp.	●						
Praeundulomya sp.	●		●				
Pachymyonia cf. occidentalis		●					
Peruvispira cf. umariensis		●		●			
Bellerophon cf. formani		●	●			●	
Naticopsis? sp.		●				●	
Modiolus cf. koneckii			●				
Macrochilina cf. winensis			●				
Quadratonucula cf. australiensis			●	●			
Phestia cf. lyonsensis				●			
Euchondia? sp.				●			
Warthia sp.				●			
Cypricardinia cf. elegantula				●	●		
Aviculopecten cf. tenuicollis				●		●	●
N. (Nuculanella) cf. bangarraensis					●		
Warthia cf. intermedia					●		
Stutchburia cf. variabilis						●	
Atomodesma cf. mytiloides						●	
Cypricardinia? sp.						●	
Schizodus cf. fitzroyensis						●	
Astartila? sp.						●	
Palaeosolen? sp.						●	
Edmondia sp.						●	
Pseudobaylea cf. freneyensis						●	
Parallelodon cf. bimodoliratus						●	●
Pseudomyalina sp. ind.							●
Astartella cf. obliqua							●
Volsellina? sp. ind.							●

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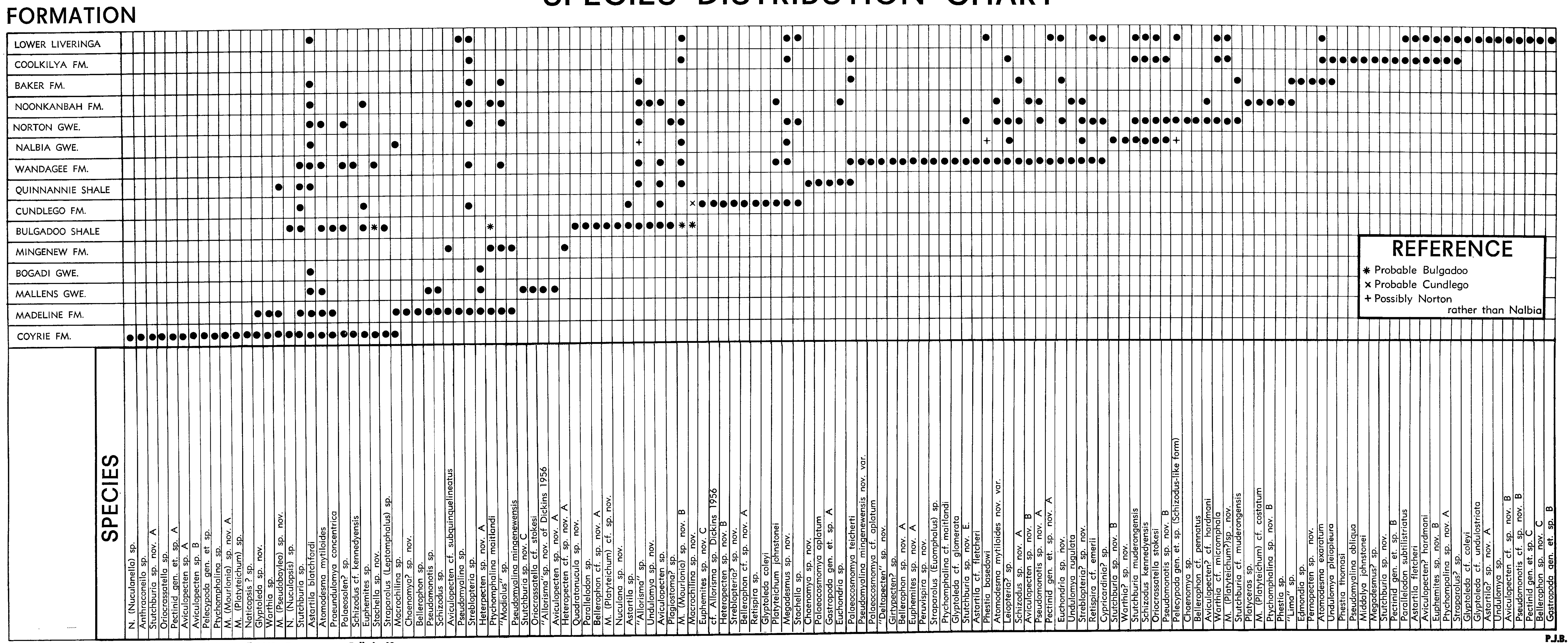
P.J.B.

SPECIES DISTRIBUTION CHART

Fig. 5



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P.J.B.

During Byro time there is a marked evolutionary development of *Aviculopecten, Praeundulomya, Undulomya, Palaeocosmomya, Glyptoleda, Atomodesma,* and *Peruvispira.* New forms of *Stutchburia, Astartila, Schizodus,* and other genera appear whose evolutionary significance is not clear. The Coolkilya Greywacke has a fauna which is rather different from that found in the Nalbia (=Norton) Greywacke. Forms that distinguish it from this and lower formations are also present in the Lower Liveringa beds of the Canning Basin and to a lesser extent in the Baker Formation, immediately below the Coolkilya. Of the 26 species identified from the Coolkilya Greywacke 15 occur in the Lower Liveringa beds and 11 in the Nalbia (=Norton). As suggested, however, in later discussion, the relationship of the Coolkilya to the Lower Liveringa is closer than is indicated by these figures. The relationship of the Nalbia, Norton, and Coolkilya Greywackes is considered in the appendix.

The youngest part of the Permian sequence is found in the Binthalya Formation above the Coolkilya Greywacke and the Mungadan Sandstone in the Kennedy Range. Marine fossils are poorly represented near the base of this formation and entirely unknown from the top: this part of the sequence apparently represents the infilling of the Permian Trough.

Faunas from the Canning Basin (including the Fitzroy Basin or Trough)

No Permian marine fossils are known definitely from the Grant Formation, the Paterson Formation, or the Braeside Tillite, although plant fragments and spores have been recorded (see McWhae et al., 1958; Veevers & Wells, 1961).

In the Nura Nura Member of the Poole Sandstone, which contains limestone beds and in this respect is similar to the Fossil Cliff and Callytharra Formations, 25 species of pelecypods and gastropods are identified. Of these 16 are found also in the Fossil Cliff Formation and 10 in the Callytharra—18 in one or other. Taking into account the distances involved and the differences in latitude, the similarity in the faunas is most striking.

The fauna identified from the Cuncudgerie Sandstone comes stratigraphically from within the formation and there can be no certainty about the correlation of the upper and lower limits of the formation. Most of the species occur in the Nura Nura Member, and the few that do not are found in either the Fossil Cliff or the Callytharra Formation. It can be concluded that the fauna of Cuncudgerie Sandstone represents, on the south-western side of the Canning Basin, the fauna in the Nura Nura Member on the north-eastern side (see also Dickins & Thomas *in* Traves et al., 1956, p. 52).

Of the 15 species recorded from the marine horizon at the base of the Poole Sandstone in the St George Range, 10 occur in the Nura Nura Member. Unlike the species in the basal beds of the High Cliff Sandstone of the Irwin River area, none suggests an age younger than the Fossil Cliff/Callytharra/Nura Nura Assemblage.

Apart from the basal parts the Poole Sandstone is apparently barren of marine fossils.

Pelecypods and gastropods are not well represented in the Noonkanbah Formation, which has similar species to the Byro Group and similar evolving complexes. As in the Byro Group, no very distinct faunal subdivisions are apparent. The scarcity of molluscs in the basal part of the Noonkanbah precludes their use for comparing the Poole-Noonkanbah boundary with the Wooramel-Byro, which must await an investigation based on the brachiopods and possibly the bryozoans and crinoids. The occurrence of *Undulomya* sp. nov. above the base of the Noonkanbah Formation and in the upper part of the Bulgadoo Shale suggests, however, that the boundaries are not far apart. As shown in Thomas & Dickins, 1954 (Assemblage Ib), the upper part of the Noonkanbah Formation can be correlated with the Wandagee Formation and Norton Greywacke at the top of the Byro Group.

As mentioned previously the Noonkanbah-Liveringa boundary is to be equated with the Norton-Baker and not the top of the Byro Group, which is placed above the Baker Formation.

Two distinct marine assemblages are found in the Liveringa Formation. The lower assemblage (in the Lightjack and Balgo Members or Lower Liveringa beds) is similar to that found in the Baker Formation and the Coolkilya Greywacke and very different from that from the underlying Noonkanbah Formation. Of the 34 species identified 15 occur in the Coolkilya and four in the Baker (18 in the Baker and Coolkilya together). Only five occur in the Noonkanbah Formation. Fifteen, however, occur in the Nalbia (=Norton). The similar environment of the Lower Liveringa, the Nalbia (=Norton), and the Coolkilya, and the different environment of the Noonkanbah, partly explains this distribution, and in correlating these formations considerable weight is placed on 'marker' fossils whose range appears to vary with time and is not dependent on the environment. *Streblopteria*? sp. nov., *Atomodesma* (*Atomodesma*) *mytiloides* Beyrich 1864 var. nov., and the brachiopod *Strophalosia kimberleyensis* Prendergast 1945 do not occur above the Nalbia (=Norton) and the Noonkanbah, and *Atomodesma* (*Atomodesma*) *exaratum* Beyrich does not occur below the Baker Formation and the Lower Liveringa beds. *Parallelodon subtilistriatus* Wanner 1922 and a new species of *Ptychomphalina* are known only from Lower Liveringa beds and the Coolkilya Greywacke, and *Pseudogastrioceras goochi* Teichert 1942 from the Lower Liveringa beds, the Coolkilya Greywacke, and possibly the Baker Formation. Some modification of the range of *Astartila blatchfordi* (Hosking) 1931 indicated in Thomas & Dickins (1954) is shown in the table.

Although the fauna of the Lower Liveringa beds is usually readily distinguishable from that of the Noonkanbah Formation, in the Shore Range at least there is a transition zone, the pelecypods and gastropods of which would suggest that these beds should be placed with the Noonkanbah rather than the Lower Liveringa. The species are identified as follows:

Pelecypods

'Modiolus' sp.
Schizodus sp.
Euchondria? sp.
Streblopteria sp.

Pseudomonotis sp. nov. A (known elsewhere only from the Noonkanbah, Wandagee, and Nalbia (= Norton) Formations).

Gastropods

Stachella sp. nov.

Bellerophon sp. nov. C (this may be *B. pennatus* Etheridge Jnr 1907).

Mourlonia (*Mourlonia*) sp. nov. B.

Ptychomphalina sp. nov. B (known elsewhere only from the Noonkanbah Formation).

Ptychomphalina maitlandi Etheridge Jnr 1903 (known only from Noonkanbah and Byro Group: in the latter it does not occur above the Norton and possibly not above the Wandagee).

On the whole, the fauna of the Lower Liveringa beds appears to be more closely related to that of the Nalbia (=Norton) than does that of the Coolkilya, which may indicate that these beds are most closely correlatable with the Baker. The scarcity of molluscs in the Baker, reflecting the silty environment, makes this correlation conjectural.

The other marine fauna in the Liveringa Formation is found in the upper part (Upper Liveringa beds including the Hardman Member). Of the 29 species listed below, not more than one or two are found in the older fauna of the Lower Liveringa beds.

Pelecypods

Phestia cf. *basedowi* (Etheridge Jnr) 1907.

Megadesmus sp.

Astartila? sp. nov. B.

Sanguinolitidae gen. et sp. nov. (cf. *Celtoides* Newell, 1957).

'*Allorisma*' sp. nov. A.

'*Allorisma*' sp. nov. B (smaller and less inflated than '*A.*' sp. nov. A).

'*Modiolus*' sp. nov.

Atomodesma cf. *mytiloides* Beyrich 1864 (possibly this should be separated as a new species).

Atomodesma cf. *semiplicatum* Reed 1944.

Aviculopecten sp. (simple *A. subquinquelineatus* type).

Aviculopecten sp. nov. C (type with wavy ribbing).

Aviculopecten sp. nov. D (spinose main ribs, large number of intermediate ribs).

Girtypecten? sp. nov.

Acanthopecten sp. nov.

Streblopteria sp.

Pseudomonotis sp. nov. C (spinose form).

Schizodus sp. nov. B (more triangular than *S. kennedyensis*).

Schizodus cf. *obscurus* (Sowerby) 1821.

Oriocrassatella sp. nov. ('*Procrassatella* type').

Astartella sp. nov.

Pelecypoda gen. et sp. nov. A (triangular form with radiating teeth).

Pelecypoda gen. et sp. nov. B (*Astartila*-shaped form).

Gastropods

Bellerophon sp.

Mogulia? sp. nov.

Retispira sp. nov. (wider slit-band and less radial lirae than *R. emerii*).

Warthia cf. *micromphala* (Morris) 1845.

Pleurotomariidae gen. et sp. nov.

Mourlonia (*Mourlonia*) sp. nov. C (distinctly marked parallel ornament).

Mourlonia (*Platyteichum*) sp. nov.

The fauna from the Mount Talbot area, which is possibly stratigraphically lower than the Hardman Member, is not included in the above list but is considered separately in the appendix. It contains ten species, of which seven occur elsewhere in the Upper Liveringa beds and three may be restricted to the Mount Talbot area.

The Triwhite Sandstone (see Traves et al., 1956), from the south-west Canning Basin, contains:

Astartila blatchfordi (Hosking) 1931.

Warthia cf. *micromphala* (Morris) 1845.

Ptychomphalina maitlandi Etheridge Jnr 1903.

The fossils suggest these beds are equivalent to the top part of the Noonkanbah Formation or less probably to the Lower Liveringa beds.

Faunas of the Port Keats Area of the Bonaparte Gulf Basin.

These faunas are not considered in detail here. As shown by Thomas (1957) there are lower marine beds which are probably equivalent to the Lower Liveringa beds and are certainly not older than the upper part of the Noonkanbah Formation. These are separated from higher marine beds by plant-bearing sandstones without marine fossils. The higher marine beds have the fauna characteristic of the Upper Liveringa beds.

Main Features of the Faunas

1. The development of the '*Eurydesma*-fauna' in the lower part of the sequence (Lyons Group), adapted apparently to a cool-water environment (Dickins, 1957) and so far known only from the Carnarvon Basin.

2. The widespread marine conditions and the similar fauna (Assemblage Ia of Thomas & Dickins, 1954) developed in the Fossil Cliff and Callytharra Formations, the Cuncudgerie Sandstone, the Nura Nura Member, and the marine horizon at the base of the Poole Sandstone. The Carnarvon Basin shows an influx of forms related to those of the Tethyan Region, and with links with Asia and Europe, which was to lead largely to a replacement of the earlier type of fauna. Probably this influx accompanied an amelioration in the climate. *Eurydesma* itself does not occur above the Lyons Group and new genera appearing in Western Australia include *Oriocrassatella, Astartella, Pseudomyalina, Atomodesma,* and *Cypricardinia*?. Especially characteristic of these beds is a form which appears to be a true *Edmondia.*

3. The impoverishment of marine faunas in the deltaic arenites that followed the widespread development of shelly limestones and calcareous beds typical of (2) above. Recent boring in Western Australia at Beagle Ridge (BMR Bores 10

and 10A—see Dickins, McTavish, & Balme, 1961; McTavish, 1961) indicates that this arenite sequence or perhaps less probably the Fossil Cliff Formation rests directly on Precambrian gneiss.

4. With the incoming of more definite marine conditions after the deposition of the arenite sequences, a fauna even more distinctly of the Tethyan type, in which many of the elements of the earlier widespread southern type are missing or poorly developed. In the Carnarvon Basin this fauna persisted until after the deposition of the Coolkilya Greywacke, and in the Canning Basin came to an abrupt end at the top of the Lower Liveringa beds. During this time the fauna developed more or less continuously, with at least one minor break at the Nalbia-Baker and the Noonkanbah-Liveringa boundary. This persistence of a fauna of a shallow-water type through a thickness of about 6,000 feet of sediment in the Carnarvon Basin is best explained by slow or repeated sinking. Even in the Canning Basin, where thicknesses are less, at least intermittent sinking is suggested. All the faunas below this major regression are referable to the Lower Permian of the classical Russian sequence.

5. In the Canning Basin a later marine transgression containing an Upper Permian fauna distinguished by the closeness of some of its species to forms found in Asia and Europe. The distinct provincialism of the faunas of the early Permian has disappeared.

Faunal Subdivisions of the Strata (Fig. 6)

Six main 'Stages' are recognized in the development of the faunas in the three basins of Western Australia and in the Port Keats area of the Bonaparte Gulf Basin. With these 'Stages' are associated important changes in the strata and they reflect the palaeontological and stratigraphical history of the western part of Australia during the Permian.*

With minor breaks, all the Lower Permian is represented by the four stages A to D. Marine faunas are present throughout. The lower part of the Upper Permian is either lacking or represented by non-marine deposits. The marine fauna of the Upper Liveringa beds suggests that uppermost Upper Permian is absent in the Canning Basin. The Upper Permian is, therefore, less completely represented than the Lower Permian.

Stage A is characterized by the '*Eurydesma* fauna' found in the Lyons Group (including the Carrandibby Formation) of the Carnarvon Basin, whose details are considered in Dickins & Thomas (1959). The fauna throughout is of a shallow-water type which together with the thickness (up to about 5,000 feet) indicates instability and sinking accompanying the changes caused by the waxing and waning of the glacial conditions. The Grant Formation, at least in part, the Nangetty Glacial Formation, and all or part of the Holmwood Shale are referable

* In the Permian of the Canning Basin the six stages proposed correspond to the six subdivisions used by Veevers & Wells (1961, Table 7—in press while this Bulletin was being written). The evidence I have considered—the thickness of shallow-water deposits together with variation in thickness from basin to basin—indicates that eustatic changes in sea level, alone, are insufficient to explain the changes in the sedimentary sequence.

to this stage on the basis of their stratigraphical position, the glacial features exhibited in the Grant and Nangetty, and the fossils of the Holmwood Shale.

While the Carnarvon Basin was fully open to the sea, the Holmwood Shale in the Irwin River area (see Teichert & Glenister, 1952) appears to have been deposited in a barred basin. This may have reflected the formation of a deeper trough here. In the Carnarvon Basin the outcrop area of the Lyons Group is more widespread than that of any of the later Permian Formations and perhaps represents the most widespread transgression of the sea during Permian time.

Stage B (Assemblage Ia of Thomas & Dickins, 1954) is characterized by the fauna found in the Fossil Cliff and Callytharra Formations, the Cuncudgerie Sandstone, the Nura Nura Member, and the marine horizon at the base of the Poole Sandstone in the St George Range of the Fitzroy Basin. This fauna has been discussed in the previous section. It is of an off-shore but not deep-water type which, together with the sediments, indicates relatively stable conditions in a well aerated sea. A small supply of land-derived clastic material allowed the development of abundant life and the accumulation of shelly material. The Cuncudgerie Sandstone and the basal part of the Poole Sandstone in the St George Range represent an exception to the general conditions; deposition of clastic material militated against development of limestone and extensive shell beds. At least in the Carnarvon Basin and probably in the Irwin River area the top of the stage is marked by sub-aerial erosion.

Stage C is marked by the absence rather than the presence of a marine fauna and is represented by the conditions found in the Wooramel Group, the upper part of the Poole Sandstone, and the arenitic formations (except possibly the Wagina Sandstone) in the Irwin River area overlying the Fossil Cliff Formation (High Cliff Sandstone, Irwin River Coal Measures, and Carynginia Formation). In the Carnarvon Basin and probably the Irwin River area uplift was followed by sinking. In the Fitzroy Basin there was renewed sinking. The large supplies of clastic material suggest the formation of topographical relief close at hand in all three areas.

Stage D is characterized by the fauna found in the Byro Group and the lower part of the Kennedy Group in the Carnarvon Basin, by the Noonkanbah Formation and Lower Liveringa beds in the Canning Basin, and by the lower marine beds in the Port Keats area. In the Irwin River area the only beds definitely referable to it are those of the Mingenew Formation. The position of the Wagina Sandstone is not clear. It has a sharp boundary with the Carynginia Formation below and, although it contains Permian plants, it could be significantly younger than the underlying formations. The top part of the Permian sequence in the Beagle Ridge Bores (BMR 10 and 10A)—see McTavish (1961)—belongs also to this stage.

A reasonably complete sequence is present only in the Carnarvon and Canning Basins. Instability developed further with the onset of definite marine conditions and barred-basin type of deposition. The alternation of finer deeper-water sediments and sandy shallower-water sediments in the Byro Group (taking into account the thickness of 3,000 feet) indicates continued sinking of the trough.

STAGES IN PERMIAN IN WESTERN PART OF AUSTRALIA

FIG 6

	SUBDIVISIONS OF URALS SEQUENCE	STAGES IN WESTERN PART OF AUSTRALIA		PERTH BASIN	CARNARVON BASIN			CANNING BASIN		BONAPARTE GULF BASIN
				IRWIN RIVER AREA	WOORAMEL RIVER AREA	NORTH END OF KENNEDY RA.		S.W. CANNING BASIN	N.W. CANNING & FITZROY BASIN	PORT KEATS AREA
UPPER PERMIAN		F							Liveringa Fm. Upper marine beds	Upper marine beds
UPPER PERMIAN		E				Kennedy Group†	Mungadan Sst.		Liveringa Fm. *middle part*	*Middle part with plants*
LOWER PERMIAN	Kungurian Stage ?	D	2			Kennedy Group† / Byro Group	Coolkilya Gw. Baker Fm.	?	Liveringa Fm. Lower marine beds	Lower marine beds
LOWER PERMIAN	Artinskian Stage	D	1	Wagina Sst† Mingenew Fm.	Byro Group *only lower part present*	Byro Group	Nalbia Gw.	Triwhite Sst† Dora Shale	Noonkanbah Fm.	*Wholly or mainly absent*
LOWER PERMIAN	Artinskian Stage	C		Carynginia Fm. Irwin Coal Measures High Cliff Sst.	Wooramel Group	Wooramel Group		?	Poole Sst. *upper part*	
LOWER PERMIAN	Artinskian Stage ?	B		Fossil Cliff Formation	Callytharra Formation	Callytharra Formation		Cuncudgerie Sst†	Nura Nura Member and Poole Sst. *lower part*	
LOWER PERMIAN	Sakmarian Stage	A		Holmwood Shale† Nangetty Glacial Formation	Lyons Group *including* Carrandibby Fm.	Lyons Group		Braeside Tillite Paterson Conglomerate	Grant Formation	*Absent, possibly present south of Victoria River Estuary.*

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

Two subdivisions, D_1 and D_2, are recognized; their faunas have been discussed previously. D_1 is represented by the Byro Group, from its base to the top of the Nalbia Greywacke, and by the Noonkanbah Formation. Assemblage Ib of Thomas & Dickins (1954) is found at the top of D_1. D_2 is represented by the Baker and Coolkilya Formations, by the lower marine part of the Liveringa Formation, and by all or part of the lower marine beds in the Port Keats area. It is characterized by Assemblage Ic of Thomas & Dickins (1954). Included in it are regressive phases in the Carnarvon, Canning, and Bonaparte Gulf Basins.

Stage E is represented by the plant-bearing sandstones (with some finer-grained sediments and coal in places) of the middle part of the Liveringa Formation (including the Condren Sandstone Member of Casey & Wells (1961, in press) and Veevers & Wells (1961)). It includes also the plant-bearing sandstones between the lower and upper marine beds of the Port Keats area. No marine fossils are known. In the Carnarvon Basin the sediments above the Coolkilya Greywacke, and especially of the Binthalya Formation, may be assignable to this stage. They represent a regressive phase and are the youngest Permian sediments found in the Carnarvon Basin.

Stage F (Assemblage II of Thomas & Dickins, 1954) is characterized by the fauna of the Upper Liveringa beds (including the Hardman Member) and the upper marine beds of the Port Keats area. This fauna is quite distinct from, and younger than, that found in D_2. It is of Upper Permian, possibly Tatarian, age.

Extra-Australian Correlations and Implications for World Palaeogeography

The considerable volume of recent work has done little to change the main correlations indicated by Teichert, especially in his 1941 paper.

Recently some important discoveries have been made and the details are being filled in. Thomas & Dickins (1954) distinguished an Upper Permian marine fauna in the Fitzroy Basin, and Dickins (1957) and Dickins & Thomas (1959) established the occurrence of *Eurydesma* and the '*Eurydesma* fauna' in the lower part of the sequence of the Carnarvon Basin. This fauna is rather different from the younger faunas in Western Australia and has affinities with the '*Eurydesma* fauna' in the other southern continents. Its occurrence has offered striking evidence that the earlier fauna of the Permian persisted longer in Eastern Australia than in other parts of the world and underwent an indigenous development there (see Dickins & Thomas, 1959, p. 88). Recently Thomas (1957) has recorded upper Lower Permian and Upper Permian faunas in the Port Keats area of the Bonaparte Gulf Basin in the Northern Territory. Hill (1958) has reviewed the palaeogeography of the lowermost Permian (Sakmarian) of the world, and Teichert (1958) the Australian sequences in relation to Gondwanaland.

Recent work in Arabia (Hudson & Sudbury, 1959), in North-eastern Siberia (Popov, 1957; Lobanova, 1959) and in Queensland (Maxwell, 1959), together with the work in Western Australia, allows a new appreciation of Permian world correlation and palaeogeography and offers a hint towards the solution of the vexing problem of the origin of the faunas of the lowermost Permian in the southern continents.

The occurrence of *Atomodesma* (unspecialized forms), *Myonia,* and *Stutchburia* (as *Netschajewia*) in Eastern Siberia (Popov, 1957; Lobanova, 1959*), a comparison of the early Permian faunas of Australia with Upper Carboniferous faunas from Peru (Thomas, 1928; Newell, Chronic, & Roberts, 1953) and the discovery in Queensland by Maxwell of a fauna which may be late Upper Carboniferous, suggest that the lowermost Permian faunas may, in part at least, have been independently derived from a fauna which was developing in the Upper Carboniferous but which, because of the widespread withdrawal of the sea from present continental areas during the Upper Carboniferous, is difficult to recognize as clearly as the lowermost Permian faunas. The work of Popov and Lobanova indicates that the southern type of fauna is found in North-eastern Siberia and is therefore more widespread than was previously thought. The Upper Carboniferous fauna from Peru could well be ancestral to a southern type of fauna and, according to Maxwell's data, a similar fauna is found in Australia in the Upper Carboniferous. The explanation suggested above is especially pertinent to South America, where the fauna apart from *Eurydesma* is not as closely related to those of Australia, India, and South Africa as they are to each other.†

The distribution of the *Gangamopteris-Glossopteris* flora presents a similar problem to that of the marine fauna. If, however, these plants had winged seeds, their widespread distribution in the southern continents may not be as difficult to explain as has sometimes been thought.

Hudson & Sudbury (1959) have recently described faunas from Arabia which they relate to the Agglomeratic Slate of Kashmir, the Speckled Sandstone of the Salt Range, and the lower part of the Western Australian sequence up to the Fossil Cliff/Callytharra/Nura Nura level. This fauna should serve as a link between Western Australia, Southern and Northern Asia, and Europe. In Hudson & Sudbury, pelecypods and gastropods have been identified by L. R. Cox, and their comparison with the fauna described in this monograph should be of considerable interest.

The position of the base of the Permian has been discussed recently by Hill (1958) and Dickins & Thomas (1959) and the present work does not add any information on this problem.

The lower boundary of 'Stage B' (i.e. the lower boundary of the Fossil Cliff, Callytharra, Nura Nura, and other formations of the same age) is placed at about the base of the Artinskian Stage (see Thomas & Dickins, 1954; Dickins & Thomas, 1959, p. 88). Current work on the ammonoids by B. F. Glenister of the University of Iowa, U.S.A., may afford additional information on the position of the Sakmarian-Artinskian boundary in Western Australia.

Thomas & Dickins (1954) and Dickins (1956) have considered evidence which

* The Lower Permian fauna described by Lobanova is much more closely related to the Australian fauna than is suggested by the reference of some of the Siberian forms to European and North American species.

†As a result of recent work some emendation of Harrington's (1955) generic determinations is possible. *Schizodus cycloliratus* Harrington appears to be a *Myonia, Allorisma inflectoventris* Harrington 1955 belongs to the group of forms I have referred to *Astartila*?, and *Stutchburia*? *argentinensis* Harrington is probably a *Praeundulomya.*

indicates that the Coolkilya Greywacke is of Kungurian age. This conclusion was based on the occurrence in the Coolkilya Greywacke of a fauna of pelecypods, which, although it appeared to be younger than Artinskian, lacked characteristic Upper Permian forms. This together with the occurrence of the ammonoids, especially *Paragastrioceras wandageense* Teichert 1942, suggested that the Artinskian-Kungurian boundary should be placed not below the base and not above the top of the Baker Formation. Most probably it is slightly above the base of the Baker Formation (the validity of the Kungurian as a separate stage has been discussed in a footnote on p. 8). Teichert (1958, p. 578) has questioned the Kungurian age of the pelecypod fauna on the basis of its stratigraphical relationship to the occurrence of the shark *Helicoprion*: he considers, rather, that the pelecypods are of Artinskian age. In this instance, however, there is no reason to think that *Helicoprion* is more reliable for correlation than the pelecypods; and moreover the pelecypod fauna referred to is found about 800 feet above *Helicoprion* according to Teichert's section (1952, p. 117), not below as thought by Teichert. On the other hand it seems unlikely that this pelecypod fauna is as young as the *Waagenoceras* zone which is found at Basleo in Timor and Sosio in Sicily and is of lower Upper Permian (Kazanian) age (see Ruzhencev, 1956, Table 4, opp. p. 34). At Basleo, the younger age of the pelecypods is shown especially in the occurrence of *Atomodesma variabile* Wanner 1922, *Atomodesma multifurcatum* Wanner 1922, and *Stutchburia timorensis* (Wanner) 1922. Sosio, as well as *Waagenoceras* and other ammonoids and forms belonging to other classes and phyla, has an Upper Permian pelecypod fauna with types of *Stutchburia* and pectinoids found in the Zechstein of Europe, the Kazanian of the Urals, and the Upper Permian upper Middle and Upper Productus Limestone of the Salt Range, India. This Upper Permian Tethyan-type fauna, of course, may have reached Western Australia substantially later than it did the Salt Range and Timor, but on the basis of the persistent interchange of faunas which was taking place between Timor and Australia at about this time and the occurrence of *Atomodesma variabile* Wanner 1922 in North-Eastern Siberia (Popov, 1957), and a two-grooved *Atomodesma* in Queensland (Dickins, 1961a), this does not seem likely.

The exact correlation of the Upper Liveringa beds and the upper marine beds in the Port Keats area with beds in other parts of the world is not clear. These are, however, correlatable with the upper Middle Productus and the Upper Productus Limestone, and if all or part of the *Waagenoceras* zone is not represented by marine deposition in the western part of Australia, they may be Tatarian rather than Kazanian. The wider relationships of the Upper Permian faunas contrast with the provincialism of the Lower Permian found in the same areas and probably indicate a return to the more equable climatic conditions that have been general during the earth's history and to which the more distinct provincialism of the Upper Carboniferous and Lower Permian and the Pleistocene and Recent, both with widespread glaciation, are notable exceptions (Brooks 1928; Dorf, 1959).

In the Canning Basin, the Port Keats area, and the Perth Basin (at Beagle Ridge in the BMR 10 and 10A Bores), the Permian is overlain by Lower Triassic shaly beds (Dickins, McTavish, & Balme, 1961) without marked discordance. These indicate a rather different sedimentary environment.

FAUNAL ASSOCIATIONS AND PALAEOECOLOGY

Amongst the pelecypods and gastropods, five associations which have palaeoecological significance are apparent:

1. An association with *Aviculopecten*.
2. An association of pelecypods with silty sediments.
3. An association of pelecypods with sandy sediments and little silt.
4. An association with byssate pelecypods.
5. An association with gastropods.

1. The first of these is discussed in detail in a later part of the report dealing with the Pectinacea. In brief, *Aviculopecten tenuicollis* is found in a number of associations where pelecypods are not common; the species was evidently free-living.

2. Some forms are found especially with siltstones and silty sandstones: nuculids, *Palaeosolen*?, *Praeundulomya, Undulomya, 'Allorisma'*, and *Palaeocosmomya*. These may occur with a brachiopod-bryozoan association. *Stutchburia, Oriocrassatella*, and *Schizodus* are usually poorly represented. A byssate form, *Atomodesma*, may also be found, but was probably washed in rather than endemic; though *Atomodesma mytiloides* and other species lacking anterior radiating grooves do have a preference for silty sediments, whereas the more specialized forms with one and three grooves (*A. exaratum* and *A.* cf. *semiplicatum*) are commonly found in sandier deposits.

3. *Oriocrassatella, Schizodus, Stutchburia*, and *Astartila* frequently occur together in large numbers in what appear to have been 'shell banks'. The pelecypod *Parallelodon* and *Mourlonia* and other gastropods may also be found. These forms were apparently adapted to an environment relatively free of silt. Their occurrence in shell banks together with their good preservation suggests that they lived in shallow water, subject to currents which, after death, accumulated their shells. This association is not commonly found close to abundant brachiopods and bryozoans.

4. The fourth association is that of the byssally attached forms such as *Atomodesma, Pseudomyalina*, and *Modiolus*: probably many Pectinacea were also bysally attached. In many places these are found together in large numbers, reflecting their attached gregarious habit. They are also to be found in other associations into which they were apparently washed after death.

5. The fifth association is that of the gastropods. Many of these may be found together, with pelecypods absent or poorly represented. Brachiopods may also be well represented and the beds may be calcareous. This probably reflects a mobile life in clear water on a hard bottom, whereas associations 2 and 3 are derived from soft bottoms.

Thomas (1958, p. 26) has discussed, in some detail, the palaeoecology of the Permian sequences of the Carnarvon and Canning Basins. He shows that three associations can be recognized arranged in order of increasing depth of sea bottom:

1. 'Molluscan': largely pelecypods, very subordinate calcareous brachiopods and bryozoans, crinoids;

2. 'Mixed': pelecypods, calcareous brachiopods and bryozoans, and crinoids;
3. 'Brachiopod': predominantly calcareous brachiopods, with bryozoans, subordinate corals and crinoids; mollusca are rare.

A study of the pelecypod and gastropod associations shows that they are affected not only by the depth but also by the character of the bottom and probably by the turbidity of the water. Further, in determining the depth of water, the type of molluscan association must be taken into account: the silt-preferring pelecypods, when associated with abundant brachiopods and bryozoans, may indicate deeper water than either the sand-preferring pelecypods ('Molluscan') or the 'Mixed' association.

Shells from different associations may, of course, be swept together; an example is apparently found in the Fossil Cliff Formation, where pelecypods and gastropods of associations 2, 3, and perhaps 5 are mixed together with abundant brachiopods and bryozoans. The good preservation, and the very large numbers of specimens, however, indicate that the remains were not moved far and were probably deposited in relatively shallow water. A feature of the Fossil Cliff Formation is the absence of *Oriocrassatella*, which is found to the north in the equivalent Callytharra Formation and the Nura Nura Member. The absence of *Stutchburia* from the marine horizon at the base of the Poole Sandstone in the St George Range may also reflect some factor in the environment other than depth or bottom type.

SYSTEMATIC DESCRIPTIONS

Class PELECYPODA

Superfamily NUCULACEA

Palaeoecology: In the Western Australian collections the Nuculacea have a definite association with siltstone or silty sandstones. The Nuculidae in particular are almost exclusively found in very silty sediments; the Nuculanidae are sometimes found in sandy sediments, although usually these have a high percentage of silt. Recent Nuculacea live on 'a bottom of mud or muddy sand, burrowing into it until the shell is just or almost covered, and feeding while buried' (Cox, 1960, p. 263). The occurrence of the Permian Nuculacea strongly suggests that they were already adapted to this kind of life.

Family NUCULIDAE d'Orbigny 1844

Discussion: The difficulty of subdividing this family is indicated by the conflicting proposals that have been made. These difficulties are reflected in this paper by the problem of deciding to what grouping the Western Australian specimens should be assigned and what ranking these groupings should be given. This position arises, apparently, from the relative stability of the nuculids, shown both in the soft parts and the shell. Thus many of the characters on which subdivision has been based have been rather variable and unsatisfactory for generic separation.

Schenk (1934) deals extensively with the characters and classification of the family and, for a general review, reference should be made to this paper. For long it has been recognized that all, or most, of the Palaeozoic forms lack the denticulate margin of *Nucula nucleus* Linné, the type species of *Nucula*. For example, Williams & Breger (1916, p. 173) proposed *Nuculoidea* as a subgenus of *Nucula* for forms without a denticulate margin.*

Schenk treats the nuculids under four broad headings: (a) Forms with denticulate ventral margins; (b) Forms with smooth inner ventral margins; (c) Forms with divaricate sculpture; (d) Forms of uncertain systematic position. He recognizes a number of genera and subgenera within these groupings.

Van de Poel (1955), leaving aside the forms with divaricate sculpture, divides the remaining nuculids into two groups on the basis of shell structure. In one group the middle shell layer (beneath the periostracum or outer layer) is composed of rods with radiating structure and rectangular section. The inner or nacreous layer has an external surface of radiating ribs (see Quenstedt, 1930, pl. 3, fig. 12, and Lucas *in* Piveteau, 1952, p. 255). In the other group the middle layer is uniform and the nacreous layer lacks any special character such as is found in the first group (see Lucas, op. cit., p. 248). These groupings are the same as

* Vokes (1949) has described marginal pectination in *Nuculoidea opima* Hall, the type species of *Nuculoidea*. It is possible, however, that these pectinations or denticulations are not the same as the denticulation in *Nucula nucleus* but correspond to weak denticulations recorded by van de Poel (1955, p. 4) in forms which he places under *Nuculoma*.

(a) and (b) of Schenk. Van de Poel applies the name *Nucula* to all forms in the first group, and *Nuculoma* to those in the second, and relegates all other genera within these groupings to subgeneric status.

Schenk's recognition of several genera and subgenera within these two groups on the basis of shape, hinge structure, and ornament seems, however, to be justified. For example *Nuculopsis* Girty (1911, p. 113; 1915, p. 115) can be distinguished from *Nuculoma* Cossmann (1907, p. 56), not only by differences in shape but also by the character of the dentition. Schenk's scheme appears to be the best so far proposed, and is in accordance with our present knowledge. Ichikawa & Maeda (1958, p. 74) also propose recognizing other genera beside *Nucula* and *Nuculoma*.

It is here proposed to recognize *Nuculopsis* Girty 1911 as a genus, and two species described are referred to the subgenera *Nuculopsis* (*Nuculopsis*) and *Nuculopsis* (*Nuculanella*).

A crenulated margin is not visible in the Western Australian species and thus they cannot be referred to any of the genera of Schenk's first group. *Nuculopsis* (*Nuculopsis*) *darlingensis* sp. nov., in the inrolled nature of the umbo, is close to *Nuculopsis* (*Nuculopsis*) *girtyi* Schenk (1934, p. 30), the type species, and the hinge structure is similar. It cannot readily be assigned to any of the other named generic or subgeneric groupings. *Nuculopsis* (*Nuculanella*) *bangarraensis* sp. nov. differs in shape and dentition from *Nuculoma* Cossmann and can be separated from *Leionucula* Quenstedt (1930, p. 110) and *Palaeonucula* Quenstedt (1930, p. 110) by its shape and lack of a chondrophore tooth and from *Nuculoidea* Williams & Breger 1916 by its shape. In dentition and shape, *N.* (*Nuculanella*) *bangarraensis* sp. nov. appears close to the type species of *Nuculanella* Tasch (1953, p. 395)—*N. piedmontia* Tasch (1953, p. 395, pl. 49, figs. 6, 7)—and is therefore referred to this group. *Nuculanella* has a rather different shape from *Trigonucula* Ichikawa (1949, p. 267), although the possibility cannot be excluded that further work may show that *Nuculanella* is a synonym of *Trigonucula*.

A new generic name is proposed for a third species.

Orientation of the Shell: In living *Nucula*, in contrast to most pelecypods, the short side of the shell is at the rear and the long side at the front, so that in most forms the umbones are distinctly pointed towards the back. Girty (1911, p. 133), in proposing the name *Nuculopsis*, concluded that the short side was anterior because an external ligament was present marginally along the long side. Schenk (1934, p. 29) convincingly demonstrates that hinges of modern *Nucula* do not differ from those of *Nuculopsis*. There is no reason to doubt that Palaeozoic Nuculas have a similar orientation to that of living forms, and in the shells described below the short side is regarded as posterior.

Genus Nuculopsis Girty 1911 (p. 134)

Type Species (by original designation): *Nucula ventricosa* Hall (1858, p. 716, pl. 29, figs. 4, 5a, 5b). Schenk (1934, p. 30) has pointed out that *N. ventricosa*

Hall 1858 is a homonym of *Nucula ventricosa* Hinds (1843, p. 100) and proposed the name *Nuculopsis girtyi,* which thus becomes the valid name of the type species.

Diagnosis: Shells without denticulate margin: beaks varying from only slightly to distinctly inrolled and opisthogyre. Anterior and posterior dentition continuous with anterior teeth above the chondrophore. No chondrophore teeth. Growth-lines or ribs only concentric ornament.

Discussion: Schenk regarded *Palaeonucula* as a subgenus of *Nuculopsis,* but the presence of a chondrophore tooth is considered to be of significance, and the absence of this feature is included in the diagnosis, excluding *Palaeonucula* from consideration under *Nuculopsis.* Recognition of *Nuculanella* is of value for the reception of Upper Palaeozoic shells in which the umbo is relatively upright, some of which have been placed by Schenk (1939) in *Palaeonucula.* According to the conclusions made here *Trigonucula* Ichikawa from the Triassic of Japan may also be a subgenus of *Nuculopsis.* The details of the hinge, however, are not available.

Subgenus NUCULOPSIS

Diagnosis: Beaks distinctly inrolled and turned towards the back: no distinctly developed lunular area.

Discussion: It seems likely that some species will be difficult to assign to either *Nuculopsis sensu stricto* or *Nuculanella* on the basis of their umbonal attitude. Because of this it would appear best to regard this character as of subgeneric value rather than generic. The character is of value, however, in separating the two groups of forms, and in the present collections two distinctly different species occur together which can be assigned to these two groups.

NUCULOPSIS (NUCULOPSIS) DARLINGENSIS sp. nov.

(Pl. 1, figs. 1-6)

Diagnosis: Nuculoid shell, more or less triangular rather than oval but with the umbones inrolled and turned distinctly towards the back: posterior teeth fewer in number and larger than anterior.

Description: The holotype is an internal impression; if the shorter side is regarded as posterior, this specimen is a right valve. Although the beak is distinctly inrolled and turned towards the back the shell is more equilateral than is common among the nuculids, the beak being situated more or less in the middle of the hinge-line. Five or six larger teeth are present posteriorly and more than ten smaller teeth anteriorly, but the exact number cannot be counted because they become small and obscure towards the umbo. A chondrophore is not visible but could be present. One or possibly two slight ridges (corresponding to grooves in the shell) run from the umbo downward and forward, but die away before reaching the margin. The surface has a number of rather coarse concentric ridges.

Paratype B is a left valve which in shape and development of the coarse concentric rugae is similar to the holotype. It shows also a number of finer concentric ribs.

Dimensions (in mm.):

	Length	Height	Thickness
Holotype .... (right valve)	4·5	3	1·5
Paratype A .... (right valve)	5	3·5	1·5
Paratype B .... (left valve)	5·5	4	1·5

Occurrence: Holotype and Paratype A, CPC* 3859 and 3860 respectively (Field No. IR 20), about ½ mile on a bearing of 334°† from Carynginia (No. 1) Well, Fossil Cliff Formation, Irwin River area. Paratype B, CPC 3861 (Field No. W 33 C (1)), not certain but close to $KNuA_1$, 1.6 miles south-west of Paradise Homestead (Lat. 18°02′30″S., Long. 124°31′00″E.) Nura Nura Member of Poole Sandstone, Fitzroy Basin. Other Specimens: UWA‡ Reg. No. 37558, Fossil Ridge, Fossil Cliff Formation, Irwin River Area; Field No. PB 9, Pintharuka 1-mile Sheet, map co-ordinates 511056, Becketts Gully, ⅘ miles above road crossing, Fossil Cliff Formation, Irwin River area; and Field No. P 1, 9 miles east-south-east of Cuncudgerie Hill, about 206 miles east-south-east of Port Hedland, Cuncudgerie Sandstone, south-western Canning Basin. A total of more than 15 specimens.

Discussion: *N.* (*Nuculopsis*) *darlingensis* seems to be especially associated with finer-grained sediments with a high proportion of silt in the matrix. It is well represented at IR 20, where *Quadratonucula australiensis* sp. nov. also occurs. It can be distinguished from *N.* (*Nuculanella*) *bangarraensis* sp. nov., with which it also occurs, by the inrolling of the umbones towards the back, and from *Quadratonucula australiensis* sp. nov. by the difference in shape. It can be readily distinguished from *N.* (*Nuculopsis*) *girtyi* Schenk 1934, the type species, because the umbo is less turned towards the front and is more centrally situated. The slight ridge of the internal impression, running downwards and forwards from the umbo is visible only in the holotype. A similar ridge, however, is present in *N.* (*Nuculanella*) *bangarraensis*.

* CPC—Commonwealth Palaeontological Collection Type No.—housed in the Museum of the Geological Branch of the Bureau of Mineral Resources, Geology and Geophysics, Canberra.

† True bearings are given throughout.

‡ UWA—University of Western Australia Collection—housed in the Department of Geology, University of Western Australia, Perth.

Subgenus NUCULANELLA Tasch 1953 (p. 395) emend.

Type Species (by original designation): *Nuculanella piedmontia* (1953, p. 395, pl. 49, figs. 6, 7).

Diagnosis: Beaks more or less upright and turned only slightly inwards and towards the rear, especially in the mature shell.

Discussion: As implied by the name, Tasch, when proposing *Nuculanella*, was under the impression that his species was closely related to *Nuculana*. An examination of three of Tasch's specimens from the Dry Shale of the Pennsylvanian of Kansas, borrowed by the courtesy of Professor W. M. Furnish of Iowa State University, leaves no doubt that the species belongs to the family Nuculidae in the sense of Schenk. It is proposed to regard it as a subgenus of *Nuculopsis*.

Little can be added to Tasch's description, but the three specimens are figured (Plate 1, figs. 13-15) especially to show the shape, which I have used for differentiation from *Nuculopsis* (*Nuculopsis*), and their dimensions are tabulated.

State University of Iowa Catalogue No.	*Length* (mm.)	*Height* (mm.)	*Thickness* (two valves) (mm.)
10424	4	3·5	1·5
10425	4	3·5	2
10426	3·5	3	1·5

Tasch implies that a pallial sinus is present, but no sinus is visible in any of the three specimens forwarded to me. Because of the lack of a sinus in related forms its presence in *Nuculanella* must be regarded as very doubtful.

In some of the species of this group, including *N.* (*N.*) *bangarraensis* sp. nov., a distinctly marked off lunular area is found. This feature may be diagnostic, for this grouping. Amongst the species that may be included in *Nuculopsis* (*Nuculanella*) are *Nucula montpelierensis* Girty (1910, p. 38, pl. 4, figs. 1-3a) from the Upper Permian Phosphate Beds of the Park City Formation of Wyoming and Idaho of the United States, *Nucula ventricosa* Hall 1858 of Waagen (1881, p. 251, pl. 19, fig. 20) from the Upper Productus Limestone, and *Nucula trivialis* Eichwald 1860 of Waagen (1881, p. 253, pl. 24, fig. 8) of the upper Middle and Upper Productus Limestone of the Salt Range of India. Although in a general way these species resemble *N.* (*N.*) *bangarraensis*, they are distinct specifically.

NUCULOPSIS (NUCULANELLA) BANGARRAENSIS sp. nov.

(Pl. 1, figs. 7-12)

Diagnosis: Outline triangular; umbones situated towards the back, almost upright except in early growth stages and only slightly inturned and pointing towards the back. Posterior part of shell projecting only slightly behind umbones.

Description: The holotype is a bivalved specimen with part of the shell preserved and partly internal impression. Distinct anterior and posterior ridges are present. The anterior ridge forms a broad lunular area. The posterior ridge is carinate and the concentric ribs on the body of the shell do not extend over the carina, behind which only growth-lines are found. No ligament nymphs are present externally. The concentric ribs and separating grooves are rounded and do not increase in number by division or interpolation. Four ribs are present in the interval between 3 and 4 mm. from the beak of the left valve.

The paratype is a bivalved internal impression. The anterior muscle is oval, elongated in a dorso-ventral direction; the posterior muscle is circular and is slightly smaller than the anterior. The well-marked pallial line is without a sinus. No pedal muscles are associated with the adductor muscle scars, but in the left valve a slight ridge on the impression (groove in the shell) runs forward and downward from the umbo about halfway to the margin. In each valve is a well-developed ligament pit, above which the anterior and posterior sets of denticles are continuous. The anterior set consists of about 16 denticles and the posterior 5—near the junction of the two sets the teeth are very small and cannot be counted with absolute accuracy.

Dimensions (in mm.):

	Length	Height	Thickness	
Holotype (external)	7·5	8	5	(two valves)
Paratype A (internal)	8	8·5	5	(two valves)
Paratype B (internal of right valve)	8	8·5	2·5	

Occurrence: Holotype and Paratype A., UWA Type Nos. 45348 and 45380 respectively (Reg. No. 37558), Fossil Ridge, Fossil Cliff Formation, Irwin River area. Paratype B, CPC 3862 (Field No. PB 7) about ½ mile on a bearing of 334° from Caryngina (No. 1) Well, Fossil Cliff Formation, Irwin River area. Other Specimens: Paratype B locality (Field Nos. PB 7; IR 20). The species occurs also in the Cuncudgerie Sandstone of the south-western Canning Basin, and the Nura Nura Member, and possibly the marine horizon at the base of the Poole Sandstone in the St George Range, of the Fitzroy Basin.

Discussion: *N.* (*Nuculanella*) *bangarraensis* sp. nov. apparently does not closely resemble any described species. It can be distinguished from *N.* (*N.*) *piedmontia* Tasch by the lesser extension of the shell posterior to the umbones and the more posterior position of the umbones at equivalent growth stages. Although the holotype of *N.* (*N.*) *bangarraensis* at maximum size has length and height approximately equal, at a height of 3.5 mm. the length is distinctly greater (4.5 mm.), thus resembling *N.* (*N.*) *piedmontia.* The differences, however, in the position of the umbo are retained even in the young shell.

The species is named after Bangarra Hill, near Fossil Ridge, Irwin River area.

Genus QUADRATONUCULA nov.

Type Species (here designated): *Quadratonucula australiensis* sp. nov.

Diagnosis: Shell nuculid, with height and length about equal, shape distinctly quadrate rather than triangular or oval; the special shape formed by the nearly straight anterior margin and the extension of the hinge-plate anteriorly to form a distinct corner. Umbo not prominently developed, turned inwards and towards the rear, although not markedly so. Ventral margin not denticulate. A chondrophore possibly present. External surface ornamented with low concentric ribs.

Discussion: The four-sided shape of the shell resulting from the distinctive anterior development of the hinge-plate seems to require the introduction of a new generic name within the family Nuculidae. Although the material does not allow certainty on the presence of a chondrophore, the general resemblance to other genera of the Nuculidae does suggest that the genus is correctly placed in this family. Although *Nucula luciniformis* Phillips (1836, p. 210, pl. 5, fig. 11)—see Hind 1897 (p. 186, pl. 14, figs. 17-22)—from the Carboniferous of England can be readily distinguished at the specific level from *Quadratonucula australiensis,* it probably belongs to the new genus.

QUADRATONUCULA AUSTRALIENSIS sp. nov.

(Pl. 1, figs. 16-24; Text-fig. 7)

Diagnosis: Umbones about two-thirds of shell length from front, rather small and not markedly turned towards the back or inrolled. Length and height about equal. Anterior umbonal ridge distinct, marking off a flattish area at the front of the shell.

Description: The holotype is an internal impression of a right valve, which shows the quadrate outline well. The anterior umbonal ridge marks off a flattish area, but the ridge and the area are not as distinct as in some other specimens. The anterior margin is straight and joins the dorsal and ventral margins at a distinct angle, making the shell four-sided. The anterior margin is longer than the posterior and the anterior set of teeth runs approximately parallel to the ventral margin and makes an angle of about 115° with the posterior set. There are about 15 anterior and 6 posterior chevron-shaped teeth. It is not possible to see whether a chondrophore is present, but the anterior and posterior teeth are continuous. The pallial line is entire and the posterior adductor muscle scar is oval and divided from the body of the shell by a shallow sulcus corresponding to a swelling on the inside of the shell. A shallow ridge on the impression runs from the umbo downwards, dying out before reaching the pallial line.

In Paratype A (the internal and external impression of a right valve) the internal impression shows similar features to the holotype, but the anterior area is better developed. Six chevron-shaped teeth are present posteriorly and apparently a chondrophore. The external surface is ornamented with low concentric ribs.

Paratype B apparently shows a chondrophore beneath the umbo and below the anterior teeth. Six chevron-shaped posterior teeth are present. Paratype C is the internal impression of a left valve. The anterior adductor muscle scar is oval in a dorso-ventral direction; the posterior muscle scar is also visible.

The musculature is shown in Text-figure 7.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Holotype	5·5	5·5	1·5
Paratype A	6·5	6	1·5
Paratype B	6	6	2
Paratype C	3·5	3	1
Paratype D	3·5	3·5	1

Occurrence: Holotype, CPC 3863 (Field No. IR 20), about ½ mile on a bearing of 334° from Caryngina (No. 1) Well, Fossil Cliff Formation, Irwin River area. Paratypes A, B, C, and D, CPC 3864, 3865, 3866, and 3867 respectively (Field No. PB 9), Pintharuka 1-mile Sheet, map co-ordinates 511056, Becketts Gully, ⅗ mile above road crossing, Fossil Cliff Formation, Irwin River area.

Other Specimens: Holotype and Paratype localities, and the Fossil Cliff Formation at Fossil Ridge (PB 10) and the main limestone band in Becketts Gully. More than 20 specimens.

The species also possibly occurs in the Cuncudgerie Sandstone of the southwestern Canning Basin and in the Nura Nura Member of the Fitzroy Basin.

Discussion: *Quadratonucula australiensis* is especially common in the silty concretions in Becketts Gully below the main limestone band of the Fossil Cliff Formation.

There is some variation in the development of the anterior ridge and the anterior area as well as in the direction of the umbonal ridge (in internal impressions). In some shells the 'ridge' is rather two ridges with an elevated area between.

Genus ANTHRACONEILO Girty 1911 (p. 132)

Type Species (by original designation): *Anthraconeilo taffiana* Girty (1911, p. 132; 1915, p. 114, pl. 15, figs. 9-13) from the Pennsylvanian Wewoka Formation of Oklahoma.

Synonym: *Anthraconeilopsis* Tasch (1953, p. 391).

Discussion: According to Girty (1915, p. 113), *Anthraconeilo* differs from *Palaeoneilo* Hall 1870 'in lacking an external ligament and in being without the sinus developed in the interior contour and in the lines of sculpture'. Girty also considered that a chondrophore was probably present in *Anthraconeilo,* perhaps because he concluded that an external ligament was absent. On the basis, however, of Girty's figures this is not certain, because an external ligamental structure is easily removed by abrasion before burial or erosion before collection. Unless a chondrophore can be shown to exist in *Anthraconeilo taffiana, Anthraconeilo* may fall into the synonymy of *Palaeoneilo* or an allied genus.

One of the specimens from Western Australia shows the internal structure of the hinge, but no chondrophore is visible; yet the species is so close to *A. taffiana* in the shape and character of the dentition that it seems unlikely that it belongs to another genus. Sometimes a chondrophore is not readily visible in fossil Nuculacea and it is not safe to draw a conclusion on a single specimen.

I am indebted to Professor W. M. Furnish of the Iowa State University for forwarding to me seven of Tasch's measured specimens of *Anthraconeilopsis kansana* Tasch (1953, p. 392, pl. 49, figs. 4, 5), the type species of *Anthraconeilopsis,* from the Dry Shale of the Pennsylvanian of Kansas. From these specimens I conclude that Tasch's reasons for separating *Anthraconeilopsis* from *Anthraconeilo* are inadequate. The 'gape' is probably caused by an accident of preservation: one specimen is completely closed and others are closed at the front or rear with 'gape' where the shell is only partly preserved. Another specimen appears likely to have been preserved partly open. The small size of the posterior teeth appears to be of little significance in such small apparently immature shells. Two of Tasch's specimens are figured (Pl. 2, figs. 1-3). They have a complex pattern of paired umbonal muscles. These muscles are regarded as a primitive feature relating the Nuculacea to the Monoplacophora—see Vokes (1954) and Yonge (1960).

Family Position: On the assumption that it possessed a chondrophore Girty placed *Anthraconeilo* in the family Nuculidae. It appears to belong here rather than to the Nuculanidae (Ledidae) which also have a chondrophore. If, however, it lacks a chondrophore this position must be reassessed.

ANTHRACONEILO sp. nov.

(Pl. 1, figs. 25-29; Text-fig. 7)

Description: The specimens are externally similar to the type species *Anthraconeilo taffiana* but less transversely elongated and more tumid. The umbo is also relatively nearer and slightly more inturned towards the short side of the shell. Internally 19 denticles, which increase in size towards the front, are visible anteriorly (assuming as in *Nucula* that the short side is towards the rear). Five, or possibly six, larger denticles are present at the back. No chondrophore is visible on the hinge-plate. The posterior adductor muscle is oval in a dorso-ventral direction and has a shallow groove at the front. The anterior adductor is also oval, but lies close to and is elongated parallel to the anterior part of the dorsal margin. It therefore differs from the two species of *Nuculopsis* described earlier in this paper, in which the anterior adductor is parallel to the anterior margin. What appear to be obscure muscular impressions extend in an arc from the lower part of the posterior adductor to the dorsal margin slightly in front of the umbo. These are, no doubt, analogous to the impressions which are shown in *Anthraconeilo kansana* (Tasch).

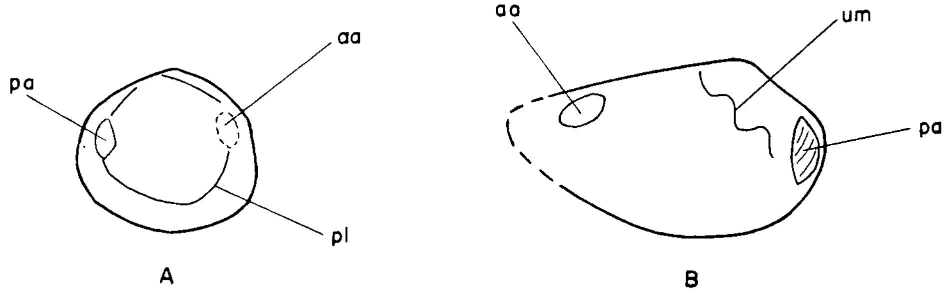


Fig. 7. A.—Quadratonucula australiensis gen. et sp. nov. Musculature of right valve. B.—Anthraconeilo sp. nov. Musculature of 'left valve'. aa: anterior adductor muscle. pa: posterior adductor muscle. pl: pallial line. um: umbonal muscles.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen A ('left valve')	18	11	5
Figured Specimen B ('left valve')	17	11	4·5

Occurrence: Figured specimen A, UWA Type No. 45349 (Reg. No. 23366), Beckett's Gully, Fossil Cliff Formation; figured specimen B, UWA Type No. 45350 (Reg. No. 23354), Fossil Ridge, Fossil Cliff Formation. This species is rare and is represented only by three or four specimens, all from the Irwin River area.

Discussion: Although the characters of the specimens are sufficient to indicate that a new species is present, the material is not regarded as altogether satisfactory for the proposal of a specific name.

Family NUCULANIDAE Stoliczka

Recently three generic names have been proposed for the Upper Palaeozoic Nuculanidae, which were previously considered under the name *Nuculana*: *Phestia* Chernyshev (1951, p. 9), *Polidevcia* Chernyshev (1951, p. 25), and *Culunana* Lintz Jnr (1958, p. 106). All differ from *Nuculana* in possessing an internal rib running ventrally from the umbo. *Polidevcia* is also said by Chernyshev to lack a chondrophore, although it seems likely, as suggested by Elias (1957, p. 750), that the alleged absence of the chondrophore is due to 'an error of observation or a typographic error', because Chernyshev has placed in this genus *Nuculana bellistriata* Stevens and *Nuculana attenuata* Fleming, forms which are known to have a chondrophore. (Apart from lacking a chondrophore, *Polidevcia* appears to differ from *Phestia* mainly in its greater transverse elongation.) According to Lintz *Culunana* also differs from *Nuculana* in having the hinge-plate continuous above the chondrophore and the anterior part of the hinge-plate distinctly wider than the posterior instead of being subequal, and in having all the posterior teeth rectangular instead of chevron-shaped. Lintz considered that *Culunana* possibly differed from *Polidevcia* only in the absence of a chondrophore. In these circumstances the proposal of a new generic name does not seem justifiable and *Culunana* is therefore placed in synonymy with *Polidevcia* (and *Phestia*).

Chernyshev indicates that his specimens lack a pallial sinus, which is also absent in Permian specimens I have examined, including the two species described below. On the other hand living forms of *Nuculana* do have a pallial sinus (Fischer, 1887, p. 985; Cox, 1960, p. 268). Palaeozoic forms also have umbonal muscles which are not apparent in living forms.

The internal rib cannot be observed in all the specimens I have examined, and even in some specimens within a species which commonly shows the rib, it is either poorly preserved or absent.

On the basis, however, of the internal rib, the presence of umbonal muscles and the absence of a pallial sinus, as well as possibly the characters indicated by Lintz for *Culunana,* a separation of the Upper Palaeozoic shells from *Nuculana* seems desirable. If the absence of a chondrophore in *Polidevcia* is regarded as unlikely, a generic distinction between *Phestia* and *Polidevcia* becomes of doubtful value and indeed the difference is apparently so little that whereas Chernyshev places *Nuculana bellistriata* in *Polidevcia,* with which Lintz agrees, Elias places the same species in *Phestia.* Although *Polidevcia* may have subgeneric value for the more transversely elongated species, I propose for the present placing it in synonymy with *Phestia,* which has page precedence, and the Western Australian species described below, which were previously considered as *Nuculana,* are referred to *Phestia.*

Genus PHESTIA Chernyshev 1951 (p. 9)

Type Species (by original designation): *Leda inflatiformis* Chernyshev (1939, p. 116, pl. 29, fig. 1).

Synonyms: *Polidevcia* Chernyshev (1951, p. 25),
Culunana Lintz Jnr (1958, p. 106).

Diagnosis: Similar in shape and structure to *Nuculana,* but lacking a pallial sinus and with a more or less well developed internal ridge or rib descending from near the umbo towards the ventral margin. One or more umbonal muscles associated with the internal rib. External ornament of fine more or less concentric ribs.

Discussion: Of the two species described below, *Phestia lyonsensis* would fall into Chernyshev's *'Polidevcia'* group, whereas *Phestia darwini* would fall into the group of *'Phestia'* in the restricted sense. In the Western Australian Permian, the transversely elongated species may be confined to the lower part of the sequence.

PHESTIA LYONSENSIS (Dickins) 1956

(Pl. 2, figs. 12-18)

1956. *Nuculana lyonsensis* Dickins, p. 8, pl. 1, figs. 7-9.

Additional material, including a number of internal impressions and internal and external impressions of the same specimens, adds to the knowledge of the characters of this species and makes correction to the original diagnosis necessary. *Amended Diagnosis*: Elongated with the posterior part much produced and the anterior margin inflated and uniformly rounded; umbones not projecting conspicuously: external ornament of numerous ribs, either concentric or forming a shallow V beneath the umbo. Distinguished from *Phestia basedowi* (Etheridge Jnr) 1907a by lesser anterior inflation and greater posterior elongation.

Description: In some specimens which are similar in all other respects, the ribs are concentric and there is no V developed beneath the umbo: hence the ribbing can vary from being concentric to having a shallow V. Internally the chondrophore, although poorly preserved, is visible in several specimens. An anterior pedal muscle has already been described (Dickins, 1956), but, in addition, a posterior pedal is present between the posterior adductor and the umbo; the pedal impressions are elongated parallel to the hinge. The pallial line is without a sinus. In internal impressions a groove (corresponding to a rib or ridge in the shell) runs ventrally from the umbo; the development of this groove varies considerably and in some specimens it is hardly present at all. It runs ventrally and turns posteriorly, but may divide, with one branch running anteriorly. In some specimens a shallow sinus is formed by the groove in the ventral margin. Immediately below the umbo two muscle scars are associated with the ridge or rib. The muscle nearer the umbo is the larger, and is more or less oval; the other is subcircular. These muscles, however, vary slightly in shape, position, and possibly number, although this latter may result from differences in preservation. In *Phestia darwini* they appear to be stable in shape, number, and general position. The larger muscle is comparable in size and position with that described by Girty (1915, p. 121, pl. 14, figs. 4, 9, 9a) in '*Leda*' *bellistriata* from the Carboniferous Wewoka Formation of Oklahoma; similar scars are illustrated and described in modern *Nucula* by Schenk (1934, p. 21, pl. 5, figs. 1, 1a). These paired umbonal muscles are regarded as a primitive feature and show the relationship of the Nuculacea to the Monoplacophora —see Vokes (1954) and Yonge (1960).

Dimensions (in mm.):

	Length	*Height*	*Thickness*	*Distance of Umbo from Front*
Hypotype A	21	10	5 (two valves)	7
Hypotype D	23	10	2	8
CPC 3871	20 (estimated)	10	5·5 (two valves)	8

Occurrence: Hypotypes A, B, and C, CPC 3868, 3869, and 3870 respectively, and Measured Specimen CPC 3871 (Field No. $KNuA_1$), 1.6 miles south-west of Paradise Homestead, Lat. 18°02'30"S, Long. 124°31'00"E; Hypotype D, CPC 3872 (Field No. W. 33 C (1)), locality not certain but close to $KNuA_1$, south-west of Paradise Homestead, all from the Nura Nura Member of Poole Sandstone, Fitzroy Basin.

Other Specimens: Hypotype localities; SG 120A, 16 miles at 120° from Mount Tuckfield, in southern part of St George Range, near base of Poole Sandstone, Fitzroy Basin; IR 20 and PB 7 about ½ mile on a bearing of 334° from Caryngina (No. 1) Well, Fossil Cliff Formation, Irwin River area; and probably P 1, 9 miles east-south-east of Cuncudgerie Hill about 206 miles east-south-east of Port Hedland, Cuncudgerie Sandstone, south-western Canning Basin. A total of more than 20 specimens.

P. lyonsensis was first described from the Lyons Group of the Carnarvon Basin (Dickins, 1956).

PHESTIA DARWINI (de Koninck) 1877
(Pl. 2, figs. 4-11)

1877. *Tellinomya darwini* de Koninck, p. 147, pl. 16, fig. 9.

1957. *Nuculana darwini* (de Koninck) 1877, Dickins, p. 18, pl. 2, figs. 1-6. (cum syn.)

Description: Anterior and posterior pedal impressions, elongated parallel to the hinge, are present between the anterior and posterior adductors and the umbo. The pallial line has no sinus. The internal ridge, or rib, running ventrally and slightly posteriorly, is poorly developed and in some specimens is almost absent. There appears to be no anterior branch similar to that found in *Phestia lyonsensis*. Where visible, two muscular impressions are associated with the ridge—the larger is nearer the umbo and elongated along the ridge; the smaller is oval and situated toward the front of the ridge. In one specimen about 16 teeth are present posteriorly and 12 anteriorly. In larger specimens a distinct sulcus on the internal impression separates the anterior adductor from the rest of the shell.

Dimensions (in mm.):

	Length	Height	Thickness	Umbonal Angle
Hypotype A	21	12·5	8 (two valves)	128°
Hypotype D	13·5	8	5 (two valves)	126°
Hypotype E	10 (estimated)	5·5	1·5	127°
CPC 3876	14	8	5 (two valves)	129°

Occurrence: Hypotypes A, B, and C, CPC 3873, 3874, and 3875 respectively, and Measured Specimen CPC 3876 (Field No. $KNuA_1$), 1.6 miles south-west of Paradise Homestead, Lat. 18°02′30″S, Long. 124°31′00″E; Hypotype D, UWA Type No. 45351 (Field No. A 108), Mount Wynne, beds overlying the limestones of the Nura Nura Member, 1.3 miles east of Nura Nura Ridge; Hypotype E, CPC 3877 (Field No. W 33 C (1)), locality not clear but close to $KNuA_1$, 1.6 miles south-west of Paradise Homestead, Fitzroy Basin, all from Nura Nura Member of Poole Sandstone of Fitzroy Basin.

Other Specimens: Hypotype localities; P 1, 9 miles east-south-east of Cuncudgerie Hill about 206 miles east-south-east of Port Hedland, Cuncudgerie Sandstone, south-western Canning Basin; SG 120A, 16 miles at 120° from Mount Tuckfield, in southern part of St George Range, near base of Poole Sandstone, Fitzroy Basin. A total of more than 30 specimens.

P. darwini has also been recorded in the Carrandibby Formation of the Carnarvon Basin (Dickins, 1957).

Discussion: The ratio of the dimensions of the larger shells from the Fitzroy Basin is very similar to that of the smaller shells from the Carrandibby Formation. A possible difference between the two is in the development of the sulcus behind the anterior adductor in internal impressions. This feature, however, is more distinct in larger specimens, and some smaller specimens from the Nura Nura Member can be matched with those from the Carrandibby Formation. On this evidence all these specimens are referred to a single species.

Superfamily ARCACEA

Family PARALLELODONTIDAE Dall

Genus PARALLELODON Meek 1866 (p. 51)*

Type Species: *Macrodon rugosus* Buckman (1844, p. 99, pl. 5, fig. 5), apparently by designation of Buckman, 1844 (see Branson, 1942a, p. 247).

Discussion: The name *Parallelodon* was first proposed by Meek as a substitute, and although he continued to use the preoccupied name *Macrodon, Parallelodon* must be attributed to Meek (or Meek & Worthen—see footnote).

* Inadvertently attributed to Worthen 1866, in Dickins (1956, p. 12). Some authorities attribute the name to Meek & Worthen 1866. Unfortunately this reference has not been available to me, and I have not been able to check on this. However, Branson (1948) and Shimer & Shrock (1944) give Meek as the authority for the name and I have followed them here.

Arkell (1930) shows the close relationship of the Palaeozoic species assigned to *Parallelodon* with those of the Mesozoic, including the type species, and concludes that all should be placed in the same genus. Though I do not necessarily agree with Arkell's conclusion, I do not consider it would be desirable to propose new generic names without an overall knowledge of Palaeozoic and Mesozoic forms; lacking this information, I propose to refer to the Western Australian species under the name *Parallelodon.* Arkell considers that *Grammatodon* is not generically separable from *Parallelodon* and, although *Grammatodon* has priority over *Parallelodon,* he retains *Parallelodon* as the generic name with *Grammatodon* as a subgenus. As Cox (1940, p. 41) and Branson (1942, p. 248) have pointed out, this procedure is contrary to the rules of zoological nomenclature and *Grammatodon* must be used for the generic name. I agree with Cox, however, that *Grammatodon* and *Parallelodon* should be regarded as seperate genera.

Since *Parallelodon subtilistriatus* Wanner 1922 was described from the Carnarvon Basin of Western Australia (Dickins, 1956), some very fine specimens of this species have come to hand from the collections of the Department of Geology of the University of Western Australia. The material has allowed development of the hinges and some of the specimens are illustrated in Plate 3, figures 1-5. The ligament structure shows an interesting feature: only the youngest chevron-shaped groove is completely visible—the front parts of the older chevrons are covered apparently with a layer of shell.

PARALLELODON BIMODOLIRATUS sp. nov.

(Pl. 3, figs. 6-14)

Diagnosis: Radial and concentric ornament distinctly developed in well preserved specimens. Shell divided into two parts by a distinct posterior carina. Ribs on posterior area more widely spaced and in most specimens more distinct than on rest of shell. Posterior area distinctly concave and ventral margin arcuate and not subparallel to dorsal margin as in *Parallelodon subtilistriatus.*

Description: The holotype is an external impression. Its whole external surface is covered by fine radiating and concentric lirae. At the outside margin there are about 10 radiating lirae per 5 mm. on the posterior flattened area and 16 per 5 mm. on the posterior part of the ventral margin. The radial lirae increase by irregular division. There are about four concentric lirae per mm.

Paratype A, the internal impression of a right valve, shows the teeth and the anterior adductor scar. The three posterior teeth are elongated along the hinge—the dorsal tooth almost parallel and the two ventral teeth set at a slight angle to the dorsal tooth: the teeth have fine striations. Three anterior teeth are present. The anterior adductor muscle is round and situated immediately under the anterior teeth.

Paratypes B and D show the shape and external ornament and Paratype E shows the internal structure of a larger specimen.

Neither the ligament area nor the dentition of larger specimens is visible. Some small specimens apparently have only two posterior teeth—the striation of the posterior teeth is clearly visible in several specimens. The development of the posterior umbonal ridge varies considerably and in Paratype B the ridge is more prominently developed in the older part of the shell, i.e. nearer the umbo. The size also varies considerably, and one specimen in the collection is more than 60 mm. long.

Dimensions (in mm.):

	Greatest Length	*Height at Umbo*	*Thickness*
Holotype	13	7	3
Paratype A	9	4·5	2
Paratype B	33	16	5
Paratype C	25	13	5
Paratype D	29	12 (estimated)	5 (estimated)
Paratype F	14	8	3

Occurrence: Holotype, Paratypes A and B, UWA Type Nos. 45352, 45353, and 45354 respectively (Reg. No. 23354), and Paratype C, UWA Type No. 45355, (Reg. No. 23350), Fossil Ridge; Paratype D, UWA Type No. 45356 (Reg. No. 23388), below Round Hill; Paratype E, UWA Type No. 45357 (Reg. No. 23363), near Holmwood; all from the Fossil Cliff Formation, Irwin River area. Paratype F, CPC 3878 (Field No. WB 266), 30 miles west-north-west of Curbur Homestead, Lat. 26°22′00″S, Long. 115°25′00″E, Callytharra Formation.

Other Specimens: PB 7 and IR 20, about ½ mile on a bearing of 334° from Caryngina (No. 1) Well; and PB 9, Pintharuka 1-mile Sheet, map co-ordinates 511056, Becketts Gully, ⅖ mile above road crossing, Fossil Cliff Formation. This species occurs also in the Fossil Cliff Formation at Fossil Cliff and in the siltstones of Bangarra Hill. A total of more than a hundred specimens.

Discussion: *P. bimodoliratus* is especially common in the calcareous beds of the Fossil Cliff Formation; in the Callytharra Formation, it is recorded from a single locality, the southernmost known outcrop of the Formation. Despite the number, good specimens are difficult to find; most specimens on the surface of the limestone are weathered, and the shells do not readily break away from the matrix.

Superfamily GRAMMYSIACEA

To this superfamily is referred a large group of Palaeozoic shells which are united by the poor development or absence of teeth and the presence of a strong opisthodetic ligament, and which are apparently adapted to a burrowing habit. Many genera have a granulated external surface. This group in part corresponds to the Palaeoconcha of Dall *in* Zittel (1913). Subdivision within this group must remain rather tentative because important characters, especially of the ligament, of key genera remain unknown.

In the Upper Palaeozoic shells of this superfamily, two rather different types of ligament occur, and this allows a broad subdivision. One group has a relatively short arcuate ligament immediately behind the umbones with strong nymphs.

Species belonging to this group described in the present paper are referred to the Edmondiidae and the Pholadomyidae (or Chaenomyidae). The other group of shells has a relatively long ligament extending backwards from the umbo and lodged in a groove or on a flattened ligament area; this group may be entirely edentulous in the Palaeozoic, and is referred to the Sanguinolitidae. It is unfortunate that for both *Edmondia* and *Sanguinolites* the character of the ligament is not clear (for *Edmondia* see Hind, 1898, p. 255).

Most of the shells in the Grammysiacea have an entire pallial line, though a pallial sinus is present in at least *Chaenomya* and *Wilkingia**; but there appears to be no great difference otherwise between sinupalliate and non-sinupalliate forms. Also there does not seem to be any great distinction between Palaeozoic and Mesozoic forms: *Chaenomya,* for example, appears to be ancestral to *Pholadomya,* and yet if it were not for the presence of later forms it could be satisfactorily fitted into the family Edmondiidae as used here. The conclusions made in this paper cut across the broad subdivision into Prionodesmacea and the Anomalodesmacea as it is apparent that the prionodesmacean Grammysiacea are more closely related to the later anomalodesmacean forms than to the taxodont and anisomyarian forms which have been included in the Prionodesmacea.

Palaeoecology of the Grammysiacea: The relationship and evolutionary development of the forms which are placed in the Grammysiacea are best explained by assuming their adaptation to a burrowing habit. The Grammysiidae and Edmondiidae are characterized by well developed ligament nymphs behind the umbones, similar to those found in living forms adapted to burrowing. This has been pointed out by Newell (1956, p. 3) in his account of Permian forms from Eastern Australia. Although most of the Palaeozoic forms lack a pallial sinus, adaptation to a burrowing habit is also indicated in *Chaenomya* and *Wilkingia* by the presence of a siphon and by their obvious relationship to the Mesozoic anomalodesmacean forms.

The burrowing habit of these forms has been strikingly confirmed in a paper by Craig (1956), based on his examination of Carboniferous rocks in Scotland. Of 37 specimens of *Edmondia sulcata* (Fleming) 1828, '34 are vertical to the bedding in a dorso-ventral direction; three lie parallel to the bedding. The orientation of eight specimens could not be determined. Of the 34 vertical specimens, 25 lie in the ash with the anterior edge declined'.

In his figure Craig shows the sediment behind the shell disturbed by movement.

* Wilson (1959) has concluded that *Hiatella sulcata* Fleming 1828, the type species of *Allorisma,* is an *Edmondia,* and has proposed the new name *Wilkingia* for sinupalliate forms which were previously referred to *Allorisma.*

Family EDMONDIIDAE King 1849

Newell (1956) has proposed placing Australian Permian genera, including *Pachydomus* (=*Megadesmus*), *Astartila, Myonia,* and *Cleobis,* in the family Pachydomidae Fischer 1887. Apart from the absence of a lamellar internal 'ossicle', which seems to be a lamellar extension of the hinge-plate into the shell cavity and may not be of great significance at a family level, it is not clear how these genera differ from *Edmondia* in a way which warrants separation into another family. Until more information is available on *Edmondia*, it is proposed to place the Australian Permian genera *Megadesmus, Astartila,* and *Myonia* in the Edmondiidae (*Cleobis* is regarded as a synonym of *Megadesmus*).

Genus EDMONDIA de Koninck 1844 (p. 66)

Type Species (by subsequent designation of Stoliczka, 1871, p. xvi): *Isocardia unioniformis* Phillips (1836, p. 209, pl. 5, fig. 18).

Discussion: Wilson (1960, p. 113) has examined the type specimens of *Isocardia unioniformis* preserved in the Gilbertson Collection at the British Museum (Natural History). They comprise three, apparently not very well preserved, specimens, and Wilson has designated the specimen Reg. No. PL 784, figured by Hind (1899, p. 293, pl. 28, fig. 1) as the lectotype. Two of the specimens, including the lectotype, 'provide evidence of internal cartilage plates'.

The function of the internal lamellar plates is not clear, although they are most probably connected with the attachment of the ligament. If they form an elongated area behind the umbo for the attachment of the ligament somewhat similar to that in *Undulomya* and *Praeundulomya*, placed marginally, but mainly internal rather than external, this would appear to contradict Hind's statement (1898, p. 255) that a small external ligament is present in *Edmondia.* It would then follow that *Edmondia* is closely related to the forms which are here placed in the Sanguinolitidae, and not to forms with relatively short strong nymphs.

Of the numerous references to the occurrence of *Edmondia* in rocks of Permian age, many are probably incorrect. *E. prichardi* sp. nov., however, appears to be a true *Edmondia*: in shape it is rather similar to *E. unioniformis,* the type species, and has similar internal lamellar plates or 'ossicles'.

EDMONDIA PRICHARDI sp. nov.

(Pl. 3, figs. 15-23; Pl. 4, figs. 15, 16.)

Diagnosis: Oval to subquadrate shells with umbo towards front and not particularly prominent. Outer surface of shell rounded from front to rear and lacking distinctly developed anterior and posterior umbonal ridges. External ornament of low regularly spaced concentric growth ridges.

Description: The holotype is a mature left valve showing the characteristic shape and ornament of the species. The length is considerably greater than the height and the umbo is less than one quarter of the shell length from the front. No distinctively developed lunule or escutcheon is visible. The external ornament is composed of rather regularly developed low concentric ridges and very fine radiating lines, about 7 per mm. near the ventro-posterior margin (see Pl. 4, fig. 15).

Other Specimens: Younger specimens tend to be less subquadrate, and their beaks, relatively, to be more prominent. Paratypes E and F are internal impressions showing the 'ossicle', which is a plate formed by the ventral extension of the hinge-plate behind the umbo. It is slightly bowed, convex outward from the hinge-line, and is directed downwards and slightly outwards. The adductor muscle scars were apparently superficial, as none are visible. A number of specimens, including Paratype B, which is figured, show fine radiating lines on the outside of the very thin inner shell layer. Whether these correspond to the lines or ridges on the outer surface is not clear.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Holotype	65	46	11
Paratype B (left valve)	63	46	12
Paratype C (right valve)	29	27	8
Paratype D (right valve)	26	21	5
Paratype E (left valve)	66 (estimated)	45	10·5
Paratype F (right valve)	91	68	19

Occurrence: Holotype and Paratype A, UWA Type Nos. 45361 and 45362 respectively (Reg. No. 23355), Paratype B, UWA Type No. 45363 (Reg. No. 23375), Fossil Ridge; Paratypes C and D, UWA Type Nos. 45364 and 45365 respectively (Reg. No. 23366), Becketts Gully, all from the Fossil Cliff Formation of the Irwin River area. Paratype E, UWA Type No. 45366 (Reg. No. 33384), 2.2 miles south of Mount Sandiman Woolshed, Mount Sandiman Station, Callytharra Formation; and Paratype F, CPC 3879 (Field No. GW 137), 130-180 feet above the base of the Callytharra Formation, 1 mile west of Callytharra Springs, Byro Station.

Other Specimens: Fossil Cliff Formation, Callytharra Formation (Field Nos. G 348, GW 80 and WB 266), and Nura Nura Member. A single specimen from the base of the High Cliff Sandstone at the old Glendevon Homestead, Woolaga Creek, Irwin River area, is not adequate to indicate whether *E. prichardi* is also present here.

Discussion: *Edmondia prichardi* is a characteristic fossil of the Fossil Cliff and Callytharra Formations and the Nura Nura Member. Its occurrence is widespread in this horizon and it is especially common in the Fossil Cliff Formation. Outside these formations the genus is only known by a single specimen from the High Cliff Sandstone at Woolaga Creek, and by a specimen, probably of a different species, from the considerably younger Baker Formation of the Carnarvon Basin (UWA Reg. No. 28123).

The species is named after Mr C. E. Prichard, geologist of the Bureau of Mineral Resources, who has done much work in Western Australia and collected some of the specimens described in this paper.

Genus MEGADESMUS Sowerby 1838 (p. 15)

Type Species (by subsequent designation of Woodward, 1854, p. 262): *Megadesmus globosa* Sowerby (1838, p. 15, pl. 3, figs. 1-2).

Synonyms: *Pachydomus* Morris (1845, p. 271),
Cleobis Dana (1847, p. 154).

Discussion: *Pachydomus* was introduced by Morris as a replacement name for *Megadesmus* because *Megadesma* had been previously used by Bowdich (1822). Under the Rules of Zoological Nomenclature, however, *Megadesmus* is not invalidated by prior publication of *Megadesma,* and therefore must stand as the valid name; and *Pachydomus,* which has appeared so long in the literature, must become a synonym (see also Vokes, 1956, p. 768).

The designation of *Megadesmus cuneatus* Sowerby 1838 as the type species by Stoliczka (1871)—see Newell (1956, p. 4) and Dickins (1957, p. 26)—was preceded by that of *Megadesmus globosus* by Woodward (1854). The earlier choice of *M. globosus* demands a reassessment of the conclusions made in Newell (1956) and Dickins (1957). It seems that *Cleobis* (type species *Cleobis grandis* Dana 1847, designated by Newell, 1956, p. 10) must become a synonym of *Megadesmus.* For reasons discussed later, Newell's (1956) proposal to regard *Astartila* as a synonym of *Pachydomus* (=*Megadesmus*) is not followed here.

MEGADESMUS sp.

(Pl. 4, figs. 1-3)

This species is represented by an incompletely preserved internal impression which is similar to the specimens from the Lyons Group of the Carnarvon Basin described as *Pachydomus*? sp. (Dickins, 1957, p. 26). The inside of the hinge is not preserved and the species cannot be reliably compared with that from the Lyons Group.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen	92	70	23

Occurrence: Figured Specimen, CPC 3880 (Field No. WB 180), about six miles south-south-east of Plant Well, Coordewandy Station, Callytharra Formation.

Genus ASTARTILA Dana 1847 (p. 155)

Type Species (by subsequent designation of Stoliczka, 1871, p. 275): *Astartila intrepida* Dana (1847, p. 155; 1849, p. 689, pl. 3, fig. 5).

Discussion: Little change is required from the diagnosis already given (Dickins, 1956, p. 16). Subsequent work has confirmed the character of the hinge. A blunt tooth in the right valve fits into a distinct socket in the left valve. Whether or not a tooth is present in the left valve seems to be a matter of descriptive terminology rather than fact. The hinge-plate is poorly developed and, as found in fully developed heterodont forms, can hardly be said to be present.

In Australia there is a group of species that can be distinguished from those referred to *Megadesmus* by their subcircular shape, smaller size, and a less strong development of the 'hinge-plate'. The retention of the name *Astartila* for this group of forms has some merit, although as Newell (1956, p. 12) has pointed out, small specimens of *Megadesmus* may be difficult to distinguish from *Astartila.* Also some species are, externally, intermediate between *Astartila* and *Megadesmus* and are difficult to assign to one or the other, especially in the absence of knowledge of the hinge characters. Such a species is *Astartila*? *tumida* sp. nov. *Astartila*? *tumida,* however, together with *A.*? *obscura* Dickins (1957, p. 25, pl. 3, figs. 1-6) from the Lyons Group and *A.*? sp. (described below), form a lineage with a common development of a wide dorso-posterior area and it might be desirable to create a name for this grouping and to consider this and *Astartila* as subgenera of *Megadesmus.*

ASTARTILA? TUMIDA sp. nov.

(Pl. 4, figs. 4-10)

Diagnosis: Shell transversely oval with length greater than height. A distinct rounded posterior umbonal swelling or ridge forms a wide area, dorsal and posterior to the swelling. Umbo prominent; distinct external ornament of concentric rugae, poorly developed behind the umbonal swelling.

Description: Anteriorly the holotype has no distinctly marked off lunular area and the beak is markedly inturned towards the front. Compared with the posterior, the anterior umbonal swelling is poorly developed and passes imperceptibly into the front part of the shell. Only part of the shell material is preserved, but the external surface apparently bears a number of rounded rugae, which are less prominent towards the outside and behind the umbonal swelling.

Other specimens show that the transverse elongation of the shell is characteristic for this species and confirm the type of external ornament.

Dimensions (in mm.):

	Length	*Maximum Height*	*Thickness*	*Height of Umbo Above Hinge-line*
Holotype (right valve)	45	33	15	5 (estimated)
Paratype A (left valve)	55	42	18	5 (estimated)
Paratype B (left valve)	72	50	29	9
Paratype C (right valve)	72	56	27	—

Occurrence: *A.*? *tumida* is represented by five specimens only, all from the Fossil Cliff Formation. Holotype, UWA Type No. 45367 (Reg. No. 23372), near Holmwood (probably from hard limestone in Becketts Gully or from Fossil Ridge); Paratypes A and B, UWA Type Nos. 45368 and 45369 respectively (Reg. No. 23324), and Paratype C, UWA Type No. 45370 (Reg. No. 23336), Fossil Cliff, Irwin River area.

Discussion: Whether the number of rugae is constant, or whether, as appears likely, the ribs increase in number towards the rear, cannot be seen. The details of the hinge and the musculature are not visible.

Astartila? *tumida* is closely related to *Astartila*? *obscura* Dickins (1957, p. 25, pl. 3, figs. 1-6) from the Carrandibby Formation, and apparently belongs to the same lineage. Both species have a prominent umbo and a distinct posterior umbonal swelling, forming an unusually wide dorso-posterior area so that the back part of the shell is very swollen. *A*.? *tumida* can be distinguished by its transverse shape, less prominent umbo (as shown by a comparison of the height of the umbo above the hinge-line), and the possession of concentric rugae. Great weight, however, cannot be placed on the external ornament, which can be rather variable in shells of this type.

ASTARTILA? sp.

(Pl. 4, figs. 11-14)

Discussion: Specimens assigned to *Astartila*? sp. come from the base of the High Cliff Sandstone at Woolaga Creek. I regard the material as inadequate to define the new species which it probably represents. The species appears to be distinguishable by the very marked development of the dorso-posterior area and the concave shape of this area behind the umbo.

Description: In two of the specimens (A and B) the length exceeds the height and the posterior umbonal ridge is distinctly developed, forming a very marked dorso-posterior area. C is less transverse and the posterior area is apparently less well developed. These differences, however, may be caused by crushing. The beak is very prominent and the external surface has a large number of regularly spaced rugae which increase towards the back by interpolation. These are less well developed behind the umbonal ridge, where fine growth-lines are visible.

Dimensions (in mm.):

	Length	*Maximum Height*	*Thickness*	*Height of Umbo Above Hinge-line*
Figured Specimen A (right valve)	63	48	18	9
Figured Specimen B (left valve)	48	41	16 (estimated)	—

Occurrence: Four specimens altogether. Figured Specimens A, UWA Type No. 45371 (Reg. No. 31540), B, UWA Type No. 45372 (Reg. No. 31539), and C, UWA Type No. 45373 (Reg. No. 31533), basal part of High Cliff Sandstone, Woolaga Creek, Irwin River area.

Genus MYONIA Dana 1847 (p. 158)

Type Species (by subsequent designation of Fletcher, 1932, p. 398): *Myonia elongata* Dana (1847, p. 158; 1849, p. 695, pl. 5, fig. 3).

Synonym: *Maeonia* Dana (1849, p. 604), an unnecessary variant spelling (see Fletcher, 1932, p. 381, and Newell, 1956, p. 7). Although Branson (1948, p. 621) states that *Myonia* Dana is a homonym of *Myonia* Adams and uses *Maeonia,* according to Neave (1940) *Myonia* Dana 1847 antedates *Myonia* Adams 1860 and Dana's usage is therefore valid.

Discussion: Although Newell (1956, p. 7) proposes placing *Pachymyonia* Dun (1932, p. 411) into the synonymy of *Myonia, Pachymyonia* does seem to have some value for a number of species that are wide across the valves and are strongly carinate. The differences, however, between *Myonia* and *Pachymyonia* are not of great consequence, and it may be better to regard the latter as a subgenus of *Myonia* rather than to give it separate generic status.

Newell also shows that *Myonia elongata* has a hinge like that of *Pachydomus* and *Pyramus,* and on this basis, like *Pachydomus,* it is referred to the Edmondiidae. I have discussed the position of *Pyramus* elsewhere (Dickins, 1961a).

In recent years *Myonia sensu lato* has been recorded from many parts of the world. Reed (1930) has recorded *Myonia* from Brazil, and the specimen from Argentina described by Harrington (1955, p. 118) as *Schizodus cycloliratus* is almost certainly a *Myonia.* Reed (1932) has also recorded *Myonia* from the Agglomeratic Slate of Kashmir, and more recently the genus has been described from North-eastern Siberia by Popov (1957) and Lobanova (1959).

The external surface of the species described below is granulated; no doubt this is a generic feature.

MYONIA SUBARBITRATA sp. nov.

(Pl. 5, figs. 2-12, 22)

Diagnosis: Shell only moderately convex; posterior carina distinct; more or less rounded and convex near the umbo but slightly concave towards the ventro-posterior margin. Between the carina and the ridge forming the edge of the ligament groove, a sharp groove forms a distinct escutcheon.

Description: In the holotype, the ligament is lodged in a groove behind the umbo. In front of the carina the outer surface is ornamented with concentric furrows and rugae (or ridges): the ridges increase infrequently in number by subdivision or interpolation and persist behind the carina, where they are less well developed and end at the furrow which forms the edge of the escutcheon, about halfway between the carina and the outer edge of the ligament groove. The escutcheon is covered only by fine growth-lines.

Paratype A shows the anterior part of the shell and umbo better than the holotype but is crushed towards the rear. The umbo is distinctly inrolled towards the front so that the beaks of adjacent valves would be almost touching. The anterior part of the dorsal margin is concave and there is a lunular area where the concentric rugae are poorly developed.

Other Specimens: The sharpness of the posterior carina varies considerably, but it is always distinct and is marked by a relatively abrupt change in the direction of the rugae.

The external surface is covered by rows of radiating papillae, so close together in some specimens that under the hand lens they appear to form a continuous line.

No teeth are visible, but the insides of the hinges are poorly preserved.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Holotype (left valve)	21 (estimated)	13	6·5
Paratype A (left valve)	27	17	8
Paratype B (right valve)	17 (estimated)	12	5·5
Paratype C (bivalved specimen)	13	9	8
Paratype D (right valve)	17	11	6·5
Paratype E (right valve)	15	11	5

Occurrence: Holotype and Paratypes A-C, CPC 3885, 3886, 3887, and 3888 respectively, 1.6 miles south-west of Paradise Homestead; Paratype D, CPC 3889 (Field No. $KNuA_1$), same as holotype locality, Nura Nura Member of Poole Sandstone. Paratype E, CPC 3890 (Field No. PB 7), about ½ mile on a bearing of 334° from Carynginia (No. 1) Well, Fossil Cliff Formation; Paratype F, CPC 4017 (Field No. W 33 C (1)), not certain but close to holotype locality.
Other Specimens: Holotype and Paratype E localities. More than 40 specimens from Nura Nura Member and two from PB 7.

Discussion: *Myonia subarbitrata* sp. nov. differs from most other species placed in *Myonia* by the possession of a distinct escutcheon marked by a groove. In shape, external ornament, and character of the ligament groove, the Western Australian species hardly differs from *Maeonia*? *arbitrata* Reed (1932, p. 41, pl. 9, figs. 5 and 5a) from the Agglomeratic Slate of Kashmir. Reed, however, neither describes nor figures an escutcheon. In shape and ornament *Myonia subarbitrata* also resembles a right valve of *Myonia* (Australian Museum No. F 21, 384) from Wyro near Ulladulla from the lower part of the 'Upper Marine' sequence (Shoalhaven Group) south of Sydney. Like *M.* ? *arbitrata,* the Wyro specimen differs from *M. subarbitrata* in lacking a groove on the dorso-posterior area marking off a distinct escutcheon. The specimen, which has an estimated length of 26 mm., and is 18 mm. high and 6 mm. thick, is figured in Plate 5, fig. 1. *M. subarbitrata* also resembles *Myonia* (?) aff. *carinata* (Morris) Dana, described by Lobanova (1959, p. 65, pl. 1, figs. 7-12) from the Lower Permian of Eastern Siberia. The Western Australian specimens are similar in shape, size, and external ornament, and although it is not mentioned in the description, a groove is shown in the photographs of *M.* (?) aff. *carinata* on the dorso-posterior area.

The name is derived from *sub,* akin to; and *arbitrata,* the species mentioned above described from India by Reed.

MYONIA sp. nov.

(Pl. 5, figs. 13-19)

Description: Included in *Myonia* sp. nov. are five specimens in which the posterior carina is either straight or slightly convex throughout and not concave behind the umbo as in *M. subarbitrata,* and some of the specimens differ in addition in that the carina is sharp and the concentric rugae are poorly developed. A distinct escutcheonal area may be absent.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen A	26	20	8
Figured Specimen B	19 (estimated)	—	5·5
Figured Specimen C	45	29	11
Figured Specimen D	23 (estimated)	14	4
Figured Specimen E	22	16	5

Occurrence: Figured Specimen A, UWA Type No. 45375 (Reg. No. 23359), Figured Specimen B, UWA Type No. 45376 (Reg. No. 23357), Figured Specimen C, UWA Type No. 45377 (Reg. No. 23390), all from Fossil Ridge, Irwin River area; Figured Specimen D, UWA Type No. 45378 (Reg. No. 23373), Fossil Cliff, Irwin River area; all four specimens from Fossil Cliff Formation. Figured Specimen E, CPC 3891 (Field No. G 202), 5⅞ miles on a bearing of 335° from Lyons River Homestead, at top of the exposed Callytharra Formation.

Discussion: Although all the specimens placed in this species have a straight or slightly convex carina and therefore differ from *M. subarbitrata,* they vary considerably amongst themselves in the sharpness of the carina, the development of the concentric ornament, and their dimensions. They differ from *Pachymyonia occidentalis* Dickins (1957, p. 28, pl. 4, figs. 5-9) from the Carrandibby Formation of the Carnarvon Basin in having a straight or slightly convex carina and in lacking strong inflation.

Genus PACHYMYONIA Dun 1932 (p. 411)

Type Species (by original designation): *Maeonia morrisii* Etheridge Jnr (1919, p. 186, pl. 28, figs. 7; 8).

PACHYMYONIA cf. OCCIDENTALIS Dickins 1957

(Pl. 5, figs. 20, 21)

Discussion: A single specimen is referred doubtfully to *Pachymyonia occidentalis* Dickins (1957, p. 28, pl. 4, figs. 5-9). In shape it resembles this species, but is apparently produced further in front of the umbo. The external surface has radiating rows of granules, with the granules placed closely together in the rows.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen	48	29	17

Occurrence: Figured Specimen UWA Type No. 45379 (Reg. No. 23372), near Holmwood (probably from hard limestone bands on Fossil Ridge or in Becketts Gully), Fossil Cliff Formation, Irwin River area.

Family PHOLADOMYIDAE Gray

On the basis of new information on the presence of granulation in *Pholadomya* and the character of the hinge in *Chaenomya, Chaenomya* appears to be closely related to *Pholadomya* rather than to *Sanguinolites,* as had been previously suggested (Dickins, 1957, p. 29). It is proposed therefore to assign *Chaenomya* to the Pholadomyidae rather than to another family such as the Sanguinolitidae, the Chaenomyidae, or the Pholadellidae. *Chaenomya* and *Pholadomya* have somewhat similar shapes, possess a pallial sinus, gape at the rear, and have a short strong external ligament behind the umbo and a granulated external surface. (Stenzel, Krause, & Twining (1957, p. 163, 164, pl. 18, figs. 13-15), describe granulation in *Pholadomya.*) Teeth are poorly developed or absent. *Pholadomya* may differ by having also a small umbonal pit occupied by ligament.

Chaenomya also appears to be related to *Pholadella* and *Cimitaria* from the Devonian, and it is doubtful whether the differences warrant their separation into a distinct family, Pholadellidae Miller.

The position of *Wilkingia* Wilson 1959 (previously *Allorisma)* is not clear, and although in 1957 I considered that *Chaenomya* was closely related to *Allorisma* and that it should be placed in the same family, it now appears that *Wilkingia* may have an elongated ligament and may thus be more closely related to forms I am proposing to place in the Sanguinolitidae. Some species, however, such as *Chaenomya*? *nuraensis* sp. nov. are difficult to assign to one or the other, especially in the absence of information on the hinge.

Genus CHAENOMYA Meek 1865 (p. 42)

Type Species (by original designation of Meek *in* Meek & Hayden): *Allorisma*? *leavenworthensis* Meek & Hayden (1858, p. 263).

Discussion: As suspected by Etheridge (1892, p. 278) a number of Permian species from Australia, especially Eastern Australia, are referable to *Chaenomya.* Some have been referred to *Sanguinolites* or *Allorisma.* The ligament is lodged in a bow-shaped groove similar to that illustrated by Newell (1956, figs. 3B and 3F). The nymphs are strongly developed, so that the ligament was arched over them in a manner similar to that found in living burrowing forms.

CHAENOMYA sp.

(Pl. 8, figs. 12-16)

Material: Three specimens, one from each of the Fossil Cliff and Callytharra Formations and the Nura Nura Member of the Poole Sandstone.

Description: The umbo is broadly and prominently developed, rising distinctly above the hinge-line behind, but in front not distinctly separated from the front part of the shell and its margin. The valves are closed at the front, but at the back a slight gape is suggested by the growth-lines. A broad (pedal) sulcus runs from the umbo to the ventral margin. The anterior margin is broadly rounded, but the shell is truncated at the rear. The ligament is external and lodged in a shield-shaped area behind the umbo. The ligament area is bounded by a rounded ridge, separated from a distinctly developed posterior umbonal ridge by a shallow groove which together with the umbonal ridge forms an escutcheon distinct from the ligament area. The posterior umbonal ridge runs to the middle part of the posterior margin.

The external surface is ornamented with a large number of low, rounded concentric rugae, which increase and decrease rather irregularly, but in general increase near the front and decrease towards the rear: increase takes place either by subdivision or intercalation and decrease by the reverse processes. The external surface also has radiating rows of granules.

Dimensions (in mm.):

		Length	*Height*	*Width*
Figured Specimen A	......	—	42	31 (two valves)
Figured Specimen B	......	80	52	15 (estimated)

Occurrence: Figured Specimen A, UWA Type No. 45374 (Reg. No. 23329), Fossil Cliff, Fossil Cliff Formation; Figured Specimen B, CPC 3881 (Field No. G 202), 5⅞ miles bearing 335° from Lyons River Homestead, Callytharra Formation; Figured Specimen C, CPC 3882 (Field No. W 33 C (1)), not certain but close to $KNuA_1$, 1.6 miles south-west of Paradise Homestead (Lat. 18°02′30″S., Long. 124°31′00″E.), Nura Nura Member.

Discussion: A comparison of the growth-lines of the three specimens suggests that a single species may be present.

Chaenomya sp. is close to the type species of the genus and belongs in *Chaenomya* in a restricted sense.

CHAENOMYA? NURAENSIS sp. nov.

(Pl. 6, figs. 10-14)

1957. *Chaenomya* sp. nov. Dickins, p. 29, pl. 4, figs. 10-12.

Diagnosis: Shell transversely elongated with posterior part of cardinal margin concave and reflexed so that back rises to about height of umbo. Umbo more or less upright and not inrolled at the front; passes gradually into anterior margin with only slight indentation in outline. Dorsal part of anterior margin less rounded than ventral part and at an angle to hinge-line. Probably gaping slightly at rear.

Description: The holotype is an internal impression and part of the external impression of a left valve. An obscure posterior umbonal ridge is present, but anteriorly the front of the umbo merges with the anterior margin of the shell with no inturning of the umbo. The anterior margin is not uniformly inflated, but the dorsal part is straighter and at a distinct angle to the hinge-line, whereas the ventral part rounds gradually into the ventral margin. The shell is truncated at the rear, with the posterior only rounding into the dorsal and ventral margins close to the junctions. The external surface is granulated and has concentric growth-lines and rugae. The granulation (below the umbo close to the ventral margin) is arranged in closely spaced rows. Seven rugae are visible on the internal impression and at the rear the growth-lines form short lamellae directed backwards. The shell is closed at the front and any gape present at the rear was slight.

The paratype shows radiating rows of closely spaced granules near the posterior margin.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Holotype	29	13	4
Paratype	21	10	2·5

Occurrence: Holotype, CPC 3883 (Field No. W 33 C (1)), locality not certain but close to $KNuA_1$ which is 1.6 miles south-west of Paradise Homestead; Paratype, CPC 3884, locality not clear but apparently same as $KNuA_1$, and another specimen from W 33 C (1); both Nura Nura Member.

Discussion: Although the new material comprises only three specimens, they justify the introduction of a new specific name. *Chaenomya*? *nuraensis* is somewhat similar to *Allorisma*? sp. nov., Dickins (1956, p. 21, pl. 2, figs. 1-2), which can now be referred to *Wilkingia*. In the latter, however, the anterior margin is more uniformly inflated, the posterior part of the cardinal margin is not inflexed, and the front part of the umbo is inturned.

In some respects *C.*? *nuraensis* is intermediate between *Chaenomya* and *Wilkingia*, and for these reasons, until more information is available, is placed only tentatively in *Chaenomya*.

The species is named after the Nura Nura Ridge, Fitzroy River area, where the type specimens were collected.

Family SANGUINOLITIDAE

To this family are referred transversely elongated forms with an elongated narrow ligament area stretching backwards from behind the umbo. Until the characters, especially of the hinge, of *Sanguinolites* and *Edmondia* are determined the grouping of these forms must remain on a rather haphazard basis. Some of the forms referred to this family appear to lack teeth and the whole group may be edentulous.

I have not been able to trace the first use of the family name Sanguinolitidae, but it is used by Hall (1885) at the top of his plates. I have not used the family name Solenopsidae Neumayr, over which Sanguinolitidae appears to take precedence. The name Solenopsidae also has the disadvantage that *Solenopsis* has been replaced by the name *Solenomorpha* as a genus of pelecypods.

Genus PRAEUNDULOMYA Dickins 1957 (p. 10)

Type Species (by original designation): *Praeundulomya concentrica* Dickins (1957, p. 11, pl. 1, figs. 1-11, text-fig. 2).

Discussion: The relationship of *Praeundulomya* to Carboniferous forms, especially to *Edmondia sulcata* (Phillips) 1836, has been discussed previously (Dickins, 1957, p. 11). I am indebted to Professor N. D. Newell for emphasizing in correspondence the close relationship of *Praeundulomya* to many Carboniferous species that have been assigned to *Allorisma*. Wilson (1959) has concluded that *Sanguinolaria sulcata* Phillips 1836 is a synonym of *Hiatella sulcata* Fleming 1828, the type species of *Allorisma* King 1844, and that *Hiatella sulcata* Fleming 1828 is an *Edmondia*. For the sinupalliate forms for which King intended the name *Allorisma*, he has proposed *Wilkingia*, with the type *Venus elliptica* Phillips (1836, p. 209, pl. 5, fig. 7). Whether *Allorisma* should be retained for a group of transversely-elongated species similar to *Praeundulomya* is an unresolved problem. Chernyshev (1950, p. 74) has proposed *Edmondiella* with the type *Sanguinolaria sulcata* Phillips 1836 for these forms, but this is unnecessary if *Allorisma* is available. *Praeundulomya* seems to differ from all these by possessing two posterior grooves, which are of importance in indicating the evolution of *Praeundulomya* and *Undulomya*. If, however, Carboniferous forms can be shown to have these posterior grooves, then the standing of the name *Praeundulomya* must be reviewed. *Praeundulomya* can be separated from *Undulomya* by its lack of definite V-ribbing and by the poorer development of the posterior grooves. The interpolation of ribs towards the rear, however, in advanced forms of *Praeundulomya* precedes the development of the distinct V-ribbing.

Although *Undulomya* has been placed in the Pholadomyidae (Fletcher, 1946, p. 398) and *Praeundulomya* and *Undulomya* in the Arcomyidae (Dickins, 1956, p. 28; 1957, p. 10), it seems unlikely that these genera belong to either family, which appear to be characterized by possessing a relatively short bow-shaped ligament behind the umbones, with heavy nymphs over which the ligament is arched.

For the present the genera are placed with reservation in the family Sanguinolitidae.

Praeundulomya subelongata sp. nov.

(Pl. 6, figs. 15-20; Text-fig. 8)

Diagnosis: Shell elongate, ribbing concentric but lacking the complexity of *Praeundulomya concentrica* Dickins 1957; two posterior grooves distinct, particularly in the middle part of the shell. Especially distinguished by the development of the posterior umbonal ridge in the younger part of the shell.

Description: In the holotype the shell projects distinctly in front of the umbo and a lunule is apparently present; behind the umbo remnants of the flattened ligament area are preserved. The umbo is inturned towards the front so that the anterior umbonal ridge is distinct from the front part of the shell. The ribs or rugae are, on the whole, concentric, and few ribs are added at the rear—there are no ribs behind the concentric continuous ribs, which have no counterparts at the front. Two posterior grooves run from the umbo to the dorsal part of the posterior margin, the grooves being situated above and behind the posterior umbonal ridge, which is broad, gently rounded and distinctly developed closer to the umbo where the shell is most tumid.

Paratype B shows part of the adductor muscles. The anterior scar is superficial and elongated dorso-ventrally. What appears to be the scar of the posterior adductor is considerably larger, sub-circular, and situated immediately above and behind the umbonal ridge.

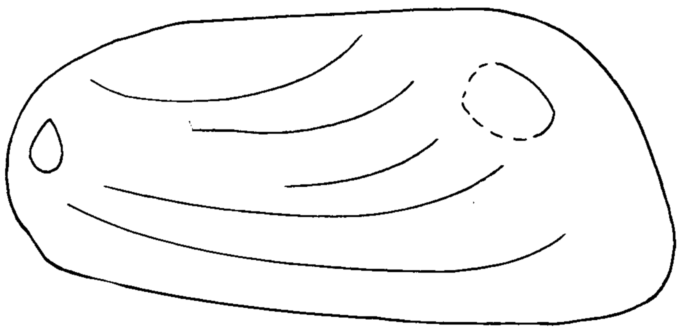


Fig. 8. Praeundulomya subelongata sp. nov. Paratype Bx1 showing the musculature (see also Plate 6, fig. 20).

Dimensions (in mm.):

	Length	*Height*	*Thickness*	*Distance of Umbo from Front*
Holotype	95	46	11	24
Paratype A				
Complete Shell	116	53	18	27
Growth Stage	82	37	9	18
Paratype B	85	42 (approx.)	11	—

Occurrence: Four specimens and a number of fragments. Holotype, UWA Type No. 45381 (Reg. No. 23386) and Paratype B, CPC 3892 (Field No. PB 8), Fossil Cliff; Paratype A, UWA Type No. 45382 (Reg. No. 23385) and another specimen (Field No. PB 14), Fossil Ridge, all specimens from the Fossil Cliff Formation, Irwin River area.

Two fragments of *Praeundulomya* from A 108, Mount Wynne, 1.3 miles east of Nura Nura Ridge, Nura Nura Member, are too incomplete for specific determination, and a specimen (Field No. G 347) doubtfully referable to the species occurs at the top of the Callytharra Formation near the wind-pump about $\frac{1}{3}$ mile north-east of the Mount Sandiman Woolshed.

Discussion: *Praeundulomya subelongata,* as the name implies, more closely resembles *P. elongata* than *P. concentrica.* It can be separated by its slightly lesser elongation and especially by the distinctive development of the posterior umbonal ridge closer to the umbo than to the posterior margin.

Genus PALAEOCOSMOMYA Fletcher 1946 (p. 401)

Type Species (by original designation): *Palaeocosmomya teicherti* Fletcher (1946, p. 402, pl. 14, figs. 4-6; pl. 15, figs. 7, 8).

Discussion: A comparison with *Cosmomya* Holdhaus (1913, p. 46) is difficult because this genus is based on a single incomplete specimen. The shape appears similar to species of *Palaeocosmomya* and the ribbing is not greatly different. It seems possible that *Cosmomya* may be from Permian rather than Jurassic rocks, as thought by Holdhaus, as the specimen came from a locality separate from the other Jurassic localities he was considering, and is included in the Jurassic only because of a similarity of lithology to the Spiti Shales. Occurring with *Cosmomya* is a species of *'Goniomya'* which is very like an *Undulomya* and which is said by Holdhaus to be different from all other species of *Goniomya.* If *Cosmomya* is Permian and not Jurassic, *Palaeocosmomya* is probably a synonym of *Cosmomya.*

Sanguinolites V-scriptus Hind (1900, p. 382, pl. 2, figs. 5-7) appears to be a *Palaeocosmomya* in a broad sense. It is similar in shape and has a similar type of ribbing. The ribbing, however, is simpler than in *P. teicherti* and more like that found in the two specimens described below. *Grammysiopsis irregularis* Chernyshev (1950, p. 17, pl. 6, fig. 52) from the zone with *Schwagerina princeps* Möller of the Urals may be a forerunner of *Palaeocosmomya.* It is similar in shape and ribbing. The ribbing, however, is less complex than the specimens described below from the Fossil Cliff Formation and the Nura Nura Member.

PALAEOCOSMOMYA sp. nov.

(Pl. 6, figs. 21, 22)

Description: The form is represented by two incomplete specimens which show the general shape and the character of the ornament. In the front part of the shell the ribs are more or less concentric, but behind the umbo a distinct V is developed. A second inverse V found in *P. teicherti* where the concentric ribbing of the front joins the V behind the umbo is absent in these two specimens. The sharp sinus or sulcus found in *P. teicherti*, running from the umbo to the ventral margin, is also absent.

Dimensions (in mm.):

	Length	*Height*	*Width*
Figured Specimen A	46 (estimated)	26	6
Figured Specimen B	—	15 (estimated)	2

Occurrence: Figured Specimen A, UWA Type No. 45383 (Reg. No. 23373), Fossil Ridge, Fossil Cliff Formation, Irwin River area; Figured Specimen B, CPC 3893 (Field No. $KNuA_1$), 1.6 miles south-west of Paradise Homestead, Nura Nura Member of Poole Sandstone.

Discussion: In its ornamentation *P.* sp. nov. is closer to *P. V-scriptus* than to *P. teicherti.* In *P. V-scriptus,* however, the V is even simpler.

Genus PALAEOSOLEN Hall 1885 (p. xlvi)

Type species (by original designation): *Orthonota siliquoidea* Hall (1870, p. 89; 1885, p. 483, pl. 78, fig. 33).

Discussion: The determination of the generic position of the species described below as *Palaeosolen*? *badgeraensis* sp. nov. has presented considerable difficulties. It is expanded slightly towards the rear and can thus be separated from species of *Solenomorpha* Cockerell 1903 (=*Solenopsis* McCoy 1844), with type species *Solenopsis minor* McCoy (1844, p. 47, pl. 8, fig. 2), which, although distinctly elongated, taper towards the rear. From *Orthonota* Conrad 1841, with the type species *Orthonota undulata* Conrad (1841, p. 51, pl., fig. 6), which it resembles in shape, it can be distinguished by the lack of the complex posterior radiating ornament. However, as indicated by Hall (1885, p. xlvi) *Palaeosolen*, in general appearance, is similar to *Orthonota*; and the Western Australian species in possessing delicate posterior radiating ornament falls in between the two genera.

Our species also shows some resemblance to species which have been placed in *Sanguinolites*, but the posterior part is more elongated, the umbo is poorly developed, and the cardinal margin in front of and behind the umbo almost forms a straight line. Nor is it altogether satisfactorily placed in *Palaeosolen* as it lacks a distinct posterior truncation and gape.

When proposing the new name Hall regarded *Palaeosolen* as a subgenus of *Solen*, and Maillieux (1937, p. 13) places *Palaeosolen* in the family Solenidae. There seems to be little evidence for this relationship and the resemblance in shape may be homoeomorphic.

PALAEOSOLEN? BADGERAENSIS sp. nov.

(Pl. 6, figs. 1-9)

Diagnosis: Umbo inconspicuous; cardinal margin in front of and behind umbo, almost forming a straight line. Posterior umbonal ridge carinate, reaching external margin at junction of ventral and posterior margins. Several fine radiating ridges behind and above carina.

Description: In the holotype, internal and external impressions of a left valve, the cardinal and ventral margins are long and straight and diverge slightly towards the back. The surface is covered with numerous fine concentric lines of growth which change direction rather abruptly at the posterior umbonal ridge. Behind this ridge the shell is flattened and several delicate radiating ridges run from the umbo towards the posterior margin. The posterior margin is oblique and slightly curved. Probably the shell gaped slightly at the front and rear. Behind the umbo on the internal impression is a long narrow flattish groove for the reception of the ligament of a type similar to that found in *Undulomya* and *Praeundulomya*. No muscles or teeth are visible.

Paratypes A and B suggest some variation in shape, especially in young specimens, with the posterior part of the ventral margin more rounded.

Dimensions (in mm.):

	Length	*Height at Umbo*	*Greatest Height*	*Thickness*
Holotype	35	9	11	2·5
Paratype A	23	6·5	8	2
Paratype B	16	6·5	6·5	1·5
Paratype C	19	6	7	1·5
Paratype D	16	5	6·5	1·5

Occurrence: Holotype, CPC 3894 (Field No. PB 7), about ½ mile on a bearing of 334° from Caryngiania (No. 1) Well; Paratypes A and B, CPC 3895 and 3896 respectively (Field No. PB 9), Pintharuka 1-mile Sheet, map co-ordinates 511056, Becketts Gully, ⅖ mile above road crossing; Paratype C, CPC 3897 (Field No. PB 14), Fossil Ridge; all from the Fossil Cliff Formation of the Irwin River area. Paratype D, CPC 3898 (Field No. W 33 C (1)), close to $KNuA_1$, 1.6 miles south-west of Paradise Homestead, Nura Nura Member of Poole Sandstone. A total of five specimens. Two specimens (Field No. SG 120A) doubtfully referable to this species occur in the base of the Poole Sandstone 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range.

Discussion: Although Paratypes A and B are slightly crushed there seems to be little doubt that they should be referred to the same species as the other specimens.

Except possibly at SG 120A this species is found in a silty matrix and was probably adapted for burrowing in a silty environment.

The species is named after Badgera Pool on the Irwin River, near the locality of the holotype.

Genus 'SOLEMYA'

Discussion: The species described below as *'Solemya' holmwoodensis* sp. nov. is in some respects remarkably similar to living representatives of *Solemya* Lamarck 1818, yet on the other hand it has considerable differences. The shape of the shell, the slight 'posterior' gape and the poor development of the gape at the 'front', the character of the internal ribbing, and the reticulation and tuberculation of the shell are similar in both the living and fossil shells. In the ligament structure, however, *'S.' holmwoodensis* differs considerably from the living representatives. On the short side are what appear to be a pair of strong external nymphs and on the long side is an elongated flattish ligament furrow such as is found in a number of forms which are referred here to the Grammysiacea and more particularly to the Sanguinolitidae. In living forms the ligament is highly modified and is commonly amphidetic, internal, and borne on a type of process peculiar to this group of shells. In all the living forms the ligament evidently differs considerably from that in *'S.' holmwoodensis* (see Vokes, 1955, p. 535). The differences seem to call for a generic separation. The generic name *Janeia* was proposed by King (1850, p. 177) for Permian *Solemya*-like shells, but its characters are inadequately known, and as I am reluctant to propose a new name, for the present, the Western Australian species is referred to *'Solemya'*.

Origin and Relationships of the Solemyidae: The origin of *Solemya* has been the subject of considerable speculation. *'Solemya' holmwoodensis,* however, gives a hint of its solution. The internal structure of the shell and the character of the internal ribbing leave little doubt of the relationship with living *Solemya.* The elongated ligament of the long side of the shell, on the other hand, suggests a relationship with the burrowing forms here placed in the family Sanguinolitidae, which have a similar type of ligament. The occurrence of two types of ligament in the one shell, and the orientation, however, are rather puzzling. From the direction of the internal ribs and by analogy with the living forms, the long side is the front and the short side the back. If this is the case then the strong 'nymphs' are behind the umbo where they are normally found in burrowing forms and the elongated ligament is at the front, instead of behind as is usually the case. This does not seem, however, to be a barrier to the postulated relationship, especially if *'Solemya' holmwoodensis* is derived from an amphidetic ancestor.

'SOLEMYA' HOLMWOODENSIS sp. nov.

(Pl. 7, figs. 1-9; Pl. 8, figs. 17-18)

Diagnosis: Transversely elongated, equivalved, and tubular. Umbo not prominent. Umbonal ridge of short side rounded and more distinct than the poorly developed ridge of the long side. External surface ornamented with concentric growth-lines and poorly developed rugae which are more distinct towards the rear. Character of external radial ornament not clear.

Description: The holotype is a bivalved specimen with the two shells still joined together but opened ventrally and slightly toward the long side at the time of burial. The shell gapes slightly on the long side ('anterior margin') and probably also at the other end ('posterior margin'). Along the longer side of the cardinal margin is an elongated flattish ligament groove similar to that found in *Undulomya* and *Praeundulomya* (see Dickins, 1957, pl. 1, fig. 11). The groove is bounded laterally by a distinct ridge. On the short side immediately adjacent to the umbo and extending along the margin is a prominent structure having the appearance of strong external ligament nymphs and made up of radiating fibres or lamellae just visible to the naked eye. The 'nymphs' are divided along the line of commissure. The shell is thin, and externally only faint radiating lines are visible. Internally towards the outer part of the shell are a number of radiating ribs which coalesce towards the inside like those found in living *Solemya* (Pl. 7, fig. 3). The internal surface also has micro-ornament, not visible to the naked eye. This comprises a network (reticulate) pattern towards the short side and a tuberculate pattern towards the long side. These patterns are illustrated in Plate 8, figures 17 and 18. A specimen from Tasmania, No. F36031, in the Shirley Collection housed in the Geology Museum of the University of Queensland, identified as *Solemya australis* Lamarck, is illustrated to show the internal radiating ribbing and the tuberculate pattern (Pl. 7, fig. 10) and the network pattern (Pl. 8, fig. 19) in the living form.

Paratype A shows internal radiating ribbing in the front part of the shell. Externally in each valve a narrow grooved line runs from the umbo in a slight curve directly to the ventral margin. This grooved line is somewhat similar to the lines which delineate the broad flat 'ribs' in the epidermal layer of living *Solemya*. Parallel with the groove are numerous fine radiating lines.

Paratype B shows a distinct oval adductor muscle impression immediately below the short side of the cardinal margin.

Dimensions (in mm.):

	Length	*Height*	*Width*
Holotype	62 (estimated)	28	11 (single valve)
Paratype A	—	29	10 (single valve)
Paratype B	63 (estimated)	29	12
Paratype C	—	27	10

Occurrence: Holotype, UWA Type No. 45384 (Reg. No. 31526), Paratype A, UWA Type No. 45385 (Reg. No. 31528), Paratype B, UWA Type No. 45386 (Reg. No. 31527), and Paratype C, UWA Type No. 45387 (Reg. No. 31529), all from the top part of the Holmwood Shale, Woolaga Creek, Irwin River area. Four specimens are available in the present collections, but I have examined others recently collected from the top part of the Holmwood Shale at Woolaga Creek by G. Playford, lately of the University of Western Australia, and I have seen specimens in situ in the top part of the Holmwood Shale about $\frac{7}{8}$ mile on a bearing of 178° from High Cliff on the Irwin River.

Discussion: The 'nymphs' are visible in all four type specimens, so they are not an accidental feature.

On the whole the Holmwood Shale is rather unfossiliferous, but towards the top are beds with calcareous nodules which are prominent on weathering, are commonly siliceous, and sometimes contain fossils. It is in these nodules that *'Solemya' holmwoodensis* is found, associated with the ammonoids *Uraloceras irwinense* Teichert & Glenister 1952 and *Metalegoceras campbelli* Teichert & Glenister 1952, and infrequent gastropods and brachiopods. Both from the mode of occurrence and relationship to *Solemya* it is likely that *'S.' holmwoodensis* was a burrowing form.

Superfamily MYTILACEA

Family Mytilidae

Genus Modiolus Lamarck 1799

Type Species (by subsequent designation of Gray, 1847): *Mytilus modiolus* Linnaeus.

Discussion: The International Commission on Zoological Nomenclature has set aside the name *Volsella* Scopoli 1777, in favour of the more commonly used name *Modiolus* Lamarck 1799 (*fide* Ichikawa & Maeda, 1958, p. 93).

In its concave ventral margin and the development of the anterior lobe, characters on which Newell (1942) based his differentiation of the two groups of shells for which he proposed the generic names, the Western Australian species described below falls between *Promytilus* and *Volsellina* and corresponds closely to the living genus *Modiolus*. It differs from *Promytilus* in having a better developed anterior lobe similar to that found in *Modiolus s.s.* In having a distinctly concave ventral margin it resembles *Modiolus* and *Promytilus* and differs from *Volsellina*.

Recently it has been shown that a number of other Palaeozoic pelecypods which have been referred to living genera are better regarded as belonging to other genera (for example *Nucula* and *Nuculana*) and it might be considered unusual for a genus of pelecypods to persist from the Palaeozoic to the Recent. However, in the absence of any criteria for differentiation the Western Australian species is referred to the genus *Modiolus*.

MODIOLUS KONECKII sp. nov.

(Pl. 8, figs. 6-11; Text-fig. 9)

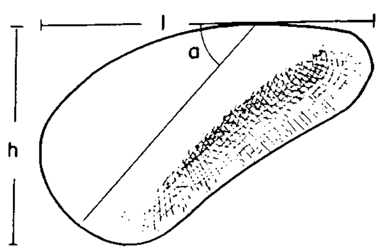
Diagnosis: Shell not particularly oblique to the cardinal margin; anterior lobe well developed. Ventral margin distinctly concave; umbonal ridge marked although rounded. External surface with radial ornament.

Description: The holotype is an almost decorticated specimen which shows the shape of the shell. Immediately in front of the umbonal ridge is a distinct sulcus which runs down ventrally to form a concave ventral margin and separates the anterior lobe from the rest of the shell. The growth-lines show that the obliquity increased during life. The paratypes show that the external ornament is composed of concentric growth lamellae and lines and of radiating ornament. The paratypes also show the variation in the concavity of the ventral margin, the obliquity of the shell, and the development of the umbonal ridge and the sulcus in front of the ridge. The ligament is lodged marginally in a furrow behind the umbones and inside the cardinal margin of the shell in a manner found in living mytilids, in which the outside of the ligament is visible between the margins of the valves.

Dimensions (in mm.):

	Length	*Height*	*Thickness*	*Angle of Obliquity**
Holotype	22	15	4	48°
Paratype A	14	9 (estimated)	3	40°
Paratype B	21	14	3	39°
Paratype C	16	10	3	34°
Paratype D	23	15	4	38°

* Angle of obliquity = angle *a* of Newell (1942, p. 25, fig. 3), the angle made by the crest of the umbonal ridge.



a = angle of obliquity

l = length

h = height

Fig. 9. Modiolus koneckii sp. nov. Holotype to show dimensions measured x 2 (see also Pl. 8, fig. 11).

Occurrence: Although widespread, this species is by no means common. Holotype, UWA Type No. 45388 (Reg. No. 32639) Becketts Gully; Paratype A, UWA Type No. 45389 (Reg. No. 23378) Fossil Ridge; Paratype B, UWA Type No. 45390 (Reg. No. 23330) Fossil Cliff; all from the Fossil Cliff Formation of the Irwin River area. Paratype C, CPC 3899 (Field No. WB 266), 30 miles west-north-west of Curbur Homestead, Lat. 26°22′00″S., Long. 115°25′00″E., Callytharra Formation; Paratype D, CPC 3900 (Field No. KPA 54) and Figured Specimen, CPC 3901 (Field No. SG 120A), 16 miles at 120° from Mount Tuckfield, in the southern part of the St George Range, near base of Poole Sandstone, Fitzroy Basin.

Other Specimens: Main limestone of Fossil Cliff Formation in Becketts Gully (UWA Reg. No. 23366); two specimens from PB 9, Pintharuka 1-mile Sheet, map co-ordinates 511056, Becketts Gully, ⅗ mile above road crossing, lowermost fossiliferous bed of Fossil Cliff Formation; one specimen from WB 266 (Paratype C locality); two specimens from PB 14, Fossil Ridge, Fossil Cliff Formation; and possibly one specimen from A 108, Nura Nura Member, Mount Wynne, apparently 1.3 miles east of Nura Nura Ridge.

Discussion: A specimen from the marine horizon at the base of the Poole Sandstone in the St George Range, which is provisionally referred to *Modiolus koneckii*, is figured. It has a more distinctly developed anterior lobe and sulcus and may represent a separate species. This specimen also shows an anterior adductor muscle which is bounded behind by a well-developed buttress (Pl. 8, fig. 5).

Modiolus koneckii differs considerably from the species from the Mingenew Formation described by Etheridge (1907b, p. 23, pl. 5, fig. 5; pl. 6, fig. 5) as *Modiola*? sp. ind. Examination of specimens from the Mingenew Formation indicates that Etheridge's species is more oblique and has a less well developed anterior lobe. *Modiolus koneckii* also appears to differ in shape and ornament from *Modiola*? *hartleyensis* Eth. Jnr (1902, p. 68, pl. 18, figs. 10 and 11), which is recorded from the Permian Upper Marine Series (now Maitland Group) of New South Wales.

The Western Australian species has been named after M. C. Konecki, geologist and petroleum technologist of the Bureau of Mineral Resources, who collected some of the specimens on which this description has been based.

Genus Lithophaga Bolten 1798

Type Species (*fide* Newell, 1942, p. 43): *L. mytiloides* Bolten (=*Mytilus lithophagus* Gmelin).

Discussion: The species described below is represented only by three specimens which are not regarded as showing the characters sufficiently well to allow introduction of a specific name. In shape it is somewhat similar on the one hand to *Stutchburia* and on the other to mytilid forms such as *Modiolus* and *Volsellina*, but it differs from both in being more cylindrical and is therefore more satisfactorily referred to *Lithophaga*. The species seems to differ too much from *Lithodomina* Waagen (1881, p. 264) to be placed in that genus.

LITHOPHAGA? sp.

(Pl. 8, figs. 1-4)

Description: The shell is transversely elongated with the umbo placed close to the front. It is rather cylindrical with a well developed rounded umbonal ridge running to the posterior margin. The external ornament is composed of very fine growth and radial lines. The radial ornament is apparently continuous and about at right angles to the growth-lines, so that towards the back it is parallel to the direction of transverse elongation, but towards the front cuts across this direction at a high angle. The radial lines are much finer than those found in *Modiolus koneckii* and are hardly visible to the naked eye. The muscles and the hinge are not visible. The two smaller specimens can be matched in the growth stages of the larger.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen A (right valve)	19	9	2·5
Figured Specimen B (left valve)	13	6	2·5
CPC 3904 .... (right valve)	10	5	2

Occurrence: Figured Specimens A and B, CPC 3902 and 3903, and CPC 3904 are from 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near the base of the Poole Sandstone, Fitzroy Basin (Field No. SG 120A).

Family MYALINIDAE Frech

Genus ATOMODESMA Beyrich 1864 (p. 68)

Type Species (by subsequent designation of Wanner, 1922, p. 63): *Atomodesma exarata* Beyrich (1864), p. 71, pl. 3, figs. 4a-b).

Diagnosis: Mytiliform or inoceramiform shells without teeth and with the ligament situated in an elongated furrow running backwards from the umbo or possibly beginning slightly in front of the umbones. The ligament furrow sometimes shows a number of longitudinal lines or ridges. An umbonal septum (the triangular ligament area of Wanner, 1940) is developed anteriorly between the ligament and the anterior margin. An anterior ear may be present. Externally the shell may be almost smooth, with only growth-lines and low rugae, or may have a variable development of coarse concentric rugae; radial grooves may also be present. Shells range from almost equivalve to distinctly inequivalve. The main shell layer is prismatic with the prisms at right angles to the surface and just visible to the naked eye. During life a thin inner nacreous layer was almost certainly present.

Hinge Structure: The structure of the hinge of *Atomodesma* has recently been discussed by Dickins (1956) and Waterhouse (1958, 1959). Consequently all the hinges available in specimens of *Atomodesma* from Western Australia have been carefully examined. Specimens of *'Aphanaia'* from Eastern Australia have also been examined. In all cases a U-shaped furrow is present, which when well preserved may show longitudinal ridges. In a few specimens these ridges are especially well developed, but in none are there distinct ligament grooves similar to those found in *Myalina* or *Pseudomyalina.* According to Waterhouse's description (1959, p. 260) the ridges and grooves in *'Maitaia'* are similar to those found in the Australian specimens, as are apparently those found in the type specimens of *Atomodesma exaratum* (letter from J. B. Waterhouse). Through the courtesy of Dr. C. A. Fleming of the New Zealand Geological Survey, I am able to figure the hinge of a plaster cast of the holotype of *'Maitaia' trechmanni* (Marwick) (see Pl. 10, fig. 1). This specimen shows a U-shaped furrow with two longitudinal ridges, but lacks any distinctly developed ligament grooves within this furrow.

The ligament area of *Atomodesma, 'Maitaia'* and *'Aphanaia'* is U-shaped and thus differs from that characteristic for *Myalina, Pseudomyalina,* and the arcids, in which the ligament grooves are developed over a flat area. On the basis of all this evidence *Atomodesma, 'Maitaia', 'Aphanaia',* and probably also *'Kolymia'* appear to have an analogous ligament structure which differs significantly from that of *Myalina* and *Pseudomyalina,* a conclusion also reached by Waterhouse (1959).

Probably the growth ridges served for the firmer attachment of the ligament to the shell in the manner shown by specimens of the living pteriid form *Pinctada* gathered from the coast of Queensland. The hinge of *Pinctada* has a flat ligament area with a resilium pit and longitudinal growth-lines. The slight ridges and grooves formed by the growth layers aid in the attachment of the ligament to the shell.

The umbonal septum, already known in *Atomodesma* and *'Maitaia',* also occurs in *'Aphanaia'.* The dimensions of three specimens from the Australian Museum identified in the collections of *Aphanaia mitchelli* (McCoy) 1847 are tabulated, and two specimens are figured in Plate 9. The impression of the umbonal septum is shown in Plate 9, figure 16.

		Length (mm.)	*Height* (mm.)	*Thickness* (mm.)
F 27115 (Between Branxton and Greta, N.S.W., Branxton 'Stage', 'Upper Marine Series')	Left valve	38 (approx.)	62	29
	Right valve	38	55	21
F 48885 (Cemetery, Maitland, N.S.W., 'Upper Marine Series')	Left valve	38	62	23
	Right valve	38	50	17
F 2170 ('Upper Marine Series', Permian, Maitland District, N.S.W.)	Left valve	39	63	23
	Right valve	39	53	17

Other Characters: In addition to the main prismatic layer Waterhouse (1958, p. 172) records a thin outer fibrous layer.

The musculature of *Atomodesma* is poorly known; Waterhouse (1958, text-fig. 1) shows the adductor muscle and the marks of the pallial line, which are also shown in a photograph by Wood (1956, fig. 23). The musculature is similar to that found in *Myalina* and other anisomyarian forms.

Synonymy and Subgenera: Newell (1942) discussed the relationship of *Atomodesma, Aphanaia, Maitaia,* and specimens from Siberia on which Licharew

(1941) based the name *Kolymia.* The material available at that time was inadequate to form any definite conclusions on the relationship of these groups of fossils. Meanwhile Wanner's (1940) work on *Atomodesma* from Timor, including a description of the hinge, became available and Popov's (1948) paper added information on *Kolymia.* In 1956 on the basis of the shape and the character of the hinge, I proposed placing *Aphanaia* in synonymy with *Atomodesma.* Popov (1957) accepted *Aphanaia* as a synonym of *Atomodesma,* proposed a new generic name *Intodesma* for shells closely related to *Atomodesma,* and provided further information on *Kolymia.* In 1958, while expressing doubt about the position of *Aphanaia,* Waterhouse proposed placing *Maitaia* in synonymy with *Atomodesma* on the basis of the hinge and shape. Recently I have had the opportunity of examining a set of about 12 specimens of *'Aphanaia' mitchelli* in the Australian Museum, Sydney, the dimensions of three of which have been given on a previous page and two of which are figured. An umbonal septum is present and the main shell layer is prismatic as in *Atomodesma.* In specimens where the ligament structure is visible, a U-shaped ligament furrow is present. In all the specimens the umbo of the left valve is distinctly more prominent than of the right. The only character, therefore, in which *Aphanaia* differs markedly from *Atomodesma* is in the greater inequality of the valves, and this hardly seems of such an order to warrant generic separation.

There seems little doubt that *Atomodesma* Beyrich 1864, *Aphanaia* de Koninck 1877, *Maitaia* Marwick 1935, *Kolymia* Licharew 1941, and *Intodesma* Popov 1957 are all very closely related, and it is proposed to regard *Atomodesma* as the generic grouping; for the time being three subgeneric categories are recognized: *A.* (*Atomodesma*), *A.* (*Aphanaia*), and *A.* (*Kolymia*). *Maitaia* is referable either to *A.* (*Atomodesma*) or *A.* (*Aphanaia*) according to whether its valves are markedly inequivalve or not. *Intodesma* is referable either to *Maitaia* and in turn to *Atomodesma,* or to *Aphanaia,* and therefore its retention even at a subgeneric level does not seem to be necessary. *A.* (*Kolymia*) is distinguished from the other categories by its well developed anterior ear. The retention of *Aphanaia* as a subgenus is dependent on the importance given to the inequality of the valves and it could well be considered as referable to *A.* (*Atomodesma*). The presence or absence of the anterior radiating grooves could be regarded as of value for subdivision above the specific level; but to introduce it as a criterion at this stage would unnecessarily complicate the terminology.

The diagnostic characters of the subgeneric groupings are as follows:

Atomodesma (*Atomodesma*).

Type: *A. exarata** Beyrich 1864.

Anterior ear absent or poorly developed; more or less equivalve; with or without anterior radiating grooves.

* *desma* is a Greek neuter noun meaning ligament, and therefore *Atomodesma exaratum* is the correct usage, which is followed in the general text. Under the heading Type Species or Type, however, the name has been quoted exactly as originally used, according to the practice followed throughout this monograph.

Atomodesma (Aphanaia).

Type: *A. mitchelli* (McCoy) 1847.

As for *A. (Atomodesma)* but left valve distinctly although not greatly larger than the right. (De Koninck (1877, trans. 1898, p. 239) states the right valve is larger than the left, but this in an error, as is indicated by his figures of *Aphanaia.*)

Atomodesma (Kolymia).

Type: *K. inoceramiformis* Licharew 1941.

Anterior ear distinctly developed. Whether an umbonal septum is present or not is unknown.

Relationship to Posidionella *and Family Position*: Ramsbottom (1959, p. 405) has recently examined the characters of *Posidionella* de Koninck 1885, which he assigns to the family Myalinidae. This genus resembles *Atomodesma* in shape and in the terminal position of the umbo, and apparently also has the ligament lodged in a single elongated furrow. *Posidionella* therefore appears to be very close to *Atomodesma* and may even be the same genus.

Atomodesma is most closely related to the Myalinidae, which it resembles in shape, in its shell structure, and in the presence of an umbonal septum. The ligament is of a similar type, but only a single furrow is found, whereas, characteristically, the Myalinidae have multiple ligament grooves. I am indebted to Professor N. D. Newell for emphasizing in correspondence that during growth and no doubt also during evolution the single ligament groove stage precedes the multiple ligament groove, and that amongst arcids, although multiple ligament grooves are general, some have only a single groove.

A consideration of the above data appears to justify the assignment of *Atomodesma* to the family Myalinidae, as has already been proposed by Newell (1942, p. 76).

Stratigraphical Distribution of Atomodesma *in the Permian of Western Australia*: Up to now not a single specimen of *Atomodesma* has been collected in the Lyons Group (Sakmarian) of the Carnarvon Basin or equivalent formations elsewhere in Western Australia. In the succeeding beds, however, *Atomodesma* is widespread and often abundant; it is generally associated with silty land-derived clastic sediments. The forms found are unspecialized and lack anterior radial grooves (the posterior radial groove often found appears to be a supra-specific feature); they range up into the Upper Permian. A large form without anterior grooves is restricted to the Wandagee Formation and the Norton Greywacke of the Carnarvon Basin (late Artinskian) and the equivalent top part of the Noonkanbah Formation of the Fitzroy Basin. A form with a single anterior radial groove, referred to *Atomodesma exaratum*, characterizes the lower marine beds of the Liveringa Formation, the Coolkilya Greywacke, and possibly the Baker Formation, all of late Artinskian to Kungurian age. A species with three anterior grooves related to *Atomodesma semplicatum* Reed (1944, p. 323, pl. 53, figs. 14a-b, 15) from the top of the Middle Productus Limestone of the Salt Range and *Atomodesma undulatum* Rothpletz (1892, p. 86, pl. 10, fig. 21) from the Permian of Timor is found in the upper marine part of the Liveringa Formation of Upper Permian age. These beds are separated from the lower marine part of the formation by a member with plant fossils only and possibly a hiatus. A multi-grooved form also occurs in the Upper Liveringa but its stratigraphical relationship to the three-grooved species is not known.

The collection recently of a two-grooved form from Queensland by S. R. Derrington and D. M. Traves of Mines Administration Pty. Ltd. (Dickins, 1961a) is of considerable interest. Two-grooved forms have also been recorded from the Basleo Beds in Timor (Wanner, 1922), and from Siberia (Popov, 1957), and it appears possible that all these beds are intermediate in age between the lower and upper marine parts of the Liveringa Formation.

ATOMODESMA (ATOMODESMA) MYTILOIDES Beyrich 1864

(Pl. 9, figs. 1-7, 9)

1864. *Atomodesma mytiloides* Beyrich, p. 71, pl. 3, fig. 3.

1892. *Atomodesma mytiloides* Beyrich; Rothpletz, p. 85.

?1922. *Atomodesma* cf. *mytiloides* Beyrich; Wanner, p. 64, pl. 153 (3), fig. 1.

Description: Specimens assigned to this species are more or less upright and only slightly inclined towards the front. Externally they may be almost smooth with only concentric growth-lines or may have a variable development of rather irregular concentric wrinkles or rugae. Unlike the specimens referred to *Atomodesma timorense,* they do not have prominent umbones. The valves are almost equal or the left valve is slightly larger than the right. An anterior ear is either absent or is poorly developed. The ligament is lodged in a U-shaped groove which may have longitudinal growth ridges. Anteriorly an umbonal septum is present. Posteriorly a more or less well-developed groove, which is distinct from the sulcus separating the posterior flat extension or ear from the main part of the shell, runs from the umbo towards the dorsal part of the posterior margin.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen A	30	43	8
Figured Specimen B	24	38 (estimated)	8
Figured Specimen C	13	18	5
Figured Specimen D			
Left valve	18	26	11
Right valve	18	24	9

Occurrence: Figured Specimen A, CPC 3905 (Field No. G 202), 5⅞ miles on a bearing of 335° from Lyons River Homestead, at top of exposed Callytharra Formation; Figured Specimen B, CPC 3906 (Field No. WB 266), 30 miles west-north-west of Curbur Homestead, Lat. 26°22′S., Long. 115°25′E., Callytharra Formation; Figured Specimen C, CPC 3907 (Field No. SG 120A), 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near base of Poole Sandstone, Fitzroy Basin; Figured Specimen D, CPC 3908 (Field

No. G 269), 5 miles south-west of Moogoree Homestead, 5½ miles south-east by east of Donnellys Well, 355 feet above the base of the Coyrie Formation, type section, Byro Group.

Other Specimens: Nura Nura Member of the Poole Sandstone (Field No. W 33 C (1)), and Fossil Cliff Formation (Fossil Ridge, Field No. PB 14). A total of more than 20 specimens. The species is also common in the Noonkanbah Formation of the Fitzroy Basin and the formations of the Byro Group of the Carnarvon Basin.

Discussion: Examination of a number of specimens from one collecting spot shows considerable variation in the shape and the concentric ornament, but there is no apparent discontinuity which could serve for the separation of different taxonomic groups; for example to separate the smoother forms from the rugose forms or those with more regular ornament from the less regular. More convex forms with a prominent umbo are separated and compared to another species already described, but even this could be a varietal difference rather than a specific one. A large form which has a restricted stratigraphical range is separated as *A.* (*Atomodesma*) *mytiloides* var. nov.

Our understanding of *Atomodesma mytiloides* is based mainly on a single drawing of a small right valve (Beyrich, 1864, pl. 3, fig. 3), which cannot be located at present, but the similarity of the Australian specimens is such that the introduction of an additional specific name is hardly justifiable.

ATOMODESMA (ATOMODESMA) MYTILOIDES Beyrich 1864, var. nov.

(Pl. 10, figs. 2-9)

Remarks: Although this variety is not from the formations from which the faunas in this monograph are being described, it is desirable to figure specimens affording information on the hinge and the anterior ear of *Atomodesma.* The variety is separated because of its large size, but otherwise it does not seem to differ significantly from other specimens of *A.* (*Atomodesma*) *mytiloides.* The variety is restricted to the Wandagee Formation and the Norton Greywacke in the Carnarvon Basin and the top part of the Noonkanbah Formation in the Fitzroy Basin.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen A (right valve)	72	99	15
Figured Specimen B (right valve)	40	52	13
Figured Specimen C (right valve)	21	33	7

Occurrence: Figured Specimen A, CPC 3912 (Field No. ML 82), Minilya Syncline, north bank of river, 190 feet above the base of the Wandagee Formation, Lat. 23°44'S., Long. 114°25'E.; Figured Specimen B, CPC 3913, as for CPC 3912, 115 feet above the base of the Wandagee Formation; Figured Specimen C, CPC 3914, locality not known, Wandagee Formation, probably from the Wandagee area.

This shell is especially common in the Wandagee Formation of the Carnarvon Basin.

ATOMODESMA (ATOMODESMA) cf. TIMORENSE (Wanner) 1922

(Pl. 9, figs. 8, 10-12)

Description: These shells are similar in most respects to those referred to *A. (Atomodesma) mytiloides.* However, the valves are distinctly more convex and the umbones more tumid and stand considerably above the hinge-line as do those of *A. (Atomodesma) timorense* (Wanner) (1922, p. 67, pl. 153 (3), figs. 7a-b). The character of the hinge is not shown in any of the specimens.

Dimensions (in mm.):

	Length	Height	Thickness
Figured Specimen A (left valve)	23	37	14
CPC 3911 .... (right valve)	24 (estimated)	36	12
Figured Specimen B	25	38	11

Occurrence: Figured Specimen A, CPC 3909, and CPC 3911 (Reg. No. F1712), 8 miles east of Lyons River Homestead, Callytharra Formation (Waterford Collection); Figured Specimen B, CPC 3910, limestone of Nura Nura Member, apparently near Mount Wynne, Fitzroy Basin.

Genus PSEUDOMYALINA Dickins 1956 (p. 25)

Type Species (by original designation): *Pseudomyalina obliqua* Dickins (1956, p. 26, pl. 3, figs. 1-7, text-fig. 2).

PSEUDOMYALINA sp.

(Pl. 10, figs. 10-15)

Description: The shell is convex and rather quadrate. The umbo is terminal and no anterior ear is visible. The outline of the posterior ear is marked off from the rest of the shell by a wide shallow sinus; only a shallow sulcus separates the ear from the body of the shell. The anterior umbonal ridge coincides with a line at which the shell distinctly bends to form a flattish area facing towards the front. The surface is covered by radiating ribs and concentric growth-lines. Some of the growth-lines are more distinct and form lamellar ridges. The radial ribs are rather irregular in their development—over the posterior ear they are fine and more or less of one order; over the body of the shell the main ribs are larger, and finer second-order ribs are developed. Multiplication takes place rather irregularly, apparently both by interpolation and subdivision. The ribs are not all continuous and may be cut off at the distinct growth-lamellae, where new ribs may also begin. The ligament structure is similar to *Pseudomyalina obliqua* Dickins 1956, the type species. In Figured Specimen B, eight longitudinal grooves are visible.

Figured Specimen C shows details of the musculature, the pits of pallial attachment, and the inner nacreous layer. Over most of the surface of the shell, the outermost prismatic layer has peeled away, leaving only the thin inner nacreous layer over the inside part of the shell. These features are shown in Pl. 10, figs. 14 and 15.

Dimensions (in mm.):

		Length	*Height*	*Width*
Figured Specimen A	......	79	71	12
Figured Specimen B	......	60 (estimated)	57	12
Figured Specimen C	......	60	54	14

Occurrence: Figured Specimen A, CPC 3915 (Field No. G 202A) and Figured Specimen B, CPC 3916 (Field No. G 202), 5⅞ miles on a bearing of 335° from Lyons River Homestead, at the top of exposed Callytharra Formation, Carnarvon Basin; Figured Specimen C, UWA Type No. 45391 (Reg. No. 23375), Fossil Ridge, Fossil Cliff Formation, Irwin River area.

Other Specimens: UWA Reg. No. 23349, Fossil Cliff Formation, probably at Fossil Cliff; and from the limestones of the Nura Nura Member, and KPA 55, 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near base of Poole Sandstone, Fitzroy Basin. A total of six specimens.

Discussion: Although represented by only six specimens, the presence of *Pseudomyalina* sp. is of importance as it represents the earliest appearance of this genus in Western Australia. In younger beds it is sometimes found in large numbers. *Pseudomyalina* sp. is less convex and oblique than *Pseudomyalina obliqua* from considerably younger beds, and the two are therefore readily separable. The specimens cannot be satisfactorily compared with *Pseudomyalina mingenewensis* (Etheridge Jnr) (1907b, p. 24, pl. 5, fig. 4; pl. 6, figs. 3, 4) until the characters of this species have been re-examined. *P. mingenewensis* is found in the Mingenew Formation of the Irwin River area, which appears to be equivalent in age to the lower part of the Byro Group of the Carnarvon Basin.

Superfamily PECTINACEA

Classification: After an extensive consideration of their structure and history, Newell has proposed a classification for the Palaeozoic Pectinacea (1938, fig. 17). Ichikawa (1958) in a most valuable monographic study of the Triassic 'Pteriidae' has extended and modified Newell's classification for the Mesozoic forms. The present classification represents a further modification of Newell's and Ichikawa's schemes. It is not proposed to use the 'Gruppe' and 'Stirps' of Ichikawa's scheme, which are not generally recognized as formal taxonomic units. Although in 1957 (p. 59), I proposed that a family Pseudomonotidae be recognized to include *Claraia*, *Entomonotis*, *Meleagrinella*, and *Maccoyella*, Ichikawa's proposals for the family Aviculopectinidae and its subdivisions reflect more closely the relationships of the forms concerned and the subfamily Pseudomonotinae is now recognized. An extension of this scheme seems suitable to cover all forms, including living shells, which are referable to the superfamily Pectinacea.

The following Palaeozoic families and their subfamilies (some of which do not occur in the Palaeozoic) are recognized:

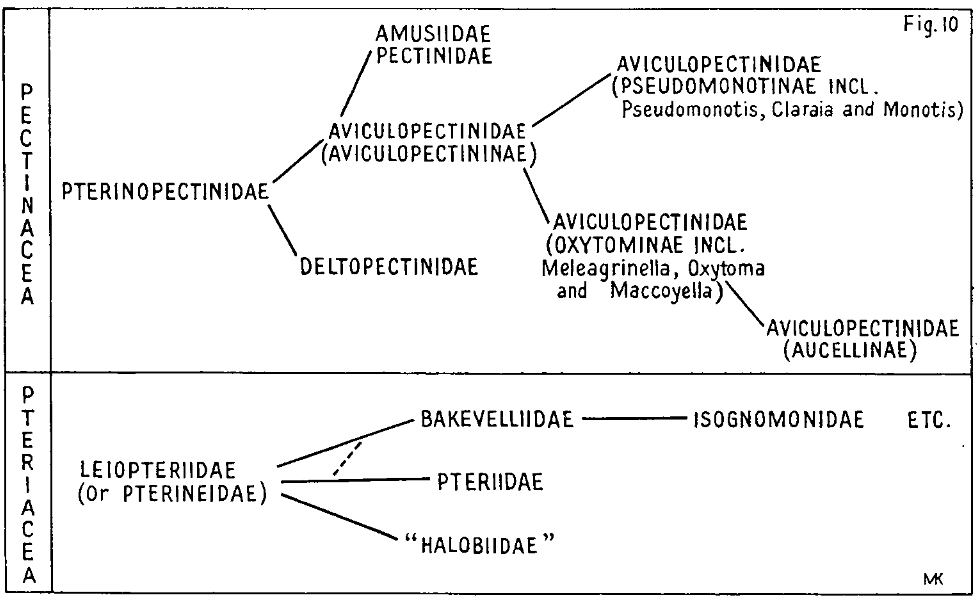
Family Pterinopectinidae Newell.

Family Deltopectinidae Dickins.

Family Aviculopectinidae Etheridge Jnr.
Subfamilies Aviculopectininae Meek & Hayden.
Streblochondriinae Newell.
Pseudomonotinae Newell.
Oxytominae Ichikawa.
Aucellinae Lahuson (or Buchiinae Cox).
Family Euchondriidae Newell.
Family Limidae d'Orbigny.

The subfamily Pernopectininae, referable to the family Amusiidae, is also found in Palaeozoic rocks, but a consideration of this family is outside the scope of the present work.

Remarks on the Proposed Classification: The relationships of some Upper Palaeozoic and Mesozoic Pectinacea and Pteriacea are shown in Figure 10. Although in the table the family Bakevelliidae is recognized, this group might better be regarded as the subfamily Bakevelliinae of the family Isognomonidae.



Posidonia Bronn 1828 (synonym *Posidomya* Bronn 1837) has been referred by Newell to the family Pterinopectinidae because the type species, *Posidonia becheri* Bronn, has a ligament with V-shaped ligament grooves (Weigelt, 1922; see Newell, 1938, p. 37). Ichikawa (1958), however, uses 'Gruppe der Posidoniiden und Posidonoiden' with the families Posidoniidae, Halobiidae, and Monotidae for Palaeozoic and Mesozoic forms. However, no authentic species of *Posidonia* is known from the Permian, and in the Mesozoic a number of forms which have been referred to *Posidonia* have been found on more careful inspection or on the collection of better material to lack the characters of this genus.

Apparently the *Posidonia* shape is one that has recurred in a number of lineages at different times and, as yet, there is no definite evidence that *Posidonia* persists above the Carboniferous. Certainly many of the species in Permian and Mesozoic rocks referred to *Posidonia* belong to other genera. Ichikawa (1958, p. 188) points out that *Posidonia* differs from the typical Pterinopectinidae in lacking a well developed byssal ear and subauricular notch and considers that it is ancestral to *Daonella* and *Halobia*. It does not yet seem possible, however, to prove that the apparent outward resemblance of *Daonella* and *Halobia* to *Posidonia* (and *Caneyella*) is not secondary rather than primary. Ichikawa (pl. 22, figs. 14 and 15) illustrates the hinge structure in *Daonella*, composed of an elongated ligament area with longitudinal ligament grooves. This structure establishes the relationship of *Daonella* and allied forms with the Palaeozoic leiopteriids. The Halobiidae can therefore be referred satisfactorily to the superfamily Pteriacea.

Ichikawa assigns the Monotidae to the 'Gruppe der Posidoniiden und Posidonoiden'; but the presence of a small anterior ear and subauricular notch taken together with the shape, the ribbing, and the structure of the main shell layer seems rather definite evidence that these forms belong with the Pectinacea. Although Ichikawa suggests that a resilifer is not present in *Monotis,* and is sceptical about its presence in the specimens of *Entomonotis richmondiana* figured by Marwick (1935), such delicate structures would only be found in very well preserved material, and on the basis of the other characters it seems that the 'Monotidae' can be placed in the Aviculopectinidae. *Entomonotis* is especially similar in shape to some species of *Pseudomonotis,* including the type species, and could be derived from *Pseudomonotis* or possibly some other aviculopectinid by reduction of the anterior byssal ear of the right valve.

The recognition of the family Deltopectinidae has been proposed (Dickins, 1957, p. 39) for the genus *Deltopecten.* It is distinguished from the other families of the Pectinacea by its ligament area, which lacks a distinctly marked-off resilifer and has longitudinal grooves which may be growth structures rather than ligament grooves. It is also distinguished by its biconvexity and the basic ornament of large radiating ribs which interlock along the margins when the valves are closed. Bearing in mind the characters which are used to separate the other families of the Pectinacea, these differences appear to warrant separation of *Deltopecten* at a family level. *Deltopecten* was derived most probably from the Pterinopectinidae, or possibly from the Aviculopectinidae.

As mentioned in a previous section, I have considered whether to propose recognition of the family Pseudomonotidae to include not only forms like *Pseudomonotis* and *Claraia* but also forms such as *Oxytoma, Meleagrinella, Maccoyella,* and *Aucella* (or *Buchia*). Ichikawa's (1958) proposal, however, to recognize the subfamilies Pseudomonotinae, Oxytominae, and Aucellinae is more in accord with our present knowledge of the evolution and character of these forms.

Species belonging to the Aviculopectininae are characterized by well-developed and differentiated anterior and posterior ears. The left valve tends to be symmetrical and the byssal ear and subauricular notch of the right valve are large and distinct.

The valves are markedly inequal. This subfamily includes species that appear to be adapted to a free-swimming existence. Evidence to suggest progressive adaptation to free-swimming habits is considered later. Included in the subfamily is *Eumorphotis* of the Triassic.

The Streblochondriinae differ from the Aviculopectininae in being biconvex and having reduced radial ornament and, especially in some advanced forms, reduced ears. The left valves especially tend to be rather symmetrical, which suggests perhaps adaptation to a free-swimming existence.

The Pseudomonotinae includes species showing a scar (cicatrix) of attachment on the right valve, and the subfamily has a marked reduction in the ears and the sinuses separating the ears from the main part of the shell. The differences which characterize this subfamily are associated with the abandonment of a free-living existence and adaptation to a fixed mode of life.

The subfamily Oxytominae typically retain ears distinct from the body of the shell, and the byssal ear and subauricular notch are prominent. The subfamily is distinguished from the Aviculopectininae by the lesser relative development of the anterior ear and the asymmetry of the left valve. The development of this group appears to be based on adaptation to byssal fixation. *Maccoyella* represents a specialized member of this family derived from *Oxytoma.* The characters of *Maccoyella* are discussed in a separate section. It seems likely that the Oxytominae were derived directly from the Aviculopectininae through *Eumorphotis* or a related form.

The Aucellinae* are not greatly different from the Oxytominae, but show a further adaptation to byssal fixation. They are even more asymmetrical and depart considerably from the typical pectinoid shape.

The multiple pits of the hinge of the Euchondriidae have been interpreted as multiple ligament pits (Newell, 1938, p. 102). Even if, however, the pits represent denticles, the differences from the Aviculopectinidae are such that it seems best to retain family rank for the grouping.

The inclusion of the Limidae within the Pectinacea is not altogether satisfactory. By Carboniferous time they are already well differentiated, but are not more closely related to any other group. They are free-living forms and have a complex shell structure. They resemble the Pectinacea in the symmetry of the shell and the character of their radial ornament. They differ, however, in lacking a subauricular notch in the right valve, and according to Jackson (1890, p. 353, pl. 27, fig. 6) living forms do not show a notch at any of the growth stages. The gill structure also differs from that of living Pectens and Jackson concludes that it more closely resembles that of the Ostreas. This may not be of great importance taxonomically, as the type of gill structure in Limas and Ostreas appears to have been developed independently and fossil Limas may have had gills similar to those

* Specimens of *Aucellina hughendenensis* (Etheridge Snr) 1872 from the Great Artesian Basin of Australia also show the interlocking lamellae of the shell layers which are characteristic of the Aviculopectinidae.

of Pectens. On the basis of this evidence it must be concluded that the Limas should be included as a family within the Pectinacea or referred to a separate superfamily, the Limacea.

Some Characters of Maccoyella *Etheridge Jnr* 1892: Specimens of *Maccoyella* referable to *Maccoyella barklyi* (Moore) in the Museum of the Geology Department of the University of Queensland have been examined to see whether they offered any evidence on the relationship of *Maccoyella* with the Pectinacea and on the classification of the Pectinacea. The examination confirms the conclusions of Ichikawa (1958) on the relationships of the Oxytominae and Aucellinae.

In the left valve of a large bivalved specimen, a thin outer layer is apparently homogeneous and the outer part of the inner layer is composed of interlocking concentric lamellae similar to those described in *Aviculopecten* by Newell (1938). The thin outer layer of the right valve is prismatic and the outer part of the inner layer is composed of concentric lamellae as in the left valve. The innermost layer is revealed in two other specimens (a left and a right valve) and is made up of irregular, sometimes radiating, fibres or lamellae, the lamellae having a more irregular character than in the outer part of the inner layer (see Pl. 11, fig. 6). In one of these shells this layer is iridescent, like the nacreous layer of living shells. In other shells the innermost layer is structureless, no doubt indicating the decomposition of the original material of this layer. The interlocking lamellae in *Maccoyella* were noticed and figured by Etheridge (1902b, pls. 1-4).

In *Aviculopecten,* Newell (1938, p. 44) records two layers of ostracum in each valve. In the left valve the outer ostracum is homogeneous and in the right it is prismatic. The outer part of the inner ostracum is composed of concentric interlocking lamellae and the inner part of an irregular radial lamellar layer. The similarity of the shell structure of *Maccoyella* and *Aviculopecten* is striking. The shell structure of *Oxytoma* is also similar (Ichikawa, 1958). On the other hand it is quite different from that found in the true Pterias in which the outer ostracum is prismatic and the inner nacreous. The shell structure of *Maccoyella* strongly confirms that the Oxytominae are to be classified with the Pectens and that the similarity of their shape to some of the Pterias reflects their adaptation to a similar mode of life—byssal attachment.

In *Maccoyella* adaptation took place in a rather different direction from that general for the Oxytominae. The hinge is specialized with the development of 'teeth': these are not true teeth, but are folds of the hinge-plate serving for the firmer attachment of the two valves to each other (see Etheridge, 1902b, pls. 1-4). Their asymmetrical development suggests adaptation to a fixed rather than a free life. Young specimens of *Maccoyella* are similar in shape to *Oxytoma,* but in adults the byssal ear, the subauricular notch, the posterior ear, and the sinus are poorly developed, and possibly in some specimens the notch is even obsolete. Jackson (1890) has shown that a subauricular notch (byssal notch) is necessary in young anisomyarians for the functioning of a foot because of its position close to the hinge-line. In other pelecypods with a functioning foot it is located so that it can be protruded by a slight opening of the ventral margins of the shell. In later life, in byssally attached forms, the byssus passes through the notch. The Pectens swim by expulsion of water through the sinus of the anterior and posterior ear (Jackson, 1890, p. 338, pl. 28, figs. 8, 8a; Dakin, 1909; Olsen, 1955) and the discrete development of the sinuses together with the symmetry of the shell are to be associated with adaptation to swimming habits. The asymmetry and poor development of the sinuses of *Maccoyella* therefore indicate that they are not swimming forms. Although it might then appear that shells of *Maccoyella* were cemented to their substratum, examination of specimens has failed to reveal any scars of attachment such as are found in *Pseudomonotis* and *Claraia*. In many shells, however, the preservation is not good. Some of the shells of *Maccoyella* are large and heavy and the notch is relatively so small that possibly they were anchored, at least partly, by their weight probably in areas devoid of strong currents.

Palaeoecology: The ecology of Upper Palaeozoic and Mesozoic Pectinacea has been discussed in recent years by Newell (1938), Kegel (1953), and Ichikawa (1958). It has also been discussed in previous parts of this work. To summarize this information, the Aviculopectininae contains forms which are progressively adapted to swimming. The Streblochondriinae may also contain swimming forms, but here the evidence is not so clear. The Pseudomonotinae are characterized by adaptation to a fixed life with the right valve cemented to the substratum. The Oxytominae and the Aucellinae appear to be characterized also by adaptation to a fixed life, but by byssal attachment rather than cementation. An exception to this may be *Maccoyella,* in which the poor development of the byssal notch may indicate cementation.

In the following section some aspects of the palaeoecology of *Aviculopecten, Girtypecten* and *Deltopecten* are considered.

1. *Aviculopecten*: Three lines of evidence indicate that species of this genus were adapted to a free-swimming life.

The mode of occurrence of *Aviculopecten tenuicollis* Dana 1847 has been compared with that of other pelecypods. Although it may occur in considerable numbers at any one locality, usually only a few specimens are to be found together. Shells are found at most fossiliferous localities, irrespective of the faunal or lithological association. This is in contrast to most of the pelecypods, for which there is commonly a marked lithological and faunal association. The bryozoan-brachiopod faunal association is a common one in the Permian rocks of Western Australia, and the environment with which this was associated was not favourable for pelecypods, which are sometimes represented only by a few scattered shells. An exception to this is *Aviculopecten tenuicollis,* which is found as commonly with this faunal association as elsewhere. In the Callytharra Formation pelecypods are relatively scarce and are both areally and vertically restricted, again except *Aviculopecten tenuicollis,* which, although rarely common at any one place, is ubiquitous. This suggests that this species was a free-moving form which on death became incorporated in whatever sediment was being formed beneath.

A second line of evidence is afforded by the evolutionary development of the auricles of *Aviculopecten*. Changes taking place are shown in the accompanying figures of the shape of the left valve.

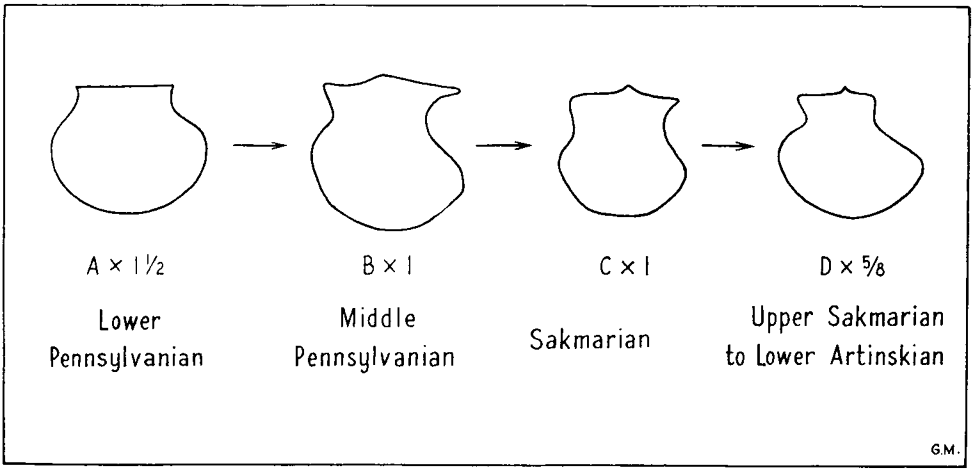


Fig. 11. Evolutionary development of the auricles of Aviculopecten in the Upper Palaeozoic. A. Aviculopecten flabellum (Price), Newell (1937, pl. 11, fig. 1), B. Aviculopecten gradicosta Newell (1937, pl. 6 fig. 1). C. Aviculopecten tenuicollis (Dana), Dickins (1957, pl. 6, fig. 7). D. Aviculopecten tenuicollis (Dana), present report, Plate 13, fig. 14.

The symmetry of the shell is retained throughout, but first there is a development of the sinuses of the anterior and posterior auricle and next a shortening of the hinge-margin relative to the length of the shell, producing a shape analogous with that of free-swimming living pectens. Jackson (1890, p. 338), Dakin (1909), and others have shown that pectens swim by expulsion of water through the sinuses. Dakin (1909) has also concluded that the symmetry of the shell is associated with swimming.

The third line of evidence is afforded by the changes which take place in the Pseudomonotinae, cemented to their substratum. The shells lose their regularity and some specimens may be quite asymmetrical. The sinuses of the ears lose discreteness and may be absent altogether. This confirms that the symmetry of the shell and the discreteness of the sinuses is associated with swimming habits. 2. *Girtypecten*: In the large collections which are available from the Permian sequences in Western Australia, *Girtypecten* has been found only in the Fossil Cliff and Callytharra Formations and possibly in the considerably younger upper marine beds of the Liveringa Formation. The Fossil Cliff and Callytharra Formations are amongst the few units in the Permian of Western Australia in which limestones are extensively developed, suggesting that there is perhaps some association between the deposition of limestone and conditions favourable for *Girtypecten*. Detrital limestones are common in both formations, but whether or not calcium carbonate was precipitated chemically is not clear. The deposition of these two formations was, however, characterized by a relatively small supply of land-derived clastic detritus; and abundant life, including brachiopods, bryozoans, crinoids and foraminifers, indicates a well aerated sea floor.

3. *Deltopecten*: The present material does not afford a great deal of evidence on whether species of this group were fixed or free living. *Deltopecten* lacks, however, the ubiquity of *Aviculopecten tenuicollis* and tends to be restricted to certain levels, where it may be represented in considerable numbers.

Discordance of the Valves: The significance of marked discordance in the size of the valves has recently been discussed by Newell & Merchant (1939), Kegel (1951), Kegel & da Costa (1951), and Ichikawa (1958). Amongst the forms described in this paper, discordant valves have been found in *Aviculopecten, Girtypecten,* and *Euchondria.* Kegel (1951) has examined 'discordance' in living pectinids and pteriids, and has suggested that discordance in fossil shells results from the lesser calcification of the marginal areas of the right valve.

Kegel's analysis is confirmed by Ichikawa (1958, p. 133) and by an examination of shells of *Pinctada chemnitzi* (Phillipi), Hynd (1955, p. 123, pl. 8, figs. 1-2, and pl. 9, figs. 1-2), which I collected from rock pools at Caloundra, about 70 miles north of Brisbane. The left valve is calcified so that it is rigid almost to the margin, whereas the right valve, apparently because of lesser calcification, is flexible for a considerable distance from the margin, and when the shell is closed, although the edges of the two valves are in apposition, the right valve is pulled inside the left and the outer part of the shell is concave whereas the rest of the valve is convex. Apparently associated with the lesser calcification of the outer part, the right valve as a whole is thinner than the left and the nacreous layer does not extend as far towards the outer margin as it does in the corresponding left valve (see Pl. 11, Fig. 4). In fossil forms a lesser calcified outer margin may have decayed more rapidly, or may have broken away, or perhaps the outer margin of the right valve may have been composed of non-calcified conchiolin.

Family DELTOPECTINIDAE Dickins 1957

Genus DELTOPECTEN Etheridge Jnr 1892 (p. 269)

Type Species (by original designation of Etheridge): *Pecten illawarensis* Morris (1845, p. 277, pl. 14, fig. 3).

Discussion: The characters of *D. illawarensis* have been considered by Newell (1938, p. 63), and the characters of *D. illawarensis* and *D. mitchelli* (Etheridge & Dun) 1906 by Dickins (1957, p. 39-41). Recognition of the genus is based not only on the bow-shaped area without a distinctly marked-off chondrophore, but also on the biconvexity of the shell in combination with the basic ornament of large radiating ribs which interlock with the ribs of the opposing valve along the ventral commissure. These characters enable species of *Deltopecten* to be readily separated from other Pectinacea with which they may be associated.

Forms referred to *D. illawarensis* and *D. mitchelli* may occur together (see Etheridge & Dun, 1906, p. 12; 26) and after examining many specimens I have come to the conclusion that there is little basis for separating two groups at the specific level.

Etheridge & Dun (1906, p. 12) observe that they 'have never seen any shell that could satisfactorily be referred to *P. illawarensis* from Illawarra', and in the large collections at the Australian Museum, Sydney, none of the specimens of this species is from Illawarra. It seems certain that Morris's specimens of *D. illawarensis*—the type specimens—came not from Illawarra but from Harper's Hill, as also, apparently, did the type specimens of *Eurydesma cordatum* Morris (see Dickins 1961a). Both *D. illawarensis* and *D. mitchelli* are recorded from Harper's Hill.

In both Western and Eastern Australia species of *Deltopecten* with simple unspecialized ribs are found low in the sequence. In Western Australia *Deltopecten* is poorly represented in the higher part of the sequence, where only a few specimens have been collected in the Carnarvon Basin from above the Callytharra Formation. In Eastern Australia, however, *Deltopecten* remains abundant and the ribbing is considerably specialized (see Dickins, 1957, p. 41).

Examination of the two specimens which Etheridge (1892, p. 269, pl. 41, fig. 3; pl. 43, fig. 2) referred to *D. illawarensis* and on which he based his diagnosis of *Deltopecten,* together with examination of other specimens from the same locality, further clarifies the problems connected with *Deltopecten.* The two specimens are refigured in Plate 11, figures 2 and 3, and Plate 12, figures 1 and 2. Etheridge was in error in referring the specimen with the chondrophore (pl. 43, fig. 2) to *D. illawarensis.* The ribs are of several orders, the main ribs being separated by relatively wide, flat interspaces. The specimen is referable to a species related to the *Aviculopecten tenuicollis*—*A. subquinquelineatus* group of forms. It is common in the beds of the Mount Britton area and probably requires a new specific name. The hinge of this species has a well marked ligament pit and although the longitudinal lines on the ligament may be rather well marked (as in Etheridge's specimen) they clearly represent growth-lines. A right valve of this species is figured in Plate 11, figure 1.

The other specimen figured by Etheridge (pl. 41, fig. 3) is a *Deltopecten,* but the ribbing is less coarse than found in *D. illawarensis.* It is also referable to a species which is common in the Mount Britton area, and which does not appear to be separable from *Deltopecten limaeformis* (Morris) (1845, p. 277, pl. 13, fig. 1). Another specimen of this species from the Mount Britton area (Queensland University, Department of Geology, No. F 20,791) is figured in Plate 12, figure 3, for comparison.

In *D. illawarensis* and *D. waterfordi* sp. nov., the primary ribs subdivide by the development of a shallow groove on the rib. Similar division is recorded in *Aviculopecten basilicus* Newell (1938, p. 52, pl. 6, figs. 13-16b) and in species of *Heteropecten* (Kegel & da Costa, 1951). A similar type of subdivision therefore seems to have occurred separately in quite distinct lineages of Upper Palaeozoic Pectinacea.

Concentric growth lamellae (or filae) which swing towards the umbo over the ribs and away over the grooves are also found in *Acanthopecten* and *Limipecten.* This is also a feature which may have developed in several lineages.

A zig-zag pattern is recorded in the interlocking lamellae of the shell of *Deltopecten waterfordi* sp. nov. Zig-zag patterns have also been recorded in *Heteropecten* from the Upper Palaeozoic of Brazil by Kegel & da Costa (1951, p. 11) and in *Indopecten* from the Triassic of the Middle East by Douglas (1929, p. 632) and Hudson & Jefferies (1961, p. 18). Whether these patterns are based on a similar structure is not known, but *Indopecten amusiiformis* Hudson & Jefferies (1961, p. 19, pl. 1, figs. 5-7) and *Indopecten clignetti* Krumbeck 1923 *asperior* Hudson & Jefferies (1961, p. 20, pl. 1, figs. 1-3; pl. 2, figs. 1-4, 8 and 9) resemble *Deltopecten* in being biconvex and having strong primary ribs that interlock along the dorsal margin.

DELTOPECTEN WATERFORDI sp. nov.

(Pl. 12, figs. 5-11)

1933. *Deltopecten illawarensis* (Morris) 1845, Hosking, p. 55, pl. 6, fig. 4.

Diagnosis: Shell sometimes large, primary ribs coarse—smaller secondary ribs may be intercalated between primaries; primary ribs flattened on top, with a tendency to divide in two. Ligament area robust and bow-shaped, with shallow longitudinal grooves parallel to the base of the ligament area; no distinctly marked-off chondrophore, but a broad shallow depression under the umbo.

Description: The holotype is a right valve. The shell is distinctly convex, although less so towards the ventral margin; it is almost acline—slightly larger at the front than at the rear. The anterior ear is large and separated from the body of the shell by a deep notch; it has six radiating ribs and fine and coarse growth-lines, the more prominent of which are lamellate. The posterior ear is only partly preserved, but sufficient remains to show that it was flat, shorter than the anterior, marked off from the rest of the shell by a broad shallow sulcus, and lacked a sinus in the outline. The ornament of the shell is of radiating ribs and concentric growth-lines and lamellae. The main part of the shell has 22 primary ribs, which are flattened even at early growth-stages and several of which are divided along their midline by a shallow groove. One or possibly two secondary ribs may be intercalated between the primary ribs. The concentric ornament is composed of numerous closely spaced growth-lines and rather widely spaced lamellae which are less well developed than on the ears. As the growth-lines or filae cross the ribs they swing towards the umbo and as they cross the intervening grooves they swing towards the ventral margin in a manner similar to that found in *Acanthopecten* and *Limipecten* but opposite to that found in the specimens I have referred to *Aviculopecten tenuicollis* (Dana) (see Pl. 13, fig. 14, and Dickins 1957, pl. 6, fig. 7).

In left valves the anterior and posterior ears are ornamented with concentric growth-lines and nodulose radiating ribs. The sulcus separating the anterior ear from the body of the shell is less distinct than in the right valve. In Paratype A, 27 primary ribs are visible on the main part of the shell and one or sometimes two secondaries are developed between most of the primaries. Towards the rear, a broad shallow sulcus is developed, running from the umbo towards the ventral margin and forming, behind, a broad fold. Details of the shell structure are shown in Paratype B (a left valve) where the shell has been broken off to form a natural cross-section—the interlocking lamellae are visible under a hand lens and have the structure described in *D. lyonsensis* (see Dickins, 1957, p. 42). Their structure is also visible in a plane parallel to the surface of the shell—over the ribs the interlocking lamellae point to the umbo, and over the grooves to the ventral margin, forming a shallow zig-zag pattern, more or less parallel to the growth-lines. Whether this pattern is similar to that described in *Heteropecten* by Kegel & da Costa (1951, p. 11) is not clear.

Paratype C, a right valve, shows a well developed hinge, relatively wide with the widest part under the umbo and bow-shaped. Seven distinct grooves run parallel to the bottom of the ligament area and run off the area front and back along the dorsal side. At the rear the ventral grooves do not run off the area but appear to pass into the divisions between the growth layers of the shell. The ligament area deepens under the umbo but has no distinctly marked off ligament pit. In front of the umbo, the ligament area is separated from the external surface of the dorsal margin by a flat ridge. Externally the anterior ear is ornamented by seven radiating ribs, two of which are divided, and the concentric ornament is of numerous growth-lines and lamellae which form nodes where they cross the ribs. On the body of the shell the flattening and division of the primary ribs take place at an early stage.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Holotype	145	141	33
Paratype A	106 +	128	27
Paratype B	—	140	32

Occurrence: Holotype, CPC 3918 (Reg. No. F 2353), 12 miles south of Lyons River Homestead, Gascoyne River area, Callytharra Formation; Paratypes A and B, CPC 3919 and 3920 (Field No. G 261), 3.85 miles south-west of Moogooree Homestead, Lat. 24°06′16″S., Long. 115°10′04″E., 350 feet above base of Callytharra Formation; Paratype C, CPC 3921 (Field No. GW 152) locality and formation uncertain but probably from the Callytharra Formation, Lat. 25°19′S., Long. 115°12′E.

Discussion: *D. waterfordi* is abundantly represented in the Callytharra Formation, although most of the specimens are fragmentary. In the Fossil Cliff Formation, however, it is represented only by a few doubtful fragments. It has not been found in the Canning Basin.

The specimen figured by Hosking (1933, p. 55, pl. 6, fig. 4) from the south bank of the Wooramel River, three miles east of Top Camp, is from the Callytharra Formation.

Although closely related, *D. waterfordi* can be separated from *D. lyonsensis,* which occurs in older rocks, by its larger size, the greater development of the ligament area, and the flattening and division of the primary ribs at an early growth stage.

D. waterfordi does not seem to differ greatly from *D. illawarensis*; it is distinguished by the flattening of the primary ribs and the greater number of secondary ribs.

In its size and type of ribbing *D. waterfordi* closely resembles *Aviculopecten* cf. *mitchelli* Etheridge & Dun 1906, Reed (1936, p. 45, pl. 12, figs. 1, 1a) from the Agglomeratic Slate of Kashmir.

DELTOPECTEN sp.

(Pl. 12, fig. 4)

Description: A single specimen, the umbonal and back part of an external impression of a right valve from the Fossil Cliff Formation, shows finer and more numerous radial ribs than *D. lyonsensis* or *D. waterfordi*. Twenty-one fine radiating ribs are visible and these are crossed by fine concentric growth-lines, forming a network in parts of the shell. The radiating ribs do not seem to increase in number during growth.

Dimensions (in mm.):

	Length	*Height*	*Width*
Figured Specimen	45 (estimated)	65	5

Occurrence: Figured Specimen, UWA Type No. 45392 (Reg. No. 23375) Fossil Cliff, Fossil Cliff Formation, Irwin River area.

Discussion: Although the ribbing of this specimen is similar to that of *Deltopecten squamuliferus* (Morris) 1845, p. 278, pl. 14, fig. 1, the material is too fragmentary to allow a satisfactory comparison with other species.

Family AVICULOPECTINIDAE Etheridge Jnr

Subfamily AVICULOPECTININAE Meek & Hayden

Genus AVICULOPECTEN McCoy 1851 (p. 171)

Type Species (by subsequent designation of Hind, 1903, p. 66): *Aviculopecten planoradiatus* McCoy (1851, p. 171).

Relationship of Limipecten *and* Aviculopecten: *Limipecten* Girty 1904 has been retained by Newell (1938, p. 67) for Aviculopectininae possessing distinctive ornament of concentric 'regular lamellae which swing downward toward the margin between the costae in short, flattened, pointed projections similar to those of *Acanthopecten*'. Newell (1938, p. 43, 67) also states that in *Aviculopecten* the ribs increase in number in the right valve by bifurcation, whereas in *Limipecten* they increase by intercalation. My observations, however, suggest that the method of increase of the ribs in the right valve is not diagnostic for *Aviculopecten;* species which are otherwise not separable from *Aviculopecten* show rib increase by intercalation. In the specimen figured in Plate 11, figure 1, rib increase takes place in the one valve both by bifurcation and intercalation. The specimen is from the Mount Britton area and referable to the same species (probably new) as the specimen referred to *D. illawarensis* by Etheridge Jnr (1892, pl. 43, fig. 2) which is refigured in Plate 11, figures 2 and 3, and is discussed on p. 18. It is proposed, therefore, that *Limipecten* be restricted to species in which the concentric lamellae swing towards the outer margin in short, pointed projections between the ribs and towards the umbo over the ribs. I have not observed this type of ornament in any of the Australian Permian shells which could be referred to *Aviculopecten* and it is not present in *A. tenuicollis, A. sprenti,* or specimens that have been referred to *A. subquinquelineatus.*

AVICULOPECTEN TENUICOLLIS (Dana) 1847

(Pl. 11, fig. 5; Pl. 13, figs. 12-17; Pl. 14, fig. 1)

1847. *Pecten tenuicollis* Dana, p. 160.
1849. *Pecten tenuicollis* Dana 1847, Dana p. 705, pl. 9, figs. 7-7a.
1887. *Aviculopecten sprenti* Johnston, p. 9.
1888. *Aviculopecten sprenti* Johnston 1887, Johnston, p. 127, pl. 14, fig. 11 (fig. 8 in error).
1906. *Aviculopecten tenuicollis* (Dana) 1847, Etheridge & Dun, p. 13, pl. 13, figs. 10-12; pl. 14, fig. 5.
1906. *Aviculopecten sprenti* Johnston 1887, Etheridge & Dun, p. 15, pl. 2, figs. 6, 7; pl. 13, figs. 1, 9; pl. 16, figs. 5, 6.
1907b. *Aviculopecten sprenti* Johnston 1887, Etheridge Jnr, p. 32, pl. 7, figs. 5, 6.
1957. *Aviculopecten tenuicollis* (Dana) 1847, Dickins, p. 45, pl. 6, figs. 7-9.

Description: Hypotypes A, B, and D show the shape of the shell and the character of the ribbing—the valves have four orders of ribs: primary, secondary, tertiary, and quaternary (this is the order of appearance on the shell and not necessarily the order of size along the ventral margin). If the order of size along the ventral margin is considered, Hypotypes A and B would have three orders and Hypotype D has four. In Hypotypes A and B ribs are intercalated near the umbo and rapidly increase in size, and at the ventral margin are indistinguishable from the initial ribs. A second intercalation farther from the umbo and a third still farther give rise to tertiary and quaternary ribs. In some parts of the shell, however, quaternary ribs are not formed.

Hypotype D varies slightly from this pattern in that the second order ribs do not increase as rapidly in size and at the ventral margin the four orders are distinct. The quaternary ribs are also developed much closer to the umbo than in Hypotype A or B.

The concentric ornament is composed of numerous fine filae which bend slightly towards the ventral margin of the shell, where they cross the radiating ribs and curve slightly towards the umbo when crossing the intervening grooves.

Hypotype C is figured to show the ligament area with a well marked ligament pit (Pl. 13, fig. 15). The surface of the ligament area is smooth except for fine longitudinal growth-lines, which are continuous across the ligament pit, indicating their true nature.

The internal impression of a right and left valve in apposition is figured (Pl. 13, fig. 12). Not only is the right valve flat whereas the left is convex, but the right valve, as preserved, is considerably smaller. Increase in rib number in the right valves appears to be by intercalation, but this is by no means certain.

Dimensions (in mm.):

	Length	*Height*	*Thickness*	*Distance from Umbo of Appearance of 2nd Order Ribs*	*Distance of 3rd Order*	*Distance of 4th Order*
Hypotype A	30	25	3	2–3	9	16
Hypotype B	43	41	3	Not visible	9	17 +
Hypotype C .... (inside of left valve)	48	42	6	—	—	—
Hypotype D	—	21	1·5	3 (estimated)	6	10
Hypotype E						
Left valve	—	24	3 +	Not visible		
Right valve	—	15	Flat	Not visible		

Occurrence: Hypotype A, CPC 3922 (Field No. G 202), 5⅞ miles on a bearing of 335° from Lyons River Homestead at top of exposed Callytharra Formation; Hypotypes B, C, D, and E, UWA Type Nos. 45393, 45394, 45395 and 45396 respectively (Reg. Nos. 23340, 23368, 32627 and 23323), Fossil Cliff, Fossil Cliff Formation, Irwin River area; Hypotype F, CPC 3923 (Field No. PB 8), Fossil Cliff, Fossil Cliff Formation, Irwin River area.

A. tenuicollis is common in the Fossil Cliff and Callytharra Formations and is found also in the Nura Nura Member of the Poole Sandstone and in the sandstones at Woolaga Creek referred to the High Cliff Sandstone.

Discussion: When assigning specimens from the Lyons Group of the Carnarvon Basin to *A. tenuicollis* (Dana) 1847, I discussed the relationship of *A. tenuicollis* (Dana) 1847, *A. sprenti* Johnston 1887 and *A. subquinquelineatus* (McCoy) 1847 (Dickins 1957, p. 45; 46). It appeared that *A. tenuicollis* and *A. sprenti* were morphologically indistinguishable and it was suggested that both might represent growth stages of *A. subquinquelineatus.* If these are synonyms Dana's name will have priority as his paper appeared before McCoy's in 1847. The type specimens of both *A. tenuicollis* and *A. subquinquelineatus* are from Harper's Hill, N.S.W.

Through the courtesy of the Director, Dr Remington Kellogg, and Dr Porter M. Kier of the Smithsonian Institution, Washington, D.C., U.S.A., I am able to refigure Dana's type specimen of *A. tenuicollis* (Pl. 14, fig. 1). Although Etheridge & Dun (1906, p. 16) mention seeing the type specimen of *A. sprenti,* the specimen may now be lost, according to information from Mr M. R. Banks, of the Department of Geology, University of Tasmania.

The specimens from the Lyons Group assigned to *A. tenuicollis* were all relatively small but the collection now described contains not only small but also considerably larger specimens. The larger specimens such as Hypotype B show a rapid expansion of the shell during the later growth stages both to the front and the rear. Although this may distinguish these shells from those of the Lyons Group, the material available is not sufficient to allow its assessment for specific differentiation.

The specimen from the Permian of Pokolbin, New South Wales, figured by Etheridge & Dun (1906, pl. 13, fig. 1) as *A. sprenti* Johnston, shows a similar expansion towards the outer margin, and Etheridge & Dun (p. 16) mention this character in their specimens of *A. sprenti.*

The tendency shown in Hypotype D to form subordinate ribs at an earlier stage and for these ribs to remain small is further developed in species of *Aviculopecten* found higher in the Permian sequence in the Carnarvon and Fitzroy Basins. In these species the primary ribs are separated by a large number of subordinate ribs.

AVICULOPECTEN? sp.

(Pl. 13, figs. 10-11)

Description: This species is represented only by a single left valve with rather distinctive ornament. The shell is oval and approximately acline, and the anterior ear is poorly differentiated. The radial ribbing is fasciculate although quite different from that of *Fasciculiconcha* Newell 1938. Near the ventral margin, the surface of the shell is wavy and the crests and troughs are covered by ribs with a broad rib on the crest. Ribs of three sizes can be distinguished near the ventral margin, but there is no regular multiplication by rank such as has been described in *A. tenuicollis*. Near the umbo the ribs are narrow and of a similar size to each other, and multiplication appears to be by intercalation. In the outer part of the shell the ribs increase in number by intercalation and by subdivision of the broad ribs.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen	—	37	3

Occurrence: Figured Specimen, CPC 3924 (Field No. KPA 55), 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near base of Poole Sandstone, Fitzroy Basin.

Discussion: Ribbing of this type has been described in *Aviculopecten basilicus* Newell (1938, p. 53, pl. 6, figs. 13-16b) and *Heteropecten* Kegel & da Costa (1951). It is present also in species which are characteristic of the Byro Group in the Carnarvon Basin and of the Noonkanbah Formation in the Fitzroy Basin. One of these, from the Upper Artinskian Cundlego Formation, appears to be closely related to or may be conspecific with *Heteropecten bastosi* Kegel & da Costa (1951, p. 23, pl. 2, figs. 1; 2, pl. 3, fig. 1, pl. 4, figs. 2; 3, pl. 6, fig. 3). *Aviculopecten*? sp., however, differs from all of these.

Genus GIRTYPECTEN Newell 1938 (p. 77)

Type Species (by original designation): *Aviculopecten sublaqueatus* Girty (1909, p. 440, pl. 9, fig. 12).

Discussion: Although the Australian shell described below differs considerably from the type species, it has important characters which relate it to *Girtypecten* and distinguish it from the apparently closely related genus *Acanthopecten.* It is prosocline, the ears are large, the hinge-line is long, and spines are developed at the intersection of the radiating ribs and the concentric ridges. It differs mainly in having a greater number of less well-developed radial costae and concentric ridges, a poor development of radial ribs apart from the main costae, and numerous fine concentric lirae between the large ridges. In all these respects the Australian species resembles more closely *Aviculopecten laqueatus* Girty (1909, p. 439, pl. 9, fig. 11), placed by Newell (1938, p. 76) in *Acanthopecten*, although apparently not with certainty. *Aviculopecten laqueatus*, however, differs in shape.

Possibly *Girtypecten sublaqueatus* is a highly specialized member of its lineage. Newell says that in the posterior auricle of *Acanthopecten carboniferus* (Stevens), the type species of *Acanthopecten*, spines similar to those on the body of the shell are developed where the concentric filae cross the radiating costae, whereas the spines on the body are developed only between the costae. This suggests that the position of the spines may not be of great significance for distinguishing *Acanthopecten* from *Girtypecten*.

GIRTYPECTEN OVALIS sp. nov.

(Pl. 13, figs. 1-4)

Diagnosis: Shell prosocline with well developed ears. Umbonal folds poorly developed and in left valve cardinal margin almost as long as shell. External surface ornamented with a relatively large number of radiating ribs and concentric ridges. A number of fine concentric filae between each prominent ridge.

Description: The holotype is a decorticated left valve showing the shape and the rib pattern. The auricles are separated from the body of the shell by poorly developed sinuses; the umbonal folds are also poorly developed. The anterior ear projects slightly in front of the body of the shell, on which 12 radiating costae and seven concentric ridges are visible. The umbonal part is broken away so that the full number of concentric ridges cannot be counted.

Paratype A, part of the external impression of a left valve, shows the external ornament. The radial ornament extends on to the anterior ear where six fine radial ribs can be seen. Ten concentric ribs are present and the radial and concentric ribs are approximately at equal intervals, forming panels over the surface of the shell. Between the concentric ribs (or ridges) are numerous fine concentric (growth) lines. One secondary radial rib is developed and there is the faintest suggestion of fine radial ornament between the large ribs. Spines are arranged along the outer margin of the shells at the junction of the radiating and the outermost concentric ridge, which is concurrent with the outer margin. The single secondary rib has a small spine at the outer margin.

Paratype B is a partly decorticated right valve in which the length is distinctly greater than the height and the length of the hinge is considerably greater than that of the shell. Both the anterior and the posterior ear project beyond the body of the shell, and anteriorly there is a distinct subauricular notch. The concentric ornament is distinct, but the radial ornament is poorly developed. The valve is almost flat; the ratio of length of hinge-line to height, compared with that in the left valve, indicates that the two valves are discordant.

Dimensions (in mm.):

	Length of Body of Shell	Length of Hinge-line	Height	Thickness
Holotype	20	17	16	3
Paratype B	11	16 +	11	0·5

Occurrence: Holotype, UWA Type No. 45397 (Reg. No. 23348), Fossil Cliff, Fossil Cliff Formation; Paratype A, CPC 3925 (Field No. WB 266), 30 miles west-north-west of Curbur Homestead, Lat. 26°22′00″S., Long. 115°25′00″E., Callytharra Formation; Paratype B, UWA Type No. 45398 (Reg. No. 23350), Fossil Ridge, Fossil Cliff Formation, Irwin River area.

Discussion: Although nowhere numerous, this species is widespread in the Fossil Cliff and Callytharra Formations.

A single right valve is referred to *Girtypecten ovalis* sp. nov. rather than to *Acanthopecten*? sp. because it is associated with left valves of *Girtypecten ovalis* and because it differs considerably from the right valves of *Acanthopecten* figured by Newell (1938, pl. 10).

Poorly preserved specimens are difficult to distinguish from *Acanthopecten*? sp., but those left valves that are more distinctly acline, more convex, or appear to have a more distinct anterior sinus have been referred to *Acanthopecten*? sp. *Acanthopecten*? sp. may also have widely spaced concentric ridges.

From the description and figure, *Aviculopecten* sp. Etheridge (1907b, p. 33, pl. 10, fig. 3) may be referable either to *Girtypecten ovalis* or to *Acanthopecten*? sp.

Girtypecten ovalis does not seem to resemble any other described species closely.

Genus ACANTHOPECTEN Girty 1903 (p. 417)

Type Species (by original designation): *Pecten carboniferus* Stevens (1858, p. 261).

ACANTHOPECTEN? sp.

(Pl. 13, figs. 5-9)

Material: Counterparts of a left valve and the fragment of an external impression. Two other left valves are doubtfully referred to the same species.

Description: Figured Specimen A is a large and orbicular shell, equilateral, and with a long hinge-line. The details of external ornament are not visible as the two parts have split along an inner shell layer. Ornament, however, is of concentric lines and strong radiating ribs, which are not restricted to the superficial layers of the shell. Twelve radiating ribs are visible, separated by wide smooth sulci. Near the external margin large, tubular spines are given off from the middle of the sulci. In Figured Specimen B the radiating ornament is composed of ribs separated by broad sulci, the ribs forming raised ridges at the junctions of the sulci.

The concentric ornament is formed of a large number of fine growth-lines, and at greater intervals imbricate ribs, on which are situated the spines at the middle of the sulci. Although in a general way parallel, in detail the ridges are not parallel with the growth-lines. The development of the spines is similar to that shown by Newell (1938, pl. 12, fig. 4).

Specimens doubtfully referred to Acanthopecten? *sp.*: These comprise two left valves (Figured Specimens C and D). One specimen shows a pattern of successive overlapping lamellae of shell (rather than ridges) on the well developed posterior ear. Both *Girtypecten* and *Acanthopecten* appear to have this character. In the other specimen, part of the impression of the ligament area is preserved, but not sufficient to show the structure of the ligament although enough to indicate that it is not of the pterinopectinid type. The ligament area is narrow and elongated, and has very fine longitudinal lines of growth. Seventeen radial ribs of a single order and seven concentric are visible on the body of the shell.

Dimensions (in mm.):

		Length	*Height*	*Width*
Figured Specimen A	......	101	95	15
Figured Specimen C	......	27	25	6
Figured Specimen D	......	28	24 +	5

Occurrence: Figured Specimen A, UWA 45399 (Reg. No. 23326), Fossil Cliff, Fossil Cliff Formation; Figured Specimen B, CPC 3926 (Field No. WB 266), 30 miles west-north-west of Curbur Homestead, Lat. 26°22′00″S., Long. 115°25′00″E., Callytharra Formation; Figured Specimen C, UWA Type No. 45400 (Reg. No. 23331), small creek 200-300 yards north of Fossil Cliff, Fossil Cliff Formation; Figured Specimen D, CPC 3927 (Reg. No. F 6743) Callytharra (Oil Search Loc. 8), Callytharra Formation, Wooramel River area.

Discussion: The ornament makes it almost certain that *Acanthopecten* is represented in the present collections. In the absence of external ornament, specimens of this species are not easy to separate from *Girtypecten ovalis* sp. nov., and such specimens have been distinguished because they are acline rather than prosocline, because the left valve is relatively more convex, or because a distinct anterior sinus is present.

Subfamily STREBLOCHONDRIINAE Newell

Genus STREBLOPTERIA McCoy 1851 (p. 170)

Type Species: *Meleagrina laevigata* McCoy (1844, p. 80, pl. 12, fig. 5) by subsequent designation of Meek & Worthen (1866, p. 333) and S. A. Miller (1889, p. 514)—*fide* Newell (1938, p. 88).

Discussion: Newell (1938) has dealt extensively with the characters of *Streblopteria* and the related genus *Streblochondria* Newell 1938. The present specimens placed in *Streblopteria* appear to lack or have poorly developed radial ornament, have a reduced anterior ear and a distinct sulcus separating this ear from the main part of the shell. This suggests that they belong to *Streblopteria* rather than *Streblochondria.* The posterior ear is poorly separated from the body of the shell, as shown in specimens of the type species of *Streblopteria* figured by Hind (1903, pl. 11, fig. 1-7). The left valves, however, are not unlike the specimens of *Streblochondria*? *tenuilineata* (Meek & Worthen) 1860, figured by Newell (1938, pl. 15, figs. 14b; c).

Insufficient material is available in the Western Australian collections for a reliable specific description; more than one species may be present.

Another single specimen shows distinct concentric rugae and is doubtfully referred to *Streblopteria.*

STREBLOPTERIA sp.

(Pl. 14, figs. 9-12)

Description: The left valve is sub-oval, slightly opisthocline or almost acline, and equilateral. The anterior ear is larger than the posterior and the anterior umbonal ridge is longer and more distinct than the posterior. The margin of the posterior ear joins the body of the shell without a sinus, but at the front a shallow sinus separates the anterior ear. The right valve is almost acline; the anterior ear is relatively small and is separated from the body of the shell by a distinct sub-auricular notch and sulcus. Externally both valves are ornamented by poorly developed concentric growth-lines. Radial ornament is absent or poorly developed.

Dimensions (in mm.):

		Length	*Height*	*Thickness*
Figured Specimen A	......	16	18	2
Figured Specimen B	......	15	16	2
Figured Specimen C	......	30	—	6
Figured Specimen D	......	19	22 (estimated)	5

Occurrence: Figured Specimen A, CPC 3932 (Field No. KPA 54), 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near base of Poole Sandstone, Fitzroy Basin; Figured Specimen B, UWA Type No. 45401 (Reg. No. 31566), basal part of High Cliff Sandstone at Woolaga Creek; Figured Specimen C, CPC 3933 (Reg. No. F 17,108) 1st ridge of Callytharra Formation 0.4 miles east of Mount Sandiman Woolshed, ¼ to ½ mile north of Mount Sandiman-Merlinleigh road; Figured Specimen D, UWA Type No. 45402 (Reg. No. 23352) Fossil Ridge, Fossil Cliff Formation.

Other Specimens: Fossil Cliff Formation—Fossil Ridge and Becketts Gully; and from the Callytharra Formation.

STREBLOPTERIA? sp.

(Pl. 14, fig. 17)

Description: This species is represented by a single incomplete specimen, which because of the position of the sulcus appears to be a left valve (both valves of the Streblochondriinae have a distinct sulcus at the front). The shell is oval, not very convex, and has 10 concentric rugae which are more widely spaced and less prominently developed towards the outer margin of the shell. Faint radial ribbing is visible towards the outer margin.

Dimensions (in mm.):

	Length	Height	Thickness
Figured Specimen	26 (estimated)	26	2

Occurrence: Figured Specimen, UWA Type No. 45403 (Reg. No. 32637), lowermost limestone bed, Becketts Gully, Fossil Cliff Formation, Irwin River area.

Discussion: This shell, in the development of concentric rugae, is similar to an undescribed species which occurs, sometimes in considerable numbers, higher in the Permian sequence in Western Australia. The younger species has a greatly reduced anterior ear in the right valve.

It is also similar to the two figured specimens from the Lower Permian of north-eastern Siberia described as *Annuliconcha* cf. *sedgwicki* (McCoy) by Lobanova (1959, p. 66, pl. 2, figs. 1; 2). *Annuliconcha* cf. *sedgwicki* has a well-developed anterior ear in the right valve.

Similar ornament is also found in the Carboniferous shell *Pseudamussium auriculatum* (McCoy) 1844, Hind (1903, p. 108, pl. 16, figs. 24-27), which appears to be closer to *Streblopteria* than *Pseudamussium.*

Family EUCHONDRIIDAE Newell 1938

Genus EUCHONDRIA Meek 1874 (p. 445)

Type Species (by original designation): *Pecten neglectus* Geinitz (1866, p. 33, pl. 2, fig. 17).

Discussion: Newell (1938, p. 104, 105) records the range of *Euchondria* as Devonian? to Upper Carboniferous. This range is extended into the Permian by the occurrence of *Euchondria weiensis* Wanner (1940, p. 378, pl. 1, fig. 2) at Tae Wei, Timor, and by the new species from Western Australia described below. In both these species the auricles are more reduced and are less distinctly marked off from the rest of the shell, and the shell is more upright and equilateral than in the North American Carboniferous species described by Newell. These changes are analogous with those in *Aviculopecten* described in an earlier part of this monograph, which are considered to result from adaptation to a free-swimming life.

EUCHONDRIA CALLYTHARRAENSIS sp. nov.

(Pl. 14, figs. 2-8)

Diagnosis: Slightly prosocline to acline; external ornament in left valve of numerous radiating ribs or costae and fine closely spaced concentric lines or filae; in right valves radiating ornament confined to auricles. Hinge length considerably less than length of valves and auricular sinuses and subauricular notch in right valve of moderate depth.

Description: The holotype is an external impression of a left valve. The shell is slightly convex, almost acline, equilateral, and with ears of almost equal size. The sulcus or furrow separating the anterior ear from the body of the shell is more distinct than the posterior, and the posterior part of the shell has an almost straight backward and downward sweep below the junction of the posterior ear with the body of the shell. Increase of ribs is by interpolation or apparently in some cases by subdivision—although the ribs are not of equal prominence no distinct orders are apparent. There are about seven radiating ribs on each of the anterior and posterior ears and 50 around the ventral margin of the shell. The concentric filae present over the body and ears are fine and closely spaced (five filae per mm. near the ventral margin) with occasional widely spaced more prominent filae.

Paratype A is an internal impression of a right valve. The shell is prosocline and only a little less convex than the holotype, a left valve. The anterior sulcus is more distinct than the posterior, but an anterior sinus ('byssal sinus') is hardly present. The impression of the hinge shows a poorly preserved central ligament pit with multiple denticles or ligament pits along the hinge on either side.

Paratype B, an internal impression of a left valve, is considerably more prosocline than the holotype. It shows the multiple denticles or ligament pits along the hinge.

Paratype C, an external impression of a right valve, shows the shape and the external ornament. The radiating ribs (about seven) on the anterior ear are distinct, but on the posterior ear are poorly developed. The concentric growth-lines are well developed on the ears, but are hardly discernible on the body of the shell. Apparently radiating ornament is absent on the latter. The subauricular notch is poorly developed.

Dimensions (in mm.):

	Length	*Height*	*Thickness*	*Length of Hinge*
Holotype	28	27	2·5	14
Paratype A	19	18	1·5	11
Paratype B	26	25	2·5	12
Paratype C	18	17	1·5	10

Occurrence: Holotype, CPC 3928, Paratype A, CPC 3929, Paratype B, CPC 3930, and Paratype C, CPC 3931, all from 5¾ miles on a bearing of 335° from Lyons River Homestead, at top of exposed Callytharra Formation (Field No. G 202). More than 20 specimens have been collected, and the species is represented in the Fossil Cliff Formation and the Nura Nura Member as well as in the Callytharra Formation.

Discussion: Fragmentary left valves of *E. callytharraensis* can be separated from the other pectinids with which they are found by their ornament—the large number of fine radiating ribs of about equal size crossed by numerous fine concentric lines. The piece of rock containing the type specimens has in it more than 15 specimens of *E. callytharraensis*—on the body of the shell all the left valves have radial ribbing which all the right valves lack. This confirms Newell's (1938) conclusion on the ornament of left and right valves. In addition all the left valves on this piece of rock are of a similar size and the right valves are uniformly smaller, indicating that the valves are discordant.

E. callytharraensis seems to be most closely related to *E. weiensis* Wanner (1940; p. 378, pl. 1, fig. 2) from the Permian of Tae Wei, Timor. It is, however, more transversely elongated than the Timor species.

Family LIMIDAE d'Orbigny

Biconvex shells lacking a 'byssal ear' in the right valve and having affinities with *Lima* and related genera have frequently been recorded from Carboniferous and Permian rocks. Although these shells are widespread, they are generally represented by a few fragmentary shells, and their characters have remained obscure.

Commonly the Palaeozoic species have been considered under the names *Lima* Brugière 1797, *Plagiostoma* Sowerby 1814, *Limatulina* de Koninck 1885, or *Palaeolima* Hind 1903—the last two names having been proposed for Palaeozoic forms. Conforming to the usage of Hind (1903), Newell (1938, p. 62) has designated *Limatulina radula* (de Koninck) (1842, p. 135, pl. 4, fig. 1) as the type species of *Limatulina* and suggested that *Limatulina* may therefore become a synonym of *Aviculopecten*. None of the Western Australian species seem to be closely related.

One of the Western Australian species (*Palaeolima* sp. nov.) is similar to *Palaeolima simplex* (Phillips) 1836, the type species of *Palaeolima,* and is therefore assigned to this genus.

A second species has fine, approximately equal radiating ribs and in this respect is similar to *Plagiostoma*. Although it is described as *Plagiostoma*? sp. nov., species of this type probably require a new generic name. The present material, however, is rather inadequate as a base for such a name.

The third species is used as the basis for the introduction of a new generic name. The shells are rather convex and are either smooth or may have very fine radiating ornament.

Orientation of Shell: In the Limidae the posterior part of the shell is the smaller, the flat area is at the front and the shell leans towards the back. This orientation, which is used here, is the reverse of that used by Hind (1903).

Genus PALAEOLIMA Hind 1903 (p. 38)

Type Species (by subsequent designation of Cox, 1943, p. 153): ?*Pecten simplex* Phillips (1836, p. 212, pl. 6, fig. 27).

Discussion: According to Hind (1903, p. 39) Phillips' type of *Palaeolima simplex* has disappeared; and this is confirmed by Dr L. R. Cox, of the British Museum (Natural History), who states in a letter of 1st July 1958 'so far as we can ascertain, the type specimen of *Pecten simplex* Phillips is no longer extant. It is not among the Gilbertson Collection specimens in this Museum, nor it is at Oxford.' To my knowledge no specimen has been designated in place of Phillips' as a type. I am grateful to Dr Cox for information on Hind's three specimens which are preserved in the British Museum and, on his advice, the specimen (No. L24706) figured by Hind (1903) in Plate 19, fig. 26, from Little Island, Co. Cork, Ireland, is hereby designated as type. Cox writes 'the specimen is not full grown, but its outline is almost complete and its ornament is preserved. . . . On the whole, I think that the original of fig. 26 would serve best as neotype.'

PALAEOLIMA sp. nov.

(Pl. 14, figs. 13-16)

Description: Figured Specimen A is a right valve with part of the posterior auricle and back of the shell missing. The body of the shell has distinct radiating ribs of unequal size, which are relatively closely spaced and increase in number by irregular bifurcation. The anterior area (or auricle) is devoid of radiating ornament except for three poorly developed ribs near its ventral margin. Like the main part of the shell it is covered by fine concentric lines. The umbo is rather blunt and does not rise much above the hinge-line. There are no anterior and posterior auricles distinctly separated from the rest of the shell. The anterior umbonal ridge is distinct and forms a flat area in front, the 'lunule'.

Figured Specimen B, a left valve, is similar to the right valve—the ears are poorly preserved but there is no 'byssal sinus'. About 21 large ribs are found around the ventral margin, some of which are flattened on top and show incipient division.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen A	—	21	3
Figured Specimen B	21	21	3·5

Occurrence: Figured Specimen A, CPC 3934 (Field No. PB 14), Figured Specimen B, UWA Type No. 45404 (Reg. No. 33790), Fossil Ridge, Fossil Cliff Formation, Irwin River area. Two specimens only.

Discussion: A new specific name is not proposed because of the small amount of only moderately well preserved material that is available. In shape *Palaeolima* sp. nov. resembles *Limatulina striaticostata* Girty (1909, p. 443, pl. 9, figs. 17-19) from the Permian Guadalupian of Texas, but the large ribs are different and the fine radial ornament between the large ribs of *L. striaticostata* is lacking in the Australian species.

Genus PLAGIOSTOMA J. Sowerby 1814

Type Species: *Plagiostoma gigantea* Sowerby 1814—*fide* Arkell (1931, p. 128), manner of designation not known.

PLAGIOSTOMA? sp. nov.

(Pl. 15, figs. 1-5)

Description: The shell is rather convex and the anterior umbonal ridge is well marked forming a distinct flattened area at the front. The external surface is ornamented with fine concentric lines and slender radiating ribs. The ribs are not of different orders, but those at the front are larger than those at the rear. The number of ribs is almost constant, with some addition towards the outer margin. A ligament pit is visible in one of the specimens.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen A	7	8	1·5
Figured Specimen B ...... (internal impression)	7·5	7	1·5
Figured Specimen C	10	11	2·5
Figured Specimen D	4	5 (estimated)	1

Occurrence: Figured Specimen A, CPC 3935 (Field No. G 202), 5⅞ miles on a bearing of 335° from the Lyons River Homestead, at top of exposed Callytharra Formation; Figured Specimen B, CPC 3936 (Field No. PB 9), Pintharuka 1-mile Sheet, map co-ordinates 511056, Becketts Gully, ⅖ mile upstream from road crossing, Fossil Cliff Formation; Figured Specimen C, CPC 3937 (Field No. PB 14), Fossil Ridge, Fossil Cliff Formation; and Figured Specimen D, CPC 3938 (Field No. GW 86) about ½ a mile west of Callytharra Springs, 41 feet above base of Callytharra Formation.

Other Specimens: One from WB 266, 30 miles west-north-west of Curbur Homestead, Lat. 26°22′00″S., Long. 115°25′00″ E., Callytharra Formation; and one from IR 20, Carynginia Gully, about ½ a mile on a bearing of 334° from Caryngina (No. 1) Well, Fossil Cliff Formation.

Discussion: The ribbing is quite distinct from that found in *Palaeolima* sp. nov.

Genus ELIMATA nov.

Type Species (hereby designated): *Elimata guppyi* sp. nov.

Diagnosis: Biconvex, inequilateral, suboval shells with anterior and posterior ears not distinctly marked off. External ornament of concentric growth-lines—radial ornament absent or possibly very faint. Anterior flattish area not distinctly marked off from the rest of shell.

Discussion: In their biconvexity, asymmetrical shape and flattened area, these shells are related to the Limidae. A thorough search in specimens of *Elimata guppyi* has failed to reveal any indication of an anterior ear in the right valve, which could be expected if they were related to the Streblochondriinae. The hinge is very delicate and it has not been possible to show that it has a ligament pit.

Plagiostoma deltoideum Girty (1909, p. 442, pl. 9, figs. 15-16a) and *Lima permiana* King (1850, p. 154, pl. 13, fig. 4) appear to belong to this genus, as well as the specimens described as *Lima permiana* King by Frebold (1931, p. 16, pl. 1, figs. 28, 29) and as *Plagiostoma*? *permiana* (King) by Newell (1955, p. 23, pl. 4, figs. 4, 5).

The generic name is based on the Latin *elimatus*: polished.

ELIMATA GUPPYI sp. nov.

(Pl. 15, figs. 6-13)

Diagnosis: Rather convex, ornamented externally by concentric growth-lines. Radial ornament absent or possibly very fine.

Description: The holotype shell is slightly opisthocline. The hinge-line is straight and considerably shorter than the length of the shell. The anterior and posterior ears are not separated from the rest of the shell by a sinus and the sulci are shallow. The anterior area is hardly distinguishable from the ear and is separated from the rest of the shell by a rounded umbonal ridge. Externally the surface is ornamented by poorly developed concentric lines.

Other specimens are similar to the holotype, and right and left valves are distinguishable only by their orientation. In some shells a few of the concentric growth-lines are more distinctly marked than the rest. Other shells show the faintest suggestion of fine radiating ornament.

Dimensions (in mm.):

	Length	*Height*	*Thickness*	*Length of Hinge-line*
Holotype	10	9	3	5
Paratype A	6	6	2	3
Paratype B	7	7·5	3	—
Paratype C	8	7·5	3	—
Paratype D	8	8	3	4

Occurrence: Holotype, CPC 3939, Paratype A, CPC 3940, Paratype B, CPC 3941, Paratype C, CPC 3942, Paratype D, CPC 3943, all from 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near the base of the Poole Sandstone (Field No. SG 120A). The species is represented by a large number of specimens from this locality.

Discussion: *Elimata guppyi* is readily separable from *Plagiostoma*? sp. nov. by its lack of distinct radial ornament and well-marked anterior ridge forming a shoulder and separating the anterior area from the rest of the shell. It is not known to resemble any described species especially and is separable for example from *Elimata deltoidea* (Girty) 1909 by its more circular shape and apparently greater convexity.

This species is named after Mr D. J. Guppy, formerly of the Bureau of Mineral Resources and now of American Overseas Petroleum Exploration Company, who has done much geological work in the Canning Basin.

Superfamily CARDITACEA?

Family MYOCONCHIDAE Newell 1957

Previously (Dickins, 1956, p. 13; 1957, p. 21), I placed the genus *Stutchburia* in the family Modiolopsidae. Since the appearance of these papers, Newell (1957) has reviewed the primitive heterodont forms and proposed a new family name Myoconchidae for the genera *Myoconcha* and *Stutchburia*—forms apparently derived from the Modiolopsidae. On the basis of the hinge-structure and other features, a separation of the Upper Palaeozoic and Mesozoic from the earlier forms appears to be justified and Newell's proposal is followed in the present paper. Newell also tentatively places the Myoconchidae and Pleurophoridae Dall 1900 (=Kalenteridae Marwick 1953) in the superfamily Carditacea and separates both at the superfamily level from the Modiolopsidae. (Marwick, 1953, p. 69, and Grant-Mackie, 1960, p. 74, refer the Kalenteridae to the superfamily Cypricardiacea.) Newell considers it probable that the Myoconchidae are derived from the Pleurophoridae. The ligament of *Stutchburia* is lodged in a groove behind the umbo in a position similar to that found in *Mytilus* and *Modiolus* (see Dickins, 1956, pl. 1, fig. 17), so that the ligament in the Myoconchidae may not be as different from that in the Mytilidae as is suggested by Newell (1957, p. 6).

Genus STUTCHBURIA Etheridge Jnr 1900

1900. *Stutchburia,* Etheridge, p. 180.

1925. *Netschajewia,* Licharew, p. 119.

?1952 *Rimmyjimina,* Chronic, p. 148.

Type Species (by original designation): *Orthonota*? *costata* Morris (1845, p. 273, pl. 11, fig. 1).

Diagnosis: Shell modioliform and with a distinct lunule and escutcheon: ligament behind the umbones, contained in a deep-set groove which is marginal rather than external; 'cardinal teeth' poorly developed and not distinctly delineated, but formed of rounded projections of hinge-line—may have projections corresponding to 2, 4b, and 3b of notation of Munier-Chalmas and Bernard. Posterior lateral teeth of right valve (P I and P III) poorly developed or possibly absent in some specimens; a posterior lateral (P II) may be present in the left valve. Ornament of concentric growth-lines or lamellae; in addition may have radial ribs confined to the back part of the shell.

Discussion: *Netschajewia* was proposed by Licharew* for *Stutchburia*-like forms which could be distinguished by having a posterior lateral tooth. Newell (1957, p. 7) records a posterior lateral tooth (P II) in *Stutchburia costata* (Morris), the type species of *Stutchburia,* and therefore proposes that *Netschajewia* be regarded as a subgenus of *Stutchburia* distinguished by its mytiloid and strongly anisomyarian shape. An examination of a suite of specimens of *Stutchburia costata* in the Australian Museum, Sydney, confirms Newell's conclusion about the posterior lateral

* In Newell (1957) *Netschajewia* is ascribed to Yakovlev in mistake for Licharew.

tooth. However, in many specimens the lateral tooth is poorly developed and in some may be absent altogether. Although these differences may be caused by differences in preservation, my examination suggests that, more probably, it results from original variation. Corroborative evidence for this is to be found in an examination of well-preserved specimens referred to *Stutchburia muderongensis* Dickins 1956 from the lower part of the Liveringa Formation of the Fitzroy Basin, Western Australia. In some specimens a lateral tooth is well developed, in others it is poorly developed, and in others again none is visible.

Certainly the presence or absence of lateral teeth will not serve as a basis for distinguishing *Stutchburia* and *Netschajewia* at a generic level, and there may not be a great deal of merit in recognizing *Netschajewia* even at the subgeneric level.

As shown by Newell (1955, p. 28; 1957, p. 9) and Dickins (1957, p. 21), the radial ribbing is rather variable even within a single species.

Palaeoecology of Stutchburia: Newell (1957, p. 6) suggests that the Myoconchidae were byssate, by analogy with the Mytilacea, in which 'there is a strong correlation between attachment and reduction of the anterior part of the body'. Our material does not afford any additional evidence on this matter. *Stutchburia*, however, is one of the most common pelecypods in the Lower Permian marine deposits of Eastern and Western Australia and frequently occurs in Western Australia in large numbers, together especially with *Schizodus* and *Oriocrassatella*, in what appear to be rather shallow-water shell-banks.

STUTCHBURIA VARIABILIS Dickins 1957

(Pl. 15, fig. 24)

1957. *Stutchburia variabilis* Dickins, p. 21, pl. 2, figs. 7-14.

This species has already been recorded from the Callytharra Formation (Dickins, 1957, p. 22). Two additional specimens, one of which is figured, from the Fossil Cliff Formation are now assigned to it. *S. variabilis* can be distinguished from *Stutchburia hoskingae* sp. nov. by its subquadrate shape, by the well developed sulcus running from the umbo ventrally and by the distinct flattish area behind the posterior umbonal ridge.

Occurrence: Hypotype, UWA Type No. 45410 (Reg. No. 23328), Fossil Cliff, Fossil Cliff Formation, Irwin River area. The second specimen (UWA Reg. No. 23328) comes from the same locality.

STUTCHBURIA HOSKINGAE sp. nov.

(Pl. 15, figs. 16-23)

1907b. *Stutchburia* sp. Etheridge Jnr, p. 33, pl. 7, figs. 7-9, ?10.

Diagnosis: Shell expanded towards the rear; without a distinct sinus in the ventral margin or a distinct sulcus running down from the umbo. Radial ribbing variable; confined to back part of shell.

Description: The holotype is a right valve. The umbo is not prominent and not particularly turned towards the front. A distinct anterior lobe is present in front of the umbo, not far behind which the valve is thickest. The external ornament is composed of concentric growth-lines and three ribs radiating backwards from the umbo. At irregular intervals stronger growth-stages form more distinct lamellae. Where the growth-lines cross the ribs they change direction, and in places small nodes are formed.

Other specimens show that the anterior adductor scar is bounded behind by a distinct buttress, which varies from almost upright in some specimens to anteriorly inclined in others. The pallial line is entire and the posterior adductor scar at the posterior end of the dorsal margin is only superficially marked. The radial ribbing is quite variable—in some specimens it is confined to the dorsal parts, in others it extends ventrally; some have a few widely spaced ribs whereas others have a larger number of more closely spaced ribs. Generally the more dorsal ribs extend to the margin whereas the more ventral ones do not. Paratype E has not less than eleven radial ribs, the closest of which are 1 mm. apart at the ventral margin. Paratype C, the internal impression of a left valve, shows a posterior lateral tooth (P II) separated from the margin by a groove for the reception of a lateral tooth (P III) of the right valve.

Dimensions (in mm.):

	Length	*Height at Umbo*	*Greatest Height*	*Thickness*
Holotype	28	10	12	3
Paratype A	34	14	17	5
Paratype B	40	14	18	5
Paratype C	17	6	9	2
Paratype E	—	9	10·5	—

Occurrence: Holotype and Paratype A, UWA Type Nos. 45405 and 45406 (Reg. No. 23354) Fossil Ridge; Paratype B, CPC 3944 (Field No. PB 10), limestone band in Becketts Gully, just below Round Hill; Paratype C, UWA Type No. 45407 (Reg. No. 23344) ? Fossil Cliff; Paratypes D and E, UWA Type Nos. 45408 and 45409 (Reg. No. 23371), Fossil Cliff. All types from the Fossil Cliff Formation, Irwin River area.

Other Specimens: IR 20, Carynginia Gully, about ½ mile on a bearing of 334° from Carynginia (No. 1) Well, Fossil Cliff Formation.

S. hoskingae is one of the commonest molluscs in the Fossil Cliff Formation and is represented in the collections by more than 100 specimens.

Discussion: As suggested by Etheridge (1907b, p. 34) *S. hoskingae* appears to be closely related to *Stutchburia randsi* (Etheridge) (1892, p. 275, pl. 14, fig. 14) from the Permian of Queensland. The type specimen of *S. randsi* is refigured in Plate 15, figures 14 and 15. It is a young shell hardly distinguishable from some specimens of *S. hoskingae,* but until further specimens of *S. randsi* are available the two cannot be reliably compared.

Dr W. G. H. Maxwell has kindly supplied information that the type specimen of *Stutchburia randsi* occurs stratigraphically lower than the Yarrol Limestone, which contains the *Anidanthus-Taeniothaerus* fauna, at about the horizon of *Eurydesma hobartense* Johnston 1887 in the Yarrol Basin.

The species is named after L. F. V. Hosking (Mrs Hanrahan) who described Permian fossils from Western Australian in the 1930's.

Superfamily ?

Family ?

Genus CYPRICARDINIA Hall 1859 (p. 266)

Type Species (by subsequent designation of Hall, 1885, p. xlvi): *Cypricardinia lamellosa* Hall (1859, p. 266, pl. 49A, figs. 1a-c) (=*Cypricardinia halli* Beushausen 1897), *non* Goldfuss 1840.

Discussion: A number of Upper Palaeozoic species have been doubtfully referred to the genus *Cypricardinia*, and amongst these belongs the new species, described below. They tend to be modioliform, have regular imbricate growth lamellae and faint radial ornament, and lack a lunule and escutcheon. Cardinal and lateral teeth are present in each valve; the ligament is lodged in a groove behind the umbo and is situated marginally rather than externally. The shells are equivalve. In the Western Australian species the anterior adductor scar lacks a distinct posterior buttress and the shell is thick. Some at least of Hind's (1897, p. 30) *Parallelodon* Group A also belong here. Girty (1909, p. 446), Licharew (1931—*fide* Newell, 1955), and Newell (1955, p. 30) have discussed their doubt about referring these forms to *Cypricardinia.* Hall (1885, p. xlvi, xlvii) states that *Cypricardinia* is inequivalve and has a well developed external ligament, characters apparently absent in the Upper Palaeozoic forms. Haffer (1959, p. 182, pl. 12, figs. 11, 12) has described and figured the hinge of *Cypricardinia lamellosa* (Goldfuss) 1840 *non* Hall 1859 from the Devonian of Europe (*C. lamellosa* Hall 1859 = *C. halli* Beushausen 1897, the type species, is also from the Devonian). The dentition of this hinge differs rather from that of the Permian species and it seems that the Upper Palaeozoic forms will require another generic name.

A specimen of *Cypricardinia*? *gregarius* (Etheridge Jnr) (1900, p. 185, pl. 33, figs. 2-5) from the 'Farley Stage', Farley, New South Wales, shows the dentition excellently and is figured in Plate 16, figures 20, 21. Although Etheridge referred this species to *Pleurophorus*, the dentition, shape, and lamellate external ornament indicate that it should be assigned to the group discussed above. Two or three cardinal teeth and two lateral teeth are visible in each valve. There is a similarity to heterodont forms, but to interpret the dentition according to the notation of Munier-Chalmas and Bernard might be misleading.

CYPRICARDINIA? ELEGANTULA sp. nov.

(Pl. 16, figs. 10-19)

Diagnosis: Shells equivalve, varying from almost oval to modioliform, becoming more modioliform with age. In the adult, external surface without marked changes in convexity, but in the young shell posterior umbonal ridge distinctly developed, so that youthful part of the shell more humped than adult part. Two distinct cardinal teeth and two or three posterior laterals in each valve.

Description: The holotype shows the shape and the external ornament. The concentric ornament is composed of fine growth-lines and rather regularly spaced imbricate lamellae, which become wider apart towards the external margin. The radial ornament is composed of faint discontinuous ribs. The shell is rather inflated.

Paratypes A, B, and E show the dentition and the hinge structure. Paratype A, which is a left valve with the hinge slightly worn, has two oblique cardinal teeth and possibly a third. Between these teeth are sockets for at least two teeth in the right valve. At the rear of the cardinal margin and below the rear part of the ligament groove are two or three lateral teeth. The ligament groove begins under the umbo and runs backward; during life the ligament would have been hidden or almost hidden from the outside of the shell.

The anterior adductor scar is oval in a dorso-ventral direction and lacks a distinct buttress at the rear. The posterior adductor muscle and the pallial line are not visible in any of the specimens.

Dimensions (in mm.) (length taken parallel and height at right-angles to hinge-line):

	Length	*Height*	*Thickness*
Holotype	16	11	3
Paratype A	20	12	3·5
Paratype B	23 (estimated)	14	4·5
Paratype C	—	17	5
Paratype D			
Left valve	23	15	5·5
Right valve	23	15	5
Paratype E			
Left valve	18 (estimated)	11	4·5
Right valve	18 (estimated)	11	4·5

Occurrence: Holotype, UWA Type No. 45411 (Reg. No. 23388), Paratype A, UWA Type No. 45412 (Reg. No. 23342?), Paratype B, UWA Type No. 45413 (Reg. No. 23371), Paratype C, UWA Type No. 45414 (Reg. No. 23371), Paratype D, UWA Type No. 45415 (Reg. No. 23342) and Paratype E, UWA Type No. 45416 (Reg. No. 23327), all from Fossil Cliff except possibly Paratype A, Fossil Cliff Formation, Irwin River area. The species also occurs in the Callytharra Formation, about 6 miles south-south-east of Plant Well, Coordewandy Station (Field No. WB 180) and doubtfully in the Callytharra Formation 2.2 miles south of Mount Sandiman Woolshed. It is doubtfully represented in the Canning Basin in the Cuncudgerie Sandstone and in the basal part of the Poole Sandstone in the St George Range.

Discussion: *Cypricardinia*? *elegantula* is represented in the Fossil Cliff Formation by many specimens and rivals *Stutchburia hoskingae* in numbers. Elsewhere, it is rare.

The shape varies considerably, although larger shells tend to become modioliform. The radial ribbing is never strongly developed and is easily removed by abrasion or weathering. *C.*? *elegantula* is similar in shape to *Stutchburia,* but can be separated by careful examination.

It is separable from other described species of *Cypricardinia*? by the details of its dentition.

Superfamily TRIGONIACEA

Family TRIGONIIDAE

Genus SCHIZODUS Murchison & de Verneuil* 1844 (p. 485)

Type Species (by designation of de Verneuil, 1845, p. 308): *Axinus obscurus* J. de C. Sowerby (1821, p. 12, pl. 314).

* Originally attributed by courtesy to Professor W. King.

SCHIZODUS FITZROYENSIS sp. nov.

(Pl. 17, figs. 10-19; Text-fig. 12A)

Diagnosis: Shell triangular with a distinct carina extending from umbo to posterior angle; cardinal teeth small with posterior cardinal tooth rather elongated. A small buttress extends downward from front part of hinge-plate.

Description: The holotype is an internal impression of a right valve. The muscle scars are shallow—the anterior adductor is oval and is bounded by a slight ridge (sulcus in the impression); the posterior adductor is round and has an anterior ridge. The pallial line is not preserved at the back, but any sinus was shallow. The hinge has two cardinal teeth: 3a is wedge-shaped and slopes towards the front, 3b is elongated and poorly separated from the cardinal margin. The buttress ridge runs down from the front of 3a to the top of the anterior adductor, above which is situated the pedal muscle between the buttress ridge and the front of the shell.

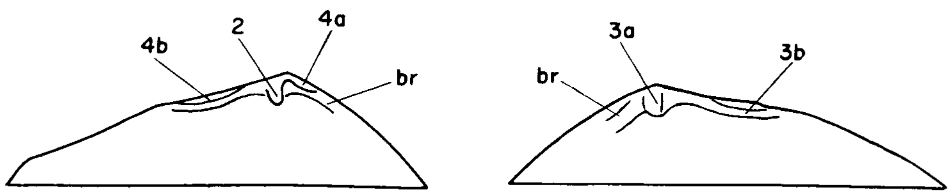


Fig. 12. Dentition of Schizodus (x 2). A.— S. fitzroyensis, Paratype A. B.—S. sandimanensis, Paratype B. 2, 3a, 3b, 4a and 4b: cardinal teeth. br: buttress ridge.

Paratype A, which is an internal impression of a left valve, is similar in musculature and shape to the holotype. The dentition consists of three cardinal teeth: 4a is well developed, 2b is robust and slopes towards the back, and 4b, like 3b, is elongated and poorly separated from the cardinal margin. The full trigoniid dentition is therefore present in this species.

Younger specimens are more triangular, but can be matched in the growth stages of older individuals.

Dimensions (in mm.):

	Length	*Height*	*Width*
Holotype	39	31	9
Paratype A	38	30 (estimated)	8
Paratype B	41	32	9·5
Paratype C	24	20	5·5
Paratype D	32	29	8
Paratype E .... (bivalved specimen)	19	16	9 (single valve)

Occurrence: Holotype, CPC 3945 (Field No. KPA 54), Paratype A, CPC 3946 (Field No. KPA 54), Paratype B, CPC 3947 (Field No. KPA 54), Paratype C, CPC 3948 (Field No. KPA 54), Paratype D, CPC 3949 (Field No. KPA 55), all from 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near the base of the Poole Sandstone; Paratype E, CPC 3950, locality not certain but apparently 1.6 miles south-west of Paradise Homestead, Fitzroy Basin (Lat. 18°02′30″S. Long. 124°31′00″E.), Nura Nura Member.

This species is common at the St George Range locality; it is less well represented in the Nura Nura Member.

Discussion: *Schizodus fitzroyensis* is very similar in shape to *Schizodus kennedyensis* Dickins 1956, which occurs much higher in the Permian of Western Australia. It is, however, readily distinguishable by the differences in the dentition. In *S. fitzroyensis* the teeth are much smaller and the posterior cardinal tooth in each valve is more elongated. In shape and dentition it is readily distinguishable from *S. crespinae* Dickins 1957, which occurs in the older Lyons Group.

SCHIZODUS SANDIMANENSIS sp. nov.

(Pl. 17, figs. 1-9; Text-fig. 12B)

Diagnosis: Shell quadrate with a prominent carina; produced posteriorly to form a distinct area which gives the squarish shape. Teeth small, posterior cardinal apparently poorly developed.

Description: In front of the carina of the holotype and running parallel to it is a shallow sulcus which forms a slight sinus in the ventral margin; the external surface shows only fine concentric growth-lines. The teeth are small and the details of the dentition are not visible.

Paratype A—the internal and part of the external impression of a left valve—shows the dentition. Three cardinal teeth appear to be present: 4a is apparently represented by a small protuberance, 2b by a small upright tooth, and 4b is hardly distinguishable from the posterior margin. The external surface is ornamented only with fine growth-lines.

Paratype B is part of the internal and external impression of a right valve larger than the holotype or paratype A. 3a is well developed, but 3b is indistinctly separated from the cardinal margin. A slight buttress runs down from 3a towards the anterior adductor scar.

Dimensions (in mm.):

	Length	*Height*	*Width*
Holotype	24	21	6
Paratype A	22	21	6·5
Paratype B	40 (estimated)	33 (estimated)	11
Paratype C	31	26	7
Paratype D .... (bivalved specimen)	10·5	7·5	9
Paratype E	11·5	10	3·5

Occurrence: Holotype, UWA Type No. 45417 (Reg. No. 33384), 2.2 miles south of Mount Sandiman Woolshed, Callytharra Formation, Paratype A, CPC 3951 (Field No. PB 7), Carynginia Gully, about ½ mile on a bearing of 334° from Carynginia (No. 1) Well, Fossil Cliff Formation; Paratype B, CPC 3952, and Paratype C, CPC 3953, both from southern part of St George Range, 16 miles at 120° from Mount Tuckfield, near the base of the Poole Sandstone; Paratype D, CPC 3954 (Field No. $KNuA_1$), 1.6 miles south-west of Paradise Homestead, Lat. 18°02′30″S., Long. 124°31′00″E., Nura Nura Member; Paratype E, UWA Type No. 45418 (Reg. No. 23357), Fossil Ridge, Fossil Cliff Formation.

Although widespread this species is nowhere plentiful. It is represented by more than 20 specimens.

Discussion: *Schizodus sandimanensis* is distinguished from *S. fitzroyensis* by the quadrate shape formed by the posterior extension of the area behind the carina. *S. crespinae* from the Lyons Group is less quadrate and the carina is less well developed; the dentition also differs.

SCHIZODUS sp.

(Pl. 17, fig. 20)

Description: Two large specimens with a subquadrate shape are referred to *Schizodus* sp. The posterior carina is moderately well developed and the shell is not very tumid. The details of the dentition are not visible.

Dimensions (in mm.):

	Length	*Height*	*Width*
Figured Specimen	50	39	6·5

Occurrence: Figured Specimen CPC 4018, from the marine horizon at the base of the Poole Sandstone in the St George Range, 16 miles at 120° from Mount Tuckfield. The other specimen is from the same locality.

Discussion: *Schizodus* sp. can be readily distinguished from *S. fitzroyensis* by its subquadrate shape. It appears to differ from *S. sandimanensis* in being less tumid and having a less well developed carina.

Superfamily ASTARTACEA

Family CRASSATELLIDAE

Genus ORIOCRASSATELLA Etheridge Jnr 1907 (p. 8)

Type Species (by monotypy): *Oriocrassatella stokesi* Etheridge (1907a, p. 9, pl. 6, figs. 2-5).

Synonym: *Procrassatella* Yakovlev (1928, p. 114).

Discussion: Newell (1958) has shown that *Procrassatella* should be regarded as a synonym of *Oriocrassatella.* Etheridge in his original description figured two specimens of *Oriocrassatella stokesi.* The better of these specimens (Etheridge, 1907a, pl. 6, figs. 2, 3) cannot be found, but the Australian Museum, Sydney, has a plaster cast. Photographs of this have been kindly forwarded by Mr H. O. Fletcher of the Australian Museum and the hinge is shown in Plate 18. Etheridge's other figured specimen, shown in his plate 6, figures 4 and 5, is also refigured, as well as additional specimens from Treachery Bay, the type locality. These latter specimens were collected by Dr G. A. Thomas of the Department of Geology, University of Melbourne. In addition the hinge is figured of a right valve (UWA Type No. 45421) of *Oriocrassatella stokesi* from north-west of Mount Marmion, Fitzroy Basin, Western Australia—from the same locality as the left valve figured by Newell (1958). Together these specimens illustrate the characters of the type species of *Oriocrassatella* and confirm Newell's conclusion. A poorly differentiated anterior cardinal (3a) and an anterior lateral may be present in the right valve.

ORIOCRASSATELLA sp.

(Pl. 18, figs. 1-5)

Although eight specimens of *Oriocrassatella* sp. are available they are not satisfactory for specific differentiation. The more distinct posterior carina and subquadrate shape of the shell distinguish at least some of the specimens from the younger *Oriocrassatella stokesi* and suggest that a different species may be represented. The concentric growth-ridges may also be more distinct than those of *Oriocrassatella stokesi*. Incomplete impressions of the hinges of a right and left valve confirm only the presence of *Oriocrassatella*.

Dimensions (in mm.):

	Length	*Height*	*Width*
Figured Specimen A	38 (estimated)	28	5·5
Figured Specimen B	24	15	3
Figured Specimen C	21	15	3
Figured Specimen D	47	33	5 (estimated)

Occurrence: Figured Specimen A, CPC 3955, Figured Specimen B, CPC 3956, Figured Specimen C, CPC 3957, all from 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near the base of the Poole Sandstone; Figured Specimen D, CPC 3958 (Field No. WB 213), Daurie Creek, 1 mile south-east of Monument Bore, Lat. 25°35′S., Long. 115°57′E., Callytharra Formation.
Other Specimens: Basal part of the High Cliff Sandstone at the old Glendevon Homestead on Woolaga Creek, and from the Nura Nura Member near Paradise Homestead.

Family ASTARTIDAE d'Orbigny

Genus ASTARTELLA Hall 1858

Type Species (by monotypy—*fide* Nicol, 1955): *Astartella vera* Hall (1858, p. 715, pl. 29, figs. 1a-e).

Discussion: Nicol's (1955) analysis indicates the close relationship of *Astartella* to *Astarte* and justifies the conclusion that *Astartella* should be placed in the family Astartidae.

Astartella obliqua sp. nov. has the denticulate ventral margin, the escutcheon, probably the lunule, and the dentition found in *Astartella*. It lacks, however, the distinct lamellate external ornament so characteristic of many species of this genus.

ASTARTELLA OBLIQUA sp. nov.

(Pl. 16, figs. 2-9; Text-fig. 13)

Diagnosis: Shell distinctly inequilateral, produced anteriorly and ventrally; external surface lacking strong lamellae.

Description: The holotype is an internal and external impression of a right valve. The anterior cardinal tooth, i.e., 1, following the notation of Nicol (1955), is well developed and robust. The posterior (3b) is poorly developed or absent. At the front the hinge has a groove, for the reception of a left lateral tooth. Posteriorly a well developed escutcheon is visible and anteriorly, apparently, a lunule. The adductor muscles are oval and situated immediately under the anterior and posterior ends of the cardinal margin—the anterior muscle is the more clearly marked and its posterior margin is especially well delineated. The whole shell is rather tumid. The external surface is ornamented with concentric growth-lines which are distinctly marked at irregular intervals.

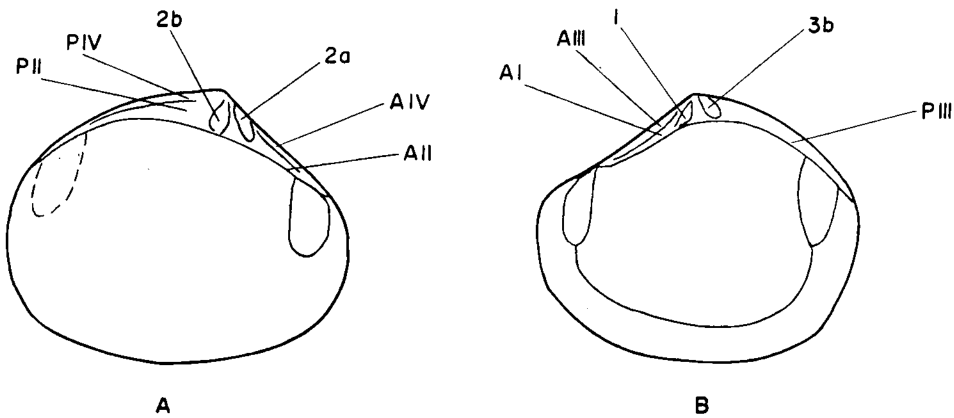


Fig. 13. Astartella obliqua. Diagrammatic restoration of hinge and musculature. A.—Left valve based on Paratypes A and B. B.—Right valve based on Holotype.

The dentition of the left valve is shown in Paratypes A and B. The hinge has a posterior groove forming two posterior lateral teeth, seemingly two cardinal teeth (2a and 2b) and two anterior lateral teeth. The notation shown in the accompanying text-figure follows that of Nicol (1955). The conventional notation, however, does not seem to be very suitable for these forms.

Dimensions (in mm.):

	Length	*Height*	*Width*
Holotype	12·5	12	2·5
Paratype A	13	12	3
Paratype B	5·5	5	1·5 (estimated)
Paratype C	6	5·5	1·5

Occurrence: Holotype, UWA Type No. 45419 (Reg. No. 33384), 2.2 miles south of Mount Sandiman Woolshed, Carnarvon Basin, Callytharra Formation; Paratype A, CPC 3959 (Field No. PB 7), Caryngina Gully about ½ mile on a bearing of 334° from Caryngina (No. 1) Well, Fossil Cliff Formation; Paratype B, CPC 3960, and Paratype C, CPC 3961, both from the southern part of the St George Range, 16 miles on a bearing of 120° from Mount Tuckfield, near base of Poole Sandstone.

Other Specimens: Nura Nura Member near Paradise Homestead (Field No. $KNuA_1$); Paratype A and B localities; Callytharra Formation (about 6 miles south-south-east of Plant Well, Coordewandy Station); and Cuncudgerie Sandstone—more than 10 specimens altogether.

Discussion: *A. obliqua* is especially characterized by the lopsided (inequilateral) appearance of the shell. It does not appear to closely resemble any described species.

Superfamily ?

Family CONOCARDIIDAE Neumayr

Genus CONOCARDIUM Bronn 1835 (p. 92)

Type Species (by monotypy): *Cardium (Conocardium) elongatum* Sowerby (1812, p. 188, pl. 82, fig. 3).

When Bronn proposed the name *Conocardium* he mentioned by name only a single species, *Cardium (Conocardium) elongatum* Sowerby 1812. Nicol (1955, p. 552) states that *Cardium (Conocardium) elongatum* Sowerby is nomenclaturally valid, and if this is correct, it must become the type species. However, Stoliczka (1871, p. XVIII) gives *Conocardium aliforme* as the typical species, Woodward (1880, p. 455) gives *C. hibernicum* Sowerby and *C. aliforme* in that order as types, Fischer (1887, p. 1036) gives *C. hibernicum* as an example of the genus, and Shimer & Shrock (1944, p. 387) give *C. hibernicum* as the type species. La Rocque (1950, p. 318) states that *C. hibernicum* is the genotype by subsequent designation.

CONOCARDIUM sp.

(Pl. 16, fig. 1)

Conocardium has been recorded from the Permian of Western Australia by Etheridge (1907b, p. 33), Glauert (1910, p. 91), and Teichert (1941, p. 377; 1951, p. 82), but it has not yet been figured.

In the present collections the genus is represented by a single incomplete specimen from the Fossil Cliff Formation. No worthwhile comparison with described species seems possible.

Description: The internal impression of the rostral and central part alone is preserved. The ventral margin of the rostrum has at least eight crenulations corresponding to the radial ribs. The central part of the shell is raised and separated on either side by a well marked groove: it has at least four ribs running from near the umbo to the ventral margin.

Dimensions (in mm.):

	Length	*Height*	*Thickness*
Figured Specimen	—	13	8

Occurrence: Figured Specimen, UWA Type No. 45420 (Reg. No. 32639), Becketts Gully, Fossil Cliff Formation, Irwin River area.

Class GASTROPODA

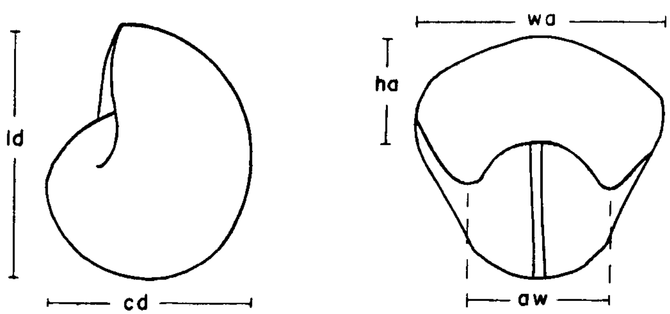
Superfamily BELLEROPHONTACEA

Knight, Batten, & Yochelson (1960), have recognized, within the superfamily Bellerophontacea, the families Cyrtolitidae, Sinuitidae, and Bellerophontidae. They placed the subfamily Euphemitinae in the family Sinuitidae because, like the other members of the family, it lacked a slit or, at the most, had a poorly developed slit. In Yochelson (1960) and in the present paper it is shown that the Euphemitinae have a definite, though short, slit, which is apparently more distinct than was believed by Knight, Batten, & Yochelson. Nevertheless I propose to retain the Euphemitinae as a subfamily within the Sinuitidae rather than to regard it as a separate family or to refer it as a subfamily to the Bellerophontidae.

Tasch (1953, p. 397) proposed amending the family Bellerophontidae to include forms with and without a slit and slit-band in order to include *Warthia* and *Mogulia*. However, Knight (1941, p. 200) showed that *Mogulia* has a slit and slit-band and *Warthia* is also now known to have these characters (Yochelson, 1960, and in the present paper). Therefore Tasch's emendation is not necessary.

Knight, Batten, & Yochelson have proposed recognizing the subfamilies Bellerophontinae and Knightitinae within the Bellerophontidae. The differences between these forms do not appear, however, to be very great, and a subfamily separation seems an unnecessary complication.

Dimensions tabulated are shown in Figure 14. These are based on those used by Netschajew and Licharew (1956).



ld = lengthwise diameter
cd = cross diameter
wa = width of aperture
ha = height of aperture
aw = axial width

Fig. 14. Dimensions of the Bellerophontacea.

Family SINUITIDAE Dall 1913

Subfamily EUPHEMITINAE Knight 1956

Genus EUPHEMITES Warthin 1930 (p. 44)

Type Species (by subsequent designation of Waagen, 1880, p. 131): *Bellerophon urii* Fleming (1828, p. 338).

Euphemus McCoy (1844, p. 25), for which Waagen designated the type species, is a homonym of *Euphemus* Laporte-Castelnau 1836. Warthin (1930, p. 44) proposed the name *Euphemites* to replace *Euphemus* McCoy 1844 (see Knight, 1941, p. 122, 123).

Discussion: Weller (1930) and Moore (1941) have explained the absence or poor development in *Euphemites* of the usual external ornament of the Bellerophontacea and the development of distinct spiral ribbing. The ornament is covered by a thin, smooth perinductura, and the spiral ornament is developed in the inductura (and the coinductura). The explanation of the apparent lack of the usual external ornament of the Bellerophontacea allows both *Euphemites* and *Warthia* to be related to the other Bellerophontacea.

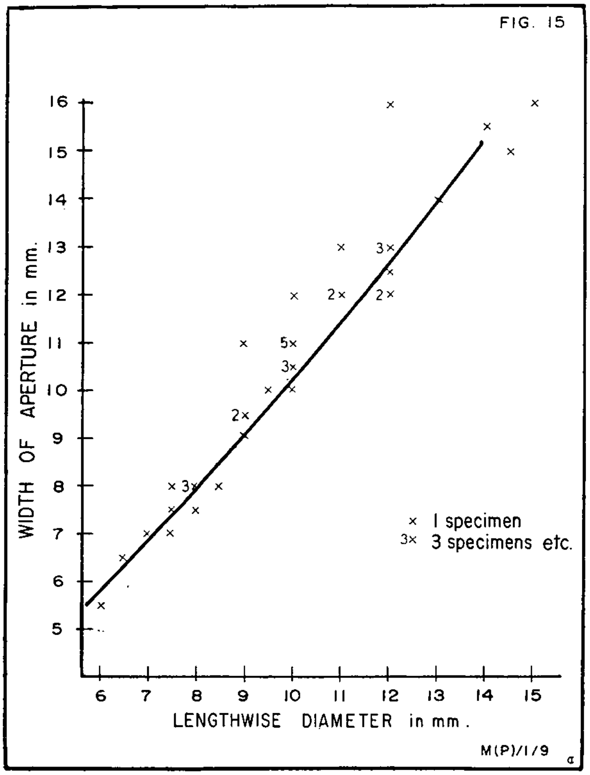
EUPHEMITES WYNNENSIS sp. nov.

(Pl. 21, figs. 1-9; Text-fig. 15)

Diagnosis: A rather inflated species of *Euphemites;* outer whorl surface evenly rounded; spiral lirae not particularly prominent.

Description: The holotype is a limonitic internal impression. The shell is highly involute and very inflated. The umbilicus is narrow and probably the shell was non-umbilicate externally. The shell, including the perinductura, inductura, and coinductura, is of moderate thickness. Laterally, during growth, the whorls expand moderately, although more than is common in *Warthia.* At the aperture, the whorl is restricted.

Paratype A is slightly crushed. It shows that the outer lip has only a shallow obscure sinus culminating at the slit. After passing over the umbilical shoulder the lip swings slightly forward and then slightly back to form a wide, broad sinus. In Paratype D, the spiral lirae are sharp, of about equal prominence, and evenly spaced. As the shell enlarges three of the lirae end abruptly and the number decreases from 15 to 12. Paratype E has 14 spiral lirae, the number of which does not change in the part of the shell visible.



Measurements of 37 specimens recorded in Text-figure 15 show a slight increase in width (as indicated by the width of the aperture) relative to lengthwise diameter during growth.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Width of Aperture*	*Height of Aperture*	*Axial Width*
Holotype	12	10	16	4 (estimated)	11
Paratype A	17	12	18	6 (estimated)	14
Paratype B	10	8·5	11	3·5	8
Paratype C	7·5	6·5	7	3	5·5

Occurrence: Holotype, CPC 3986, Paratype A, CPC 3987, Paratype B, CPC 3988, Paratype C, CPC 3989, Paratype D, CPC 3990, all from 1.6 miles south-west of Paradise Homestead, Fitzroy Basin (Lat. 18°02′30″S., Long. 124°31′00″E.), Nura Nura Member; Paratype E, CPC 3991, also from the Nura Nura Member, apparently at the same locality. The species is represented by 137 specimens, all from the Nura Nura Member.

Discussion: In proportions and ornamentation *E. wynnensis* appears to be rather close to the species described as *E. carbonarius* (Cox) var. by Netschajew & Licharew (1956, p. 38, pl. 13, figs. 1-10) from the Upper Carboniferous of Ferghana, and to the species described as *Euphemus* cf. *carbonarius* Cox by

Reed (1944, p. 351, pl. 69, figs. 6, 6a-b, 7) from the Middle and Upper Productus Limestone of the Salt Range. This relationship appears to be rather contradictory; perhaps *Euphemites* of this type are long ranging.

The species is named after Mount Wynne, close to the locality where the type specimens were collected.

Genus WARTHIA Waagen 1880 (p. 131)

Type Species (by subsequent designation of de Koninck, 1882, p. 81): *Warthia brevisinuata* Waagen (1880, p. 161, pl. 15, figs. 6a-g).

Discussion: Moore (1941, p. 147) emphasized that the outline of *Warthia* closely corresponded to that of *Euphemites* and that *Warthia,* like *Euphemites,* had a thin, smooth external layer (perinductura) which covers the usual ornament developed in the Bellerophontacea. *Warthia,* however, is even closer to *Euphemites* than Moore supposed, because, although he considered that it lacked a slit and slit-band, Yochelson (1960) and the present work have shown these features to be present. Two excellently preserved specimens are figured in Plate 22, figures 9-12: one shows the slit and the slit-band. Lunulae are visible on the slit-band, but growth-lines are not visible over the surface of the shell. As the distance of the slit-band from the aperture increases, the slit-band is gradually obscured and finally completely covered by the inductura. In the other specimen the slit-band shows up through a thin inductural layer.

The slit and slit-band completely link *Warthia* with the rest of the Bellerophontacea, especially with *Euphemites.*

Although the type species, *W. brevisinuata,* is considerably more inflated than any of the Australian species and the type specimens are rather poorly preserved, the Australian species apparently do belong to *Warthia.*

WARTHIA INTERMEDIA sp. nov.

(Pl. 21, figs. 10-19)

Diagnosis: Inflation moderate; outer whorl cross-section rounded and with a very slight keel.

Description: The material available is made up of limonitic internal impressions. The shell is highly involute and, although a small umbilicus is shown in the internal impressions, probably externally the shell was non-umbilicate. The outer whorl cross-section is very rounded except for the very slight keel developed at the periphery. The inductura must have been very thin. Shallow restrictions and ridges mark the growth of the shell and show a wide sinus and a poorly developed slit.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Width of Aperture*	*Height of Aperture*	*Axial Width**
Holotype	12	10	8	3·5	7
Paratype A	10	8·5	6	3	5
Paratype B	9	7	5·5	2·5	5
Paratype C	5·5	4·5	3·5	2	3

* Because of the small expansion of the whorls with growth, this is not a very satisfactory measurement.

Occurrence: Holotype, CPC 3979, Paratype A, CPC 3980, Paratype B, CPC 3981, and Paratype C, CPC 3982, all from 1.6 miles south-west of Paradise Homestead (Field No. $KNuA_1$), Fitzroy Basin (Lat. 18°02′30″S., Long. 124°31′00″E.), Nura Nura Member. The species is represented by more than 20 specimens from the Nura Nura Member. A specimen, CPC 3983, from SG 120A, from 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, marine horizon at base of Poole Sandstone, is doubtfully referred to *W. intermedia.*

Discussion: Among the described species *W. intermedia* is of intermediate lateral inflation (or obesity): it is less inflated than *W. brevisinuata* Waagen, but more than *W. micromphala* (Morris) (1845, p. 288, pl. 18, fig. 7).

Because of the absence of external ornament, specific differentiation in *Warthia* is difficult and is dependent mainly on differences in dimensions. In overall dimensions *W. intermedia* is very similar to *W. perspecta* Fletcher (1958, p. 149, pl. 15, figs. 3-10) from New South Wales, which is widespread in the upper part of the 'Lower Marine' beds (Ravensfield Sandstone) and the 'Upper Marine' beds (Gerringong Volcanics, Capertee and Maitland Groups). *W. perspecta* differs, however, in lacking the very slight peripheral carina.

WARTHIA? CARINATA sp. nov.

(Pl. 22, figs. 1-8)

Diagnosis: Inflation moderate; distinguished by keeled shell with slit-band forming a flat area at periphery.

Description: The material is composed entirely of limonitic internal impressions. The shell is involute and expands only slowly, as is typical in *Warthia.* Although the specimens have small umbilici, almost certainly they were non-umbilicate externally. The growth is marked by low but distinct ridges, which show a wide sinus with a distinct slit at its culmination. A flat area at the periphery, running back from the end of the slit, marks the slit-band. In cross-section the shell is distinctly carinate.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Width of Aperture*	*Height of Aperture*	*Axial Width*
Holotype	6	5	4	2	2·5
Paratype A	10	8	6	3	4·5
Paratype B	7	6·5	5	2·5	3·5
Paratype C	6	4·5	3·5	2	2·5

Occurrence: Holotype, UWA Type No. 45432, Paratype A, UWA Type No. 45433, Paratype B, UWA Type No. 45434, and Paratype C, UWA Type No. 45435, all from Mount Wynne from beds overlying the limestones of the Nura Nura Member, 1.3 miles east of Nura Nura Ridge (Field No. A 108); Nura Nura Member.

Five specimens from type locality and 10 from 1.6 miles south-west of Paradise Homestead (Field No. $KNuA_1$), Nura Nura Member.

Discussion: *Warthia*? *carinata* is found in the Nura Nura Member of the Poole Sandstone together with *W. intermedia*; and whether or not these shells represent crushed specimens of *W. intermedia* has been considered. Not only do the shells lack signs of crushing, but the slit is more distinctly developed, the slit-band forms a flattish area on the periphery, and the shells expand more rapidly with growth than in *W. intermedia*. These characters indicate that a different species is represented. The carination and the character of the slit-band may indicate that the species should be referred to an unnamed genus, but, for the present, it is referred doubtfully to *Warthia,* to which it is closely related.

Family BELLEROPHONTIDAE McCoy 1851

Genus BELLEROPHON Montfort 1808 (p. 51)

Type Species (by original designation—*fide* Knight, 1941, p. 52): *Bellerophon vasulites* Montfort (1808, p. 50).

Discussion: Knight (1941, p. 52) describes the confusion surrounding the characters of the type species. He designates a neotype, which he describes and figures.

BELLEROPHON FORMANI sp. nov.

(Pl. 19, figs. 14-22)

Diagnosis: Non-umbilicate at adult stage; height about equal to width; slit-band rather narrow; concentric growth ornament of fine lines.

Description: The holotype, an internal impression, shows the dimensions and the shape. The sinus is wide and shallow with a narrow slit at the apex, 6 mm. in length—only a slight ridge is formed at the slit-band.

In other specimens, the slit-band is seen to be narrow and raised slightly above the rest of the shell; the lunulae and the growth-lines are well marked. Low ridges are developed at intervals, parallel to the growth-lines. Mature specimens have no umbilicus. Considerable variation is shown in the dimensions, especially in the ratio of the width of the aperture to the lengthwise diameter. This ratio apparently does not vary significantly with size in the material available.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Width of Aperture*	*Axial Width*
Holotype	30	22	31	19
Paratype A	24	16 (estimated)	25	16
Paratype B	20	—	21	15
Paratype C	14 (estimated)	10	16	10
Paratype D	11	—	14 (estimated)	10
Paratype E	12	—	14 (estimated)	10

Occurrence: Holotype, CPC 3966 (Field No. KPA 55), Paratype A, CPC 3967 (Field No. KPA 55), Paratype B, CPC 3968 (Field No. KPA 54), Paratype C, CPC 3969 (Field No. SG 120A), Paratype D, CPC 3970 (Field No. KPA 54), and Paratype E, CPC 3971 (Field No. KPA 54), all from 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near base of Poole Sandstone. The species is represented by more than 50 specimens from the type locality.

Discussion: Most of the specimens are preserved as internal or external impressions, which are not altogether satisfactory for the study of planospiral gastropods.

Bellerophon formani, although it is similar to many described Upper Palaeozoic species, does not appear to be identifiable with any of them.

It is named as a tribute to Mr F. G. Forman, consulting geologist, previously of the Geological Survey of Western Australia.

BELLEROPHON cf. FORMANI

(Pl. 19, figs. 5-13)

Specimens from the base of the High Cliff Sandstone at Woolaga Creek and from the Fossil Cliff Formation are referred with reservation to *Bellerophon formani*. The specimens from Woolaga Creek may belong to *B. formani,* but as they are few and only moderately well preserved this is not certain. The specimens from the Fossil Cliff Formation are all small and seem to be similar to small specimens of *B. formani*. The specimens from the Fossil Cliff Formation are described and the dimensions of the specimens both from the Fossil Cliff Formation and from Woolaga Creek are tabulated.

Description of Specimens from Fossil Cliff Formation: The shell is non-umbilicate, with the slit-band raised very slightly above the surface of the rest of the shell, and is covered by fine lunulae. The external surface is ornamented with a large number of very fine growth-lines parallel to the outer lip. These are more prominently developed at irregular intervals to form low ribs. The sinus is wide, with a narrow rather short slit at its apex.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Width of Aperture*	*Height of Aperture*	*Axial Width*
From Woolaga Creek (High Cliff Sandstone)					
Figured Specimen A ...	32	—	36	—	25
Figured Specimen B ... (an internal impression)	35	27	38	18	26
From Fossil Cliff Formation (Irwin River)					
Figured Specimen C ...	21	16	22 (estimated)	10	15
Figured Specimen D ...	14	11	13	7	10
Figured Specimen E ...	11	9	11	5	8

Occurrence: Figured Specimen A, UWA Type No. 45422 (Reg. No. 31534), Figured Specimen B, UWA Type No. 45423 (Reg. No. 31535), both from High Cliff Sandstone at the Old Glendevon Homestead on Woolaga Creek, Irwin River area. Figured Specimen C, UWA Type No. 45424, Figured Specimen D, UWA Type No. 45425, and Figured Specimen E, UWA Type No. 45426, all three Reg. No. 23397 and from the Fossil Cliff Formation at Fossil Cliff.

The material is made up of two specimens from Woolaga Creek, many from Fossil Cliff, and some from the Fossil Cliff Formation in Becketts Gully.

Discussion: Etheridge (1907b, p. 35, pl. 7, figs. 11-15) described specimens from the Fossil Cliff Formation of Irwin River as *Bellerophon costatus* Sowerby (1834, p. 110, pl. 470, fig. 4). The specimens in Etheridge's figures 11, 12, 13, 15, and possibly 14 appear to belong to the same species as those described above from the Fossil Cliff Formation. Through the courtesy of the British Museum (Natural History), London, I have been able to examine three specimens collected by Foord (1890, p. 154) from the Fossil Cliff Formation, and referred to by Etheridge (1907b, p. 36). Of these one (P.G. 3543) shows external ornament and is referable to the species described above. The second (P.G. 3542) is a decorticated specimen which may be a *Stachella.* The third (P.G. 7424) appears to be a *Bellerophon,* but is not identifiable with certainty.

BELLEROPHON sp. nov.

(Pl. 19, figs. 1-4)

Description: The ratio of lengthwise diameter to axial width is high—the width of the aperture is not shown in any of the specimens. The species is distinguished by the carinate outer whorl surface which forms a distinct arched keel. Although Figured Specimen A is slightly crushed, the other specimens confirm that the keel is an original feature. Probably adult specimens had no umbilicus. The ornament is composed of concentric growth-lines.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Height of Aperture*	*Axial Width*
Figured Specimen A	25	19	10	14
Figured Specimen B	20	14	9	12

Occurrence: Figured Specimen A and B, UWA Type Nos. 45427 and 45428 (Reg. No. 23397), Fossil Cliff, Fossil Cliff Formation.
Other Specimens: Reg. No. 23399, also from the Fossil Cliff Formation at Fossil Cliff. Five specimens altogether.

Discussion: Although the material available is not satisfactory for a specific description, the keel readily distinguishes this species from other *Bellerophon* with which it occurs.

Genus RETISPIRA Knight 1945 (p. 335)

Type Species (by original designation): *Retispira bellireticulata* Knight (1945, p. 335, pl. 49, figs. 1a-c).

Discussion: Knight's (1945) evidence shows that the Upper Palaeozoic bellerophontids with both transverse and spiral ornament, which have frequently been referred to *Bucanopsis,* are a distinct group separable 'by its simple, inducturnal inner lip and its lack of the sharp ridge on the floor of the interior of the whorl' (inducturnal is apparently a misprint for inductural). The status of this grouping, however, appears to be less certain. In this paper the grouping is provisionally given generic rank.

A new species, *clarkei*, which is provisionally referred to *Retispira*, probably belongs to a genus so far unrecognized. It has a wide umbilicus, is strongly carinate at the umbilical shoulder and the slit-band, and lacks a flaring aperture. It is represented by only two specimens and no generic name is proposed because it is hoped that additional specimens may be found.

RETISPIRA IRWINENSIS sp. nov.

(Pl. 20, figs. 20-24)

Diagnosis: Shell wide; spiral and transverse ornament fine and closely spaced; spiral lirae more prominent at irregular intervals, the stronger lirae separated by several finer ones. A narrow external umbilicus.

Description: The slit-band of the holotype is rather narrow, and although it is raised above the level of the rest of the shell in some places, in others it is level with it. The slit-band has three spiral lirae, of which the centre one is the most prominent. The slit-band is bounded on either side by a prominent lira; the lunulae are well marked. The transverse ornament is distinct and varies from equally prominent to less prominent than the spiral ornament. The spiral lirae are more or less of two orders. The more prominent lirae are separated by one, two, or three finer lirae. A small external umbilicus is present. The slit is not visible.

Paratype A is slightly larger than the holotype and shows delicate features of the ornament. The slit-band has four spiral lirae. Over the outer whorl surface, the more prominent spiral lirae may be separated by up to five fine lirae. The lirae tend to be broken where the growth-lines cross them. The growth-lines, although distinct, are not as prominent as the spiral lirae.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Width of Aperture*	*Height of Aperture*	*Axial Width*
Holotype	13	12	16 (estimated)	—	11
Paratype A	Too incomplete for measurement				
Paratype B	10·5	10	13	5 (estimated)	9

Occurrence: Holotype and Paratype A, UWA Type Nos. 45429 and 45430 (Reg. No. 23397), Fossil Cliff Formation at Fossil Cliff; Paratype B, UWA Type No. 45431 (Reg. No. 33715), Fossil Cliff Formation in Becketts Gully.

Other Specimens: Six from Fossil Cliff Formation at Fossil Cliff.

Discussion: At present no worthwhile comparisons with other described species seem possible.

'RETISPIRA' CLARKEI sp. nov.

(Pl. 20, figs. 14-19)

Diagnosis: Shell flaring only slightly towards aperture; 'slit-band' without distinct bounding lirae and with many spiral lirae. Spiral lirae on surface of whorl closely spaced, of differing prominence and with nodes along their length formed by intersection of less prominent transverse growth ornament.

Description: The holotype is represented by the internal impression and part of the external impression, which show the shape of the shell and the external ornament. The umbilicus is wide and deep and is terminated by a distinct carina at the umbilical shoulder. This carina is separated by a sulcus from another carina at the periphery. The 'slit-band' forms a flattened top to the carina. The external ornament is indicated in the diagnosis.

The paratype is a larger, external impression and shows additional features of the umbilicus and the external ornament. The 'slit-band' has no distinctive bounding lirae but an apparent discontinuity of the growth-lines suggests the presence of at least a shallow slit. The 'slit-band' has at least seven spiral lirae. Parts of the earlier whorls can be seen within the umbilicus.

Dimensions (in mm.):

	Lengthwise Diameter	*Width of Aperture*	*Axial Width*
Holotype	8	6	4·5

Occurrence: Holotype and Paratype, CPC 3977 and 3978 (Field No. IR 20) Caryngínia Gully, about ½ mile on a bearing of 334° from Caryngínia (No. 1) Well, Fossil Cliff Formation.

Discussion: This species is represented by only two specimens, but because of its distinctive features, I have no hesitation in assigning to it a new specific name. It is less involute than is general in the Bellerophontidae, and in this respect it is similar to species belonging to genera placed in the Sinuitidae. Its ornament, however, is similar to that of *'Retispira'*.

This species is named after the late Professor E. de C. Clarke, as an acknowledgement of the contribution he made to the geology of Western Australia.

Genus STACHELLA Waagen 1880 (p. 132)

Type Species (by subsequent designation of de Koninck, 1883, p. 123): *Bellerophon pseudohelix* Stache (1877, p. 309, pl. 7, figs. 7a-d).

Discussion: Asymmetrical bellerophontids are rather rare. Tasch (1953, p. 397) describes asymmetrical bellerophontids from the Pennsylvanian 'Dry Shale' of Kansas, U.S.A. For these he proposed the new name *Euphemitella,* with the new species *Euphemitella emrichi* Tasch (1953, p. 398, pl. 49, figs. 8; 9) as type. Although his single figured specimen is similar in shape to species of *Stachella,* according to Tasch, no slit or slit-band is present. Like the Western Australian species referred to *Stachella, Euphemitella* has spiral ornament. In the Treatise, Knight, Batten, & Yochelson (1960, p. 184) regard *Euphemitella* as an unrecognizable genus or genera.

The characters of the Permian asymmetrical bellerophontids are poorly known and so far only a few species, all referable to *Stachella*, have been recorded. They are neither plentiful nor widespread and are known only from the Tethyan region—Southern Europe (Austria and Italy), India, and now Western Australia. The discovery of *Stachella* in Western Australia, therefore, extends the geographical range. The associated fauna, however, during Artinskian time (as distinct from the fauna in the Lyons Group of definite Sakmarian age) is closely related to that of the Tethyan province, and the fauna can be regarded as occupying an extension of this province. All the previous occurrences appear to be of Upper Permian age, but in Western Australia *Stachella* is first found in the late Sakmarian to early Artinskian rocks and persists into younger beds.

When proposing the name *Stachella,* Waagen (1880, p. 172) discussed the possibility that the asymmetry was caused by injury or aberrance. The present material fully confirms Waagen's conclusion that it was not. The shape and ornament indicate that the specimens described below belong to a single taxonomic group which is not referable to any other species with which they are associated. As indicated by Waagen, either side may be the more convex. A distinct bellerophontid-type slit and slit-band are formed at the apex of the sinus in the outer lip.

In previously described species only fine transverse ornament has been recorded, but the Western Australian species, now referred to the genus, has fine spiral ornament with the threads of similar prominence. The spiral ornament may not have previously been recorded in this genus because of poor preservation.

The shape, the character of the slit-band, and the ornament suggest that *Stachella* is most closely related to *Retispira* Knight, 1945.

STACHELLA CRUCILIRATA sp. nov.

(Pl. 20, figs. 1-13)

Diagnosis: Shells of moderate size, not particularly asymmetrical; spiral lirae all of similar size, closely spaced and fine.

Description: The holotype is an external and internal impression of the same specimen. In outline the right side makes a lesser angle with the plane of the slit-band than does the left (with the aperture at the top and facing away from the observer). The umbilicus is narrow on both sides. The shell is angular at the slit-band, the apex of which forms a slight keel; it is more asymmetrical at the mature stages of growth. The outer lip is evenly rounded except at the sinus, at the distal end of which a short parallel-sided slit about 2 mm. long is formed. The lunulae are closely spaced and distinct—no spiral ornament is visible on the slit-band. Both the transverse growth-lines and the spiral lirae are very fine, closely spaced, and of similar prominence. Paratype A is similar to the holotype, but the asymmetry is developed on the other side of the shell. The number of spiral lirae apparently increases by subdivision at irregular intervals.

In an examination of 81 specimens from a single locality in the Nura Nura Member, 35 specimens had the angle between the outer whorl surface and the plane of the slit-band smaller on the left side and 26 on the right. In 20 specimens it was indefinite—either the whorl surface was at about the same angle and the asymmetry was expressed only in the lateral extension of the whorl or the specimens were too poorly preserved to allow comparison of the angles.

Dimensions (in mm.):

	Lengthwise Diameter	*Cross Diameter*	*Width of Aperture*	*Height of Aperture*	*Axial Width*
Holotype (internal impression)	18	—	14	—	—
Paratype A (internal impression)	12·5	—	11	—	—
Paratype B	19	12 (estimated)	16	11	5·5
Paratype C	14	9·5	12	6	4
Paratype D	11·5	8	10·5	5·5	4

Occurrence: Holotype and Paratype A, CPC 3972 and 3973 (Field No. PB 9), Pintharuka 1-mile Sheet, map co-ordinates 511056, Becketts Gully, 0.4 miles above road crossing, Fossil Cliff Formation; Paratypes B, C, and D, CPC 3974, 3975, and 3976 (Field No. $KNuA_1$), 1.6 miles south-west of Paradise Homestead, Fitzroy Basin (Lat. 18°02′30″S., Long. 124°31′00″E.), Nura Nura Member.

Other Specimens: From holotype and paratype localities and from the Fossil Cliff Formation at Fossil Cliff (UWA Reg. No. 23397) and at Caryngina Gully, about ½ mile on a bearing of 334° from Caryngina (No. 1) Well, Irwin River area—a total of more than 100 specimens.

Discussion: *Stachella crucilirata* does not appear to be closely related to any of the described species; it does not closely resemble the type species, *S. pseudohelix* (Stache) 1877, figured by Knight (1941, pl. 12, figs. 2a-d), nor the two species described by Waagen (1880) from the Productus Limestone of the Salt Range.

Superfamily PLEUROTOMARIACEA Swainson 1840

Family PLEUROTOMARIIDAE Swainson 1840

Discussion: Permian pleurotomarians show considerable variation in shell characters, which makes the choice of taxonomic groups unusually difficult. Batten (1958) has suggested this 'may be related to adaptive response to great environmental changes characteristic of the Permian'. This, however, can only be part of the explanation, because the pleurotomarians of the Carboniferous and possibly other periods show similar variability, which is not shared by the pelecypods and the other groups of gastropods.

Because of this variability a rather broad grouping and subdivision may prove more satisfactory than a too detailed subdivision based on variable and perhaps unimportant differences. The taxonomist is faced with the position that in any very detailed subdivision, despite the large number of categories he will require, many intermediate forms will remain. It is already apparent that some characters that have been used are of little value; for example the height is of value for generic separation only within wide limits, and changes in whorl cross-section, unless of a fundamental character, can only be used with considerable caution.

Although, in the Treatise, Knight, Batten, & Yochelson (1960) place most of the genera described below in the family Eotomariidae, they do not seem to differ so greatly in their shell characters from *Pleurotomaria* that they should be placed in a different family. They do not seem, in any case, to be especially closely related to *Eotomaria. Baylea*, on the other hand, is separated and placed in the family Raphistomatidae for reasons that are not apparent. Therefore in the present paper a wider understanding is preferred of the family Pleurotomariidae and to it are referred the species described.

The following generic names are used: *Baylea* de Koninck 1883, *Mourlonia* de Koninck 1883, *Ptychomphalina* Fischer 1885, and *Peruvispira* Chronic 1949. Within *Mourlonia* four subgenera are recognized: *Mourlonia, Platyteichum* Campbell 1953, *Pseudobaylea* nov., and *Woolnoughia* nov. This scheme is based on the assumption that *Mourlonia* can be distinguished from *Ptychomphalina*. This problem has been discussed in Dickins (1957, p. 47, and 1961c)—it appears from Knight's (1941) description and figures that two species and genera are included under *Mourlonia carinata* (J. Sowerby) and *Ptychomphalina striata* (J. Sowerby), the type species of the two genera concerned. It is not clear, however, that the holotypes are different and their re-examination is required for a solution of this problem. Other genera apparently closely related to *Mourlonia* are *Mourlonopsis* Fletcher 1958 and possibly *Gosseletina* Fischer 1885 and *Eirlysia* Batten 1958. *Walnichollsia* Fletcher 1958 may also fall within the limits of *Mourlonia* in a wide sense.

One species which is referred doubtfully to *Mourlonia* is not assigned to any of the subgenera.

Genus MOURLONIA de Koninck 1883 (p. 10)

Type Species (by original designation): *Helix carinatus* J. Sowerby (1812, p. 34).
Diagnosis: Spire of moderate height within rather wide limits; whorl cross-section rather simple—broadly convex and any angulations in the outline are simple. Both transverse and spiral (revolving) ornament of a simple type; spiral lirae generally of more or less equal prominence. Slit-band narrow or of moderate width, margins non-complex—its position varies slightly but is either peripheral or slightly above the periphery. The slit-band may or may not have spiral lirae on it. Umbilicus in mature forms often narrow or absent, but may be of moderate width. Where the later whorls are more complicated, the earlier whorls are simpler and more rounded as in the subgenus *Mourlonia.*
Discussion: In the diagnosis rather wide limits have been given to the height of the spire—it is not as high, however, as is typical for the Murchisoniidae nor as low as commonly found in the Euomphalidae. In uniting these forms I have given importance especially to the simplicity of the ornament and the cross-section. The character of the slit is not known in all of these groups. The slit-band may or may not have spiral lirae and the importance of this is unknown.

Subgenus MOURLONIA de Koninck 1883

Type Species: As for genus.

Diagnosis: Evenly convex cross-section without abrupt changes in direction, upper whorl surface entirely convex; ornament simple; spiral lirae of about equal prominence except those bounding the slit-band which may be more prominent.

MOURLONIA (MOURLONIA) LYNDONENSIS (Dickins) 1957

(Pl. 24, figs. 5-6)

1957. *Mourlonia? lyndonensis* Dickins, p. 46, Plate 8, figures 1-5.

Remarks: A single small specimen from the Carrandibby Formation appears to represent this species. The apical angle,* the ornament and the character of the slit-band are similar, but perhaps the whorl cross-section is a little more globular. The upper whorl surface appears to have seven spiral lirae and the lower surface, only the top part of which is preserved, has eleven.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*
Hypotype	3 (estimated)	5	94°

Occurrence: Hypotype, CPC 4008 (Field No. WB 52), one mile west of Callytharra Springs, Byro Station, Carrandibby Formation, top 15 feet, Carnarvon Basin.

* Where the angle of the spire to the axis of the shell does not change to any extent during growth, measurement of a representative angle is not difficult. The apical angle, the spiral angle (or spire angle), and the pleural angle correspond. Where this angle changes during growth, however, a representative angle becomes difficult to measure. Although in these circumstances the pleural angle can be measured accurately, in itself it is not particularly useful in the comparison of different species. The apical angle is therefore here used in the classical sense, to indicate the general angle, formed by the shell in the apical direction. In this sense it corresponds closely to the spiral angle.

MOURLONIA (MOURLONIA) sp. nov.

(Pl. 23, figs. 18-21)

Description: The shell has five whorls. The sutures are distinctly marked and the spire is of moderate height. The slit-band is of moderate width, well marked, and close to the periphery. Because the suture is below the lower margin of the slit-band and the upper whorl surface is entirely convex, the shell is distinctly stepped. Most of the lower surface of the last whorl is not preserved. The spiral and transverse ornament are about equally well developed—the spiral ornament is of fine, closely, and more or less evenly spaced lirae of equal prominence except for the lirae on either side of the slit-band, which are more distinct than the others. Fourteen lirae are visible on the upper surface of the last whorl. The transverse growth-lines are also fine and evenly spaced; they are better developed close to the suture where nodes are formed at the intersections of the transverse lines with the spiral lirae. The lunulae are well marked.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*
Figured Specimen	7 (estimated)	9 (estimated)	75°

Occurrence: Figured Specimen, CPC 3992 (Field No. WB 266), 30 miles west-north-west of Curbur Homestead, Lat. 26°22′00″S., Long. 115°25′00″E., Callytharra Formation.

Discussion: This species is represented by only a single specimen and no new name is proposed. It does not appear to represent any described species.

Subgenus PLATYTEICHUM Campbell 1953 (p. 23)

Type Species (by original designation): *Platyteichum costatum* Campbell (1953, p. 23, pl. 7, figs. 11-14).

Diagnosis: Similar to *Mourlonia* (*Mourlonia*) but distinguished by having the upper part of the upper whorl surface flat or concave and rising to meet the previous whorl with a tendency to form an even spire. No spiral lirae on the slit-band.

Discussion: I have refigured the holotype of *P. costatum* (Dickins, 1961b) and suggested that it may be a synonym of *Mourlonia*? *coniformis* Etheridge Jnr (1892, p. 287, pl. 41, fig. 5). The early whorls are more rounded and resemble those of *Mourlonia* (*Mourlonia*).

This taxonomic group is not represented in the present material.

Subgenus PSEUDOBAYLEA nov.

Type Species (hereby designated): *Pseudobaylea freneyensis* sp. nov.

Diagnosis: In the mature part of the shell, whorl surface divisible into three parts —upper, outer, and lower: upper surface meets outer at a distinct angle to form an elbow at which is situated a narrow slit-band. Outer surface joins lower surface imperceptibly in a continuous curve. Upper whorl surface is convex throughout, so spire step-like. Ornament of spiral lirae and transverse ornament similar to that of *Mourlonia* (*Mourlonia*). Umbilicus probably narrow or absent.

Discussion: At first it was considered that *Pseudobaylea freneyensis* was closely related to *Baylea*. It differs, however, from the type species of *Baylea*, *B. yvania* (Léveillé) 1835, in lacking a sinus in the outer lip close to the suture and in having a narrow slit-band and the spiral lirae of almost equal prominence. In addition the upper whorl surface is convex throughout. In all these respects, on the other hand, *P. freneyensis* is closely related to the forms I propose placing within *Mourlonia*. A species is described later which is referred without hesitation to *Baylea*. It shows specialization of those features which distinguish the type species of *Baylea*: the slit-band is wide with a number of spiral lirae on it; the upper-whorl surface is flat or concave and has a distinct revolving (spiral) trough on its upper part; the curve between the outer whorl surface and the lower is sharp and the growth-lines show a sinus immediately below the suture. All this evidence shows that *Pseudobaylea* is not a descendant of *Baylea*, but a later off-shoot of the main *Mourlonia*-line.

Pseudobaylea is probably represented in Timor by *Pleurotomaria timorensis* Wanner (1922, p. 20, pl. 151 (1), figs. 9a-b) and by the specimens referred to *Pleurotomaria conglobata* Wanner 1922 by Hamlet (1928, p. 87, pl. 11, figs. 3a-c). It is possibly represented by *Yvania reticulata* Wanner (1942, p. 161, pl. 2, fig. 6), *Yvania* cf. *salomonensis* (Gemellaro), Wanner (1942, p. 162, pl. 2, fig. 7), and the specimens referred to *Yvania conglobata* (Wanner) 1922 by Wanner (1942, p. 159, pl. 2, figs. 2-3). All these species, however, are considerably more specialized than *Pseudobaylea freneyensis*. *Yvania permica* Wanner (1942, p. 160, pl. 2, fig. 4) and *Yvania bitauniensis* Wanner (1942, p. 160, pl. 2, fig. 5) may be referable rather to *Mourlonia* (*Platyteichum*). In India *Pleurotomaria* aff. *conglobata* Wanner, Reed (1932, p. 65, pl. 12, fig. 7), from the Agglomeratic Slate of Kashmir and *Pleurotomaria nuda* Dana, Waagen (1891, p. 120, pl. 4, figs. 4a-c) from the Speckled Sandstone of the Salt Range appear to be referable to *Pseudobaylea*.

MOURLONIA (PSEUDOBAYLEA) FRENEYENSIS sp. nov.
(Pl. 23, figs. 1-11)

Diagnosis: Shell of moderate height, steplike upper whorl surface of mature shell slightly convex and meeting outer whorl surface at an angle at which slit-band is situated. Ornament simple, composed of fine numerous transverse and spiral lirae; spiral lirae, except the two bounding slit-band, of almost equal prominence.

Description: The holotype has five whorls. The cross-sections of the earlier whorls are more rounded and *Mourlonia*-like than the mature whorls, which have an angulation where the upper surface meets the outer surface. A slight shoulder is also developed where the outer surface merges with the lower surface. The whole whorl surface is convex except immediately below the slit-band in the last whorl, where it is slightly concave. The sutures are distinct and situated considerably below the slit-band. The transverse ornament is composed of fine growth-lines which, after leaving the suture, swing backwards in a gentle curve to the slit-band, below which they swing forward slightly and then backward down over the shoulder. At the bottom part of the shoulder they swing forward again and then pass down into the umbilicus, forming a broad sinus over the shoulder. The spiral lirae are of equal prominence, except the two on either side of the slit-band, which are slightly more distinct than the others. Nodes may be formed where the transverse and spiral ornament cross. The slit-band is rather narrow; it is raised slightly above the surface of the rest of the shell. No spiral lirae are visible on the band. The last whorl has five lirae above the slit-band and at least sixteen below it. The umbilicus is of moderate size and possibly the inner part was filled by callus during life. The outlines of the paratypes vary considerably in convexity and the angulation at the slit-band. The overall tendency, however, is for the mature whorls of large specimens to show the subgeneric characters more definitely. In Paratype A the last whorl has a distinct concave trough below the slit-band.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*	*No. of Lirae above Slit-band*	*No. of Lirae below Slit-band*
Holotype	14	11·5	73°	5	about 8
Paratype A	21 (estimated)	18 (estimated)	72°	5	about 8
Paratype B ...... (probably slightly crushed)	16	15	75°	—	—
Paratype C	13	12	80°	—	—
Paratype D	12·5 (estimated)	12	76°	5	—
Paratype E	Accurate measurement not possible.			7	9
Paratype F	11	—	75°	6	about 8
Paratype G	Accurate measurement not possible.			5	8

Occurrence: Holotype and Paratypes A-D, CPC 3999-4003, all from 1.6 miles south-west of Paradise Homestead, Fitzroy Basin (Field No. $KNuA_1$), Lat. 18°02'30"S., Long. 124°31'00"E., Nura Nura Member of Poole Sandstone; Paratype E, CPC 4004 (Field No. SG 120A), 16 miles at 120° from Mount Tuckfield in the southern part of the St George Range, near base of Poole Sandstone, Fitzroy Basin; Paratype F, CPC 4005, and Paratype G, CPC 4006, both from Carynginia Gully about ½ mile on a bearing of 334° from Caryngínia (No. 1) Well (Field No. IR 20), Fossil Cliff Formation.

Other Specimens: Fossil Cliff Formation at Fossil Cliff (UWA Reg. Nos. 23389 and 32630—seven specimens), from the hard limestone in Becketts Gully (UWA Reg. No. 32633—one specimen), from Becketts Gully, 0.4 miles above road crossing, Pintharuka 1-mile Sheet, map co-ordinates 511056 (Field No. PB 9), and from the Paratype F and G locality (Field Nos. PB 7 and IR 20). Additional specimens also from the holotype and Paratype E localities. The specimens from Woolaga Creek identified by me in Playford (1959, p. 19) as *Baylea*? sp. probably belong to this species.

Discussion: *Pseudobaylea freneyensis* is widespread geographically and is plentiful, especially in the Nura Nura Member, which has yielded more than 150 specimens. The relationship with other species is partly covered in the discussion on the subgenus. *P. freneyensis* appears to be most closely related to *Pleurotomaria* aff. *conglobata* Wanner, Reed (1932, p. 65, pl. 12, fig. 7) from the Agglomeratic Slate of Kashmir: it is less closely related to *Pleurotomaria nuda* Dana, Waagen (1891, p. 120, pl. 4, figs. 4a-c) from the Speckled Sandstone of the Salt Range.

Subgenus Woolnoughia nov.

Type Species (hereby designated): *Woolnoughia angulata* sp. nov.

Diagnosis: In mature whorls, cross-section broadly rounded except at periphery, where it is more angular, and near suture, where upper whorl surface is flattish and rises to meet previous whorl; no distinct outer surface. Suture deeply placed and considerably below slit-band so that spire has pagoda-like shape; slit-band rather broad, situated at about periphery, ornamented with spiral lirae. External umbilicus rather wide; ornament similar to that of *Mourlonia* (*Mourlonia*). Whorls of younger part of shell rounded and *Mourlonia*-like.

Discussion: *Woolnoughia* resembles *Platyteichum* in the shape of the whorl cross-section, but differs in having the suture considerably below the slit-band, a broader slit-band, and a distinct umbilicus.

The subgenus is named in honour of the late Dr W. G. Woolnough, who made a notable contribution to Australian geology, not least amongst which was his work on the Permian rocks of the Irwin River area.

MOURLONIA (WOOLNOUGHIA) ANGULATA sp. nov.

(Pl. 23, figs. 12-17)

Diagnosis: Spire rather high. In mature whorls, slit-band raised slightly above surface of rest of shell and marked on either side by a lira more prominent than other spiral lirae; slit-band slightly above periphery on last whorl and with one distinct spiral lira on it and apparently another two faint lirae, one on either side of the main lira.

Description: Only the last five whorls of the holotype are preserved. On the last whorl the upper surface is flattish near the suture and gently convex towards the slit-band. Immediately below the slit-band the surface of the whorl rounds quickly to join the gently convex lower surface, so that the periphery forms a rounded angulation in the outline. The early whorls are more rounded and *Mourlonia*-like, and the suture is situated closer to the slit-band. An external umbilicus is rather wide and probably passes down into a narrow umbilicus between the whorls. The spiral ornament, except the lirae associated with the slit-band, is fine; the lirae are closely spaced and of about equal prominence. The transverse ornament is made up of fine growth-lines of about equal prominence to the spiral lirae. After leaving the suture the growth-lines swing back to the slit-band, below which they swing slightly forward again, then backward and forward again to form a shallow sinus over the shoulder and then down into the umbilicus. The slit-band is rather broad with lunulae and one distinct lira—another faint lira appears to be present on either side of this. The lira bounding the slit-band on either side is more prominent than the other spiral lirae.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*	*Apical Angle 4th Whorl Stage*	*No. of Spiral Lirae above Slit-band*	*No. of Spiral Lirae below Slit-band*
Holotype	44	32 (estimated)	38°	53°	About 13	More than 16
Paratype A	34	27	42°	53°	—	—
Paratype B ... . (a four-whorled specimen)	20	17	55°	—	—	—

Occurrence: Holotype, UWA Type No. 45436 (Reg. No. 23394), Paratype A, UWA Type No. 45437, Paratype B, UWA Type No. 45438 and Paratype C, UWA Type No. 45439 (paratypes all UWA Reg. No. 23389), all from the Fossil Cliff Formation at Fossil Cliff. A total of eight specimens, all from the Fossil Cliff Formation.

Discussion: *Woolnoughia angulata* is not known to be closely related to any previously described species.

MOURLONIA? OBSCURA sp. nov.

(Pl. 22, figs. 13-21)

Diagnosis: Shell of moderate height, whorls rather well-rounded. External ornament of obscure growth-lines and a large number of fine, closely spaced spiral lirae of about equal prominence. No definite slit-band.

Description: The holotype is composed of four rather evenly rounded whorls. The sutures are distinctly but not deeply marked and situated at about the periphery of the shell. The growth-lines are indistinct and too poorly developed to reconstruct the shape of the outer lip. A slit-band is apparently situated slightly above the periphery and marked on either side by a lira which is hardly more prominent than the other spiral lirae. The 'slit-band' has one spiral lira on it. Above the 'slit-band' the last whorl has about 10 spiral lirae and the upper part of the surface below (only the upper part is preserved) has about 15.

In Paratype A, the shell is slightly higher than in the holotype. An obscure 'slit-band' also appears to be present. Above the 'slit-band' the last whorl has about 12 lirae and on the upper part of the shell below, about 20. Paratype B seems to have a rather wide external umbilicus.

Paratypes D and E are representative of a few specimens which are similar to the Holotype and Paratypes A, B, and C, except for an angulation (carination) at the umbilical shoulder and the flattish base. They are referred doubtfully to *Mourlonia*? *obscura,* but may represent a different species. So few specimens are available, however, that the absence of transitional forms could be accidental. None of the specimens with the basal carination show the external ornament.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*
Holotype	3	6	95° (estimated)
Paratype A	4·5	7 (estimated)	91° (estimated)
Paratype B	6·5	9·5	104°
Paratype C	4	6	97°
Paratype D	4	6·5	104°
Paratype E	5	6·5	95°

Occurrence: Holotype, CPC 3993 (Field No. PB 7), Carynginia Gully about ½ mile on a bearing of 334° from Carynginia (No. 1) Well, Fossil Cliff Formation; Paratype A, CPC 3994 (Field No. PB 9), Becketts Gully, 0.4 miles above road crossing, Pintharuka 1-mile Sheet, map co-ordinates 511056, Fossil Cliff Formation; Paratypes B, C, and D, CPC 3995, 3996, and 3997 (Field No. $KNuA_1$), 1.6 miles south-west of Paradise Homestead, Nura Nura Member (Lat. 18°02′30″S., Long. 124°31′00″E.), and Paratype E, CPC 3998, locality not clear but apparently close to that of Paratypes B, C, and D, Nura Nura Member.

Other Specimens: Same locality as Paratype E (five specimens) and from the Fossil Cliff Formation at Fossil Cliff (one specimen UWA Reg. No. 23389).

Discussion: Until it can be definitely established whether or not a slit-band is present, no satisfactory conclusion on the relationship of this species can be made. It does not appear to resemble any described species closely.

Genus PTYCHOMPHALINA Fischer 1885* (p. 850)

Type Species (by monotypy): *Helix*? *striatus* J. Sowerby (1817, p. 159, pl. 171, fig. 1).

Discussion: The characters and relationship of *Ptychomphalina* have been discussed elsewhere (Dickins, 1957, p. 47, and 1961c). Examination of material since has shown that very faint spiral lines may be present in some specimens. This ornament is illustrated in specimens of *Ptychomphalina maitlandi* Etheridge (1903, p. 24, pl. 1, figs. 13-15) and *Ptychomphalina talboti* sp. nov. shown here in Plate 24.

* Originally attributed by courtesy to Professor E. Bayle

PTYCHOMPHALINA TALBOTI sp. nov.

(Pl. 24, figs. 12-19)

Diagnosis: Spire conical; whorl cross-section very angular at mature stage with slit-band situated at periphery.

Description: The upper surface of the whorl is flattish and meets the lower surface with a distinct angle at the periphery. The slit-band is situated close to this angle. The lower surface is gently convex and at the mature stage, at least, the base completely lacks an umbilicus. The suture is situated close to the lower margin of the slit-band so that the shell is conical. The columellar lip is thickened by callus in a manner typical of *Ptychomphalina,* and thin callus extends only slightly outside the aperture. The slit-band is of moderate size, raised slightly above the rest of the surface and bordered on either side by a fine lira; the slit-band is ornamented only with lunulae. The transverse growth-lines are especially well developed on the upper whorl surface and on the younger whorls, which are more rounded than those of the mature part of the shell. A slight revolving (spiral) trough may be present immediately below the slit-band. The growth-lines after leaving the suture swing backward in a curve to the slit-band, immediately below which they swing very slightly forward over the trough and gently backwards down over the base.

Details of the structure of the shell layers are shown by Paratype A. The outer surface is slightly weathered and, except for the slit-band, is made up of spirally arranged interlocking lamellae. The slit-band is formed of lamellae parallel to the lunulae. The inner surface is made of interlocking lamellae arranged transversely to the whorls.

On the base of Paratype C very fine spiral lines are visible.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*
Holotype ...	...... 18 (estimated)	16	72°
Paratype B	...... 32 (estimated)	30	68°
Paratype D	 21	19	70°

Occurrence: Holotype, CPC 4007 (Field No. PB 14), Fossil Ridge, Fossil Cliff Formation; Paratype A, UWA Type No. 45440 (Reg. No. 23397) Fossil Cliff, Fossil Cliff Formation; Paratypes B and C, UWA Type Nos. 45441 and 45442 (UWA Reg. No. 23389), Fossil Cliff, Fossil Cliff Formation; and Paratype D, Queensland University Geology Museum No. 27, 126, Fossil Cliff or Fossil Ridge, Fossil Cliff Formation.

Other Specimens: Waltharri Pools (UWA Reg. No. 23401—one specimen); Carynginia Gully about ½ mile on a bearing of 334° from Carynginia (No. 1) Well, Fossil Cliff Formation. More than 15 specimens altogether, all from the Fossil Cliff Formation.

Discussion: *Ptychomphalina talboti* sp. nov. can be readily separated from *P. maitlandi* Etheridge 1903, which is very common in the Byro Group of the Carnarvon Basin and the Noonkanbah Formation of the Fitzroy Basin, by the angularity of the whorl cross-section. In *P. maitlandi,* three specimens of which are figured in Plate 24 for comparison, both the upper and lower whorl surfaces are more gently convex.

P. talboti shows some resemblance to the holotype of *Euconospira spiroperforata* Batten (1958, p. 230, pl. 40, figs. 13, 14) from the Wolfcamp Formation of Sakmarian age of the Southwestern United States. The reasons for Batten's decision to refer this species, which appears to be a *Ptychomphalina,* to *Euconospira* are not clear.

The species is named after H. W. B. Talbot, as an acknowledgement of the pioneer geological work he did in Western Australia, early in the present century.

Genus PERUVISPIRA Chronic 1949 (p. 146)

Type Species (by original designation): *Peruvispira delicata* Chronic (in Newell, Chronic, & Roberts, 1949, p. 147; 1953, p. 139, pl. 28, figs. 9-12).

Synonym: *Pleurocinctosa* Fletcher (1958, p. 139).

Discussion: The characters and relationships of *Peruvispira* have been discussed in Dickins (1961c), where it is suggested that *Peruvispira* is derived from *Ptychomphalina.*

PERUVISPIRA cf. UMARIENSIS (Reed) 1928

(Pl. 24, figs. 7-8)

Remarks: The species is represented by two or possibly three small specimens which are not sufficient to decide whether or not they should be referred to *Peruvispira umariensis* (Reed) (1928, p. 389, pl. 34, fig. 12; pl. 35, figs. 11-13). The specimen figured is similar in the proportions of its shell to that of *P. umariensis,* but differs in having the slit-band slightly wider and the third spiral lira very distinctly marked. In its other characters it is similar to *P. umariensis.*

P. umariensis was first described by Reed from the Umaria beds of Peninsular India and has since been recorded from the Lyons Group in Western Australia (Dickins, 1957, p. 47, pl. 9, figs. 1-5).

Dimensions (in mm.):

		Height	Width	Apical Angle
Figured Specimen	......	7	4	41°

Occurrence: Figured Specimen, CPC 4009 (Field No. PB 7), Carynginia Gully about ½ mile on a bearing of 334° from Carynginia (No. 1) Well, Fossil Cliff Formation.

Other Specimens: One from Carynginia Gully and another possible one from the Fossil Cliff Formation at Holmwood (UWA Reg. No. 23398).

Genus BAYLEA de Koninck 1883 (p. 10)

Type Species (by original designation): *Trochus yvanii* Léveillé 1835.

Synonym: *Yvania* Fischer (1885, p. 851)*—see Knight (1941, p. 51).

Discussion: *Baylea perthensis* sp. nov. seems to show all the characteristic features which distinguish *Baylea* from closely related pleurotomarian forms. It is, however, considerably more specialized than the type species from the Lower Carboniferous. The growth-lines reveal a shallow sinus in the upper whorl surface immediately adjacent to the suture. The upper whorl surface is flat or concave, the slit-band is rather broad and has spiral lirae on it. The whorl surface is divided into three parts by distinct angles in the outline and the upper part of the outer whorl surface has a concave trough.

* Originally attributed by courtesy to Professor E. Bayle.

BAYLEA PERTHENSIS sp. nov.

(Pl. 26, figs. 10-16)

Diagnosis: Upper surface divided into two distinct parts; peripheral part concave. Slit-band relatively broad, forming junction of upper and outer whorl surfaces and ornamented with spiral lirae. Distinct concave area on outer surface, immediately below slit-band.

Description: The mature whorl cross-section of the holotype is quadrate; immediately below the suture, the upper surface is flat or slightly convex for a short distance, then distinctly concave until it reaches the upper boundary of the slit-band. The upper whorl surface has not less than five spiral lirae. The slit-band is flat and bounded on either side by a distinct lira; on it are five finer spiral lirae. Below the slit-band, the outline is concave and then convex over the shoulder of the umbilicus, forming the boundary between the outer and lower surface. A moderately wide external umbilicus is visible which passes up between the whorls. The outer and lower surfaces of the last whorl have more than 36 fine equidistant spiral lirae of one order. The earlier whorls are more rounded, like those found in *Mourlonia* itself. The suture is shallow and situated considerably below the slit-band, close to the base of the outer surface. The growth-lines and, therefore, also the outer lip are complex. After leaving the suture, the growth-lines swing forward and then curve backwards to the slit-band, forming a sinus immediately adjacent to the suture. Below the slit-band, the growth-lines pass down and curve backward and forward again to form a broad sinus, over the umbilical shoulders. Immediately after leaving the slit-band, the growth-lines may curve slightly forward before passing backwards, but this cannot be seen clearly.

The paratypes confirm the characters of the holotype.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*
Holotype	9	8	68° (estimated)
Paratype A	9 (estimated)	8·5	75°
Paratype B	9	9	77°

Occurrence: Holotype, UWA Type No. 45446 (Reg. No. 23398), Paratypes A and B, UWA Type Nos. 45447 and 45448 (Reg. No. 23389), all from the Fossil Cliff Formation at Fossil Cliff.

Other Specimens: Three additional specimens from the Fossil Cliff Formation at Fossil Cliff (UWA Reg. Nos. 23389 and 23397) and one from the hard limestone band in Becketts Gully (UWA Reg. No. 32633). The species is also found in the upper part of the Holmwood Shale at High Cliff (one specimen). I have also seen it in samples from the upper part of Holmwood Shale from the Woolaga Creek area collected by Mr G. Playford.

Discussion: *Baylea perthensis* does not seem to be closely related to any described species.

Superfamily EUOMPHALACEA Koninck 1881

Family EUOMPHALIDAE Koninck 1881

Genus STRAPAROLUS* Montfort 1810 (p. 174)

Type Species (by original designation): *Straparolus dionysii* Montfort (1810, p. 174).

* Originally spelt with a single l—*fide* Knight (1941, p. 337).

Subgenus LEPTOMPHALUS Yochelson 1956 (p. 197)

Type Species (by original designation): *Straparolus* (*Leptomphalus*) *micidus* Yochelson (1956, p. 220, pl. 12, figs. 1-4).

Discussion: Yochelson proposes the name *Leptomphalus* for discoidal euomphalids with 'the whorls smoothly rounded or with a weakly developed angulation on the outer edge of the upper whorl surface'. Members of the subgenus appear to be confined to the Permian. Morphologically this group of forms is not easy to distinguish from *Straparolus* (*Philoxene*) of the Devonian, unless the slightly higher spire of the latter, which Yochelson regards as diagnostic, is of some evolutionary importance. The cementation of foreign matter to the shell of *Philoxene* would seem of little value taxonomically unless it can be tabulated better than at present (see Knight, 1941, p. 242). *Leptomphalus* may be a synonym of *Paromphalus* Grabau (1936, p. 32), but the latter is not definitely recognizable from Grabau's description and figures (see Knight, 1941, p. 235, pl. 73, figs. 3a-d).

As suggested by Yochelson, *Leptomphalus* appears to be descended from the keeled *Euomphalus* rather than directly from *Philoxene*. It is proposed to follow Yochelson and to recognize *Leptomphalus* as a subgenus, referring to it *Straparolus* (*Leptomphalus*) *besselensis*, a new species in which no keel can be observed, and *Straparolus* (*Leptomphalus*) sp. nov., based on a single specimen which has a poorly developed keel on the upper whorl surface and a very low spire.

STRAPAROLUS (LEPTOMPHALUS) BESSELENSIS sp. nov.

(Pl. 24, figs. 1-4)

Diagnosis: Discoidal and completely lacking a spire. Basal umbilicus wide and shallow; sutures distinct and whorl cross-section completely rounded.

Description: The mature shell has at least four whorls. At the top of the shell, the earlier whorls are level or slightly lower than the last whorl so that no spire is developed. The base has a wide shallow external umbilicus. The whorl cross-sections are completely rounded and no carina is visible at either the top or the bottom of the whorl. No spiral ornament is visible, but the transverse ornament is composed of numerous growth-lines which, after leaving the suture, curve slightly backwards and then slightly forward as they near the periphery to form a very shallow sinus, then pass over the outer surface into the umbilicus. The sutures are distinctly marked.

Dimensions (in mm.):

	Height (= *width of last whorl*)	*Width*
Holotype	1·5 (estimated)	8·5
Paratype A	1·5 (estimated)	7
Paratype B	1·5 (estimated)	6

Occurrence: Holotype, CPC 4010, Paratype A, CPC 4011, Paratype B, CPC 4012, and Paratype C, CPC 4013, all from 1.6 miles south-west of Paradise Homestead, Fitzroy Basin (Field No. $KNuA_1$), Lat. 18°02′30″S., Long. 124°31′00″E., Nura Nura Member of Poole Sandstone. More than 30 specimens from Nura Nura Member at the type locality.

Discussion: Although the shells are preserved only as external and internal impressions, the detail of the growth-lines indicates that the roundness of the whorl cross-section and the distinctiveness of the suture is not likely to have been caused by the loss of one or more shell layers.

Straparolus (*Leptomphalus*) *besselensis* does not appear to resemble any described species closely. In degree of involution, distinctiveness of suture, and whorl cross-section, it is similar to the specimen from the Permian of Amarassi, Timor, assigned by Wanner (1942, pl. 3, fig. 3) to *Euomphalus sundaicus* Wanner 1942, but according to his description (p. 171) *E. sundaicus* has a keel, whereas no keel is visible in the Western Australian species. Similarily, in *Euomphalus pusillus* Waagen (1880, p. 91, pl. 9, fig. 3) from the Upper Productus Limestone of the Salt Range, a low keel is described.

The species is named after Mount Bessel, close to the type locality.

STRAPAROLUS (LEPTOMPHALUS) sp. nov.

(Pl. 25, figs. 1-3)

Description: This shell is represented by a single specimen which is composed of four whorls and is not quite discoidal but has a very low spire. The whorl cross-section is evenly rounded except for a poorly developed keel or carina at the periphery. At the periphery there is also a faint suggestion of a slit or sinal band. The umbilicus is broad and shallow. The specimen is partly decorticated and the growth-lines are not visible.

Dimensions (in mm.):

		Height	*Width*	*Apical Angle*
Figured Specimen	......	4	8	142°

Occurrence: Figured Specimen, UWA Type No. 45449 (Reg. No. 23389), Fossil Cliff Formation at Fossil Cliff.

Discussion: The single specimen is inadequate for a specific description and no name is proposed. It is readily distinguishable from *Straparolus* (*Leptomphalus*) *besselensis* sp. nov. by its spire and slight carina—it differs also in the involution of the shell. Strictly speaking it differs from *Leptomphalus* in having a low spire, and this, together with the faint indication of a band, may give a hint that it belongs to another taxonomic group.

Superfamily PLATYCERATACEA Hall 1859

Family PLATYCERATIDAE Hall 1859

Genus PLATYCERAS Conrad 1840 (p. 205)

Type Species (by subsequent designation of Tate, 1869, p. 34): *Pileopsis vetusta* J. de C. Sowerby (1829, p. 223, pl. 607, fig. 1).

Discussion: Although Knight (1934, p. 147) proposed that *Platyceras* should be restricted to forms with the earlier whorls coiled and in contact, later he himself (*in* Shimer & Shrock, 1944, p. 473), Bowsher (1955, p. 2), and Yochelson (1956, p. 209) have used this name in a wider sense for species in which either the shell is uncoiled or the early whorls have a varying degree of coiling. Several subgenera have been recognized (see Yochelson, 1956). The Western Australian species described below, which are similar to the North American Permian species placed by Yochelson (1956, p. 210) in the subgenus *Orthonychia* Hall 1843, seem to come closest to the subgenus *Platyceras*. One of the specimens described as *Platyceras* cf. *abundans* (Wanner) 1922 and figured in Plate 25, figure 7, is only slightly less coiled than *Platyceras vetustum* (J. de C. Sowerby) 1829, the type species of *Platyceras* (see Knight, 1941, pl. 88, figs. 1a-d). The Western Australian specimens described as *Platyceras* cf. *abundans,* all from the same collecting spot, show, however, considerable variation in the degree of coiling—in the specimen mentioned above the early part of the shell is coiled in contact with the later part, but at the other extreme one shell is almost entirely without coiling. Progressive uncoiling seems to be a feature of these shells during the Carboniferous and Permian Periods, a trend which has already been noted by Bowsher (1955, p. 9).

The Western Australian species described seem to differ considerably from the uncoiled Eastern Australian Permian species for which Fletcher (1958, p. 120) has proposed the name *Rhabdocantha.*

Although in 1922 Wanner used the generic name *Capulus,* which is based on a Mesozoic type species, in 1942 he abandoned this in favour of *Platyceras* and agrees with Knight (1934, p. 146) that the similarity of the two is caused by convergence following the adaptation of an attached habit. Now, there seems little basis for the confusion of the two.

The specimens described below can be separated into two groups which are referred to two species. One group is narrower and the shell is not divided into distinct areas, whereas the other is broader and the shell is divided into three areas. These differences may reflect attachment to different hosts and the groupings may represent varieties rather than species.

PLATYCERAS cf. ABUNDANS (Wanner) 1922

(Pl. 25, figs. 7-18)

cf.:

1922. *Capulus abundans,* Wanner, p. 48, pl. 152(2), figs. 8-10c.

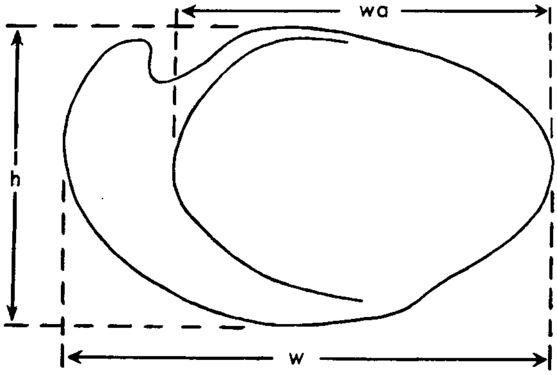
1922. *Capulus deformis,* Wanner, p. 47, pl. 152(2), fig. 7.

1928. *Capulus abundans,* Hamlet, p. 91, pl. 11, figs. 10-11.

1928. *Capulus wanneri,* Hamlet, p. 94, pl. 11, figs. 12-13, 18.

1942. *Platyceras varians abundans,* Wanner, p. 198, pl. 3, figs. 19a, b.

Description: Shell rather narrow, expanding only slowly. Both the protoconch (or nucleus) and the main part of the shell are coiled to a greater or lesser extent, varying from about half a coil to 1½ coils. The protoconch is distinct and its boundary with the rest of the shell is marked by a rapid expansion. The protoconch may be smooth, whereas the rest of the shell has numerous fine growth-lines. The only radial ornament is made up of lines which mark the position of sharp changes in the direction of the growth-lines—the aperture and the shape of the shell are rather simple. The shell is thick and the columellar lip is considerably thickened.



wa = width of aperture
h = height
w = width

Fig. 16. Dimensions of platyceratid gastropods.

As shown in Figure 16, the dimensions follow the convention used for the other spired gastropods. The width is the greatest width and is the largest dimension measurable, the width of the aperture is measured parallel to this direction, and the height is equal to the greatest width at the aperture taken at right angles to the width.

Dimensions (in mm.):

	Height	*Width*	*Width of Aperture*	*No. of Coils*
Figured Specimen A	15	25	17	1½
Figured Specimen B	14	25	18	¾
Figured Specimen C	14	19	8 (estimated)	½
Figured Specimen D	14	19	9	⅓
Figured Specimen E	—	33	23	1¼ (incl. nucleus)

Occurrence: Figured Specimen A, UWA Type No. 45450, Figured Specimen B, UWA Type No. 45451, Figured Specimen C, UWA Type No. 45452, Figured Specimen D, UWA Type No. 45453 and Figured Specimen E, UWA Type No. 45454, all UWA Reg. No. 23393 from the Fossil Cliff Formation at Fossil Cliff. Other Specimens: From the Fossil Cliff Formation at Fossil Cliff (UWA Reg. Nos. 23332 and 23395—two specimens) and from the Callytharra Formation about 1 mile west of Callytharra Springs, Byro Station, 22-35 feet above the base (Field No. GW 84—one specimen).

Discussion: In size, shape, variation in coiling, and simplicity of structure, the Western Australian specimens show considerable resemblance to *Platyceras abundans* (Wanner) (1922, p. 48, pl. 152(2), figs. 8-10c). Wanner, later, in 1942, regarded *P. abundans* as a subspecies of *P. varians* (Wanner) 1922, but it seems more satisfactory to retain it as a specific grouping.

Wanner's specimens are from the Basleo Beds of Timor and therefore are considerably younger than the Australian specimens. There seems no reason, however, to propose an additional name.

PLATYCERAS sp. nov.

(Pl. 25, figs. 4-6)

Description: The shell is similar to *Platyceras varians* (Wanner) (1922, p. 50, pl. 152(2), figs. 13a-b), but it is considerably broader and the threefold division is very distinctly marked. In all three specimens, the first part of the shell is definitely coiled, although in none is more than a single whorl visible. The ornament is composed of numerous distinct, closely spaced growth-lines which indicate that the outline of the shell was irregular. The threefold division of the shell is formed by two distinct grooves associated with the two main changes in direction of the aperture.

Dimensions (in mm.):

	Height	*Width*	*Width of Aperture*
Figured Specimen A	37	38	—
Figured Specimen B	28	35 (estimated)	28 (estimated)
Measured Specimen	23 (estimated)	25 (estimated)	—

Occurrence: Figured Specimen A, CPC 4014 (Field No. ML 94), approximately 2 miles north-north-east of Round Hill Well, Winning Station, near base of Callytharra Formation; Figured Specimen B and Measured Specimen, CPC 4015 and 4016 (Field No. ML 22), about 5½ miles east-south-east of Donnellys Well, Williambury Station, 5-28 feet above the base of the Callytharra Formation.

Discussion: *Platyceras* sp. nov. is readily distinguishable from *Platyceras* cf. *abundans* by its breadth and the threefold division of the shell. It does not seem referable to any of Wanner's or Hamlet's species or subspecies from Timor, but, because so many names are available, and because the present material is not very extensive, I am reluctant to propose a new name.

Superfamily SUBULITACEA Lindström 1884

Family SUBULITIDAE Lindström 1884

Genus MACROCHILINA Bayle 1880 (p. 241)

Type Species (by subsequent designation of Keyes, 1889, p. 421): *Buccinum acutum* J. de C. Sowerby (1827, p. 127).

Synonyms: *Macrocheilus* Phillips 1841, preoccupied by *Macrocheilus* Kirby 1838; *Duncania* Bayle 1879, preoccupied by *Duncania* de Koninck 1872 and *Duncania* Portales 1874.

Discussion: Knight (1941, p. 186) deals at length with the synonymy and correct type species for *Macrochilina*. His conclusions are followed. The specimens described below either lack or have only poorly developed columellar folds—the very distinct folds of *Soleniscus* Meek & Worthen 1861 are lacking, and the species is referred therefore to *Macrochilina*.

MACROCHILINA WINENSIS sp. nov.

(Pl. 26, figs. 1-7)

Diagnosis: Height of spire variable but moderate for *Macrochilina*; growth-lines very fine.

Description: The holotype has seven whorls with a rounded protoconch (nucleus). The earlier whorls are more rounded than the later and have a greater apical angle. The ornament is composed only of very fine, closely spaced growth-lines, which are slightly stronger at irregular intervals. The sutures are not deeply marked, the anterior notch ('incurrent canal') is poorly developed. The callus (or inductura) is thin and extends only slightly outside the aperture.

In Paratypes B and C, part of the last whorl is broken away—both appear to have a poorly developed lower columellar fold and a slightly better developed upper fold.

Dimensions (in mm.):

	Height	*Width*	*No. of Whorls*	*Apical Angle*
Holotype	11	6	7	43°
Paratype A	8	4	6	40° (estimated)
Paratype B	17	7	8	34°

Occurrence: Holotype, UWA Type No. 45455 (Reg. No. 23377), Paratype A, UWA Type No. 45456 (Reg. No. 23378), both from Fossil Cliff Formation at Fossil Ridge; Paratype B, UWA Type No. 45457 (Reg. No. 23396), Fossil Cliff Formation at Fossil Cliff, Paratype C, UWA Type No. 45458 (Reg. No. 30011), Becketts Gully, labelled Upper Holmwood Shale, but probably Fossil Cliff Formation.

Other Specimens: Fossil Cliff Formation at Fossil Cliff (UWA Reg. Nos. 23391 and 23396—three specimens from each) and three specimens from Becketts Gully, labelled Upper Holmwood Shale but probably Fossil Cliff Formation. A total of 13 specimens.

Discussion: *Macrochilina winensis* does not seem to closely resemble any described species—in a general way it is similar to the considerably younger *Macrocheilus* cf. *brancoi* Gemmellaro, Wanner (1922, p. 46, pl. 152(2), fig. 4), from the Permian Basleo Beds of Timor.

The specific name is an abbreviation of 'irwinensis' from the Irwin River, near where the type specimens were collected.

Superfamily NERITACEA Rafinesque 1815

Family NERITOPSIDAE Gray 1847

Genus NATICOPSIS McCoy 1844 (p. 33)

Type Species (by subsequent designation of Meek & Worthen, 1866, p. 364, footnote): *Naticopsis phillipsii* McCoy (1844, p. 33, pl. 6, figs. 4a-b).

Discussion: The two specimens described below are not readily referable to any genus because of their unsatisfactory preservation. They are referred doubtfully to *Naticopsis* because of their general resemblance in shape.

NATICOPSIS? sp. nov.

(Pl. 26, figs. 8-9)

Description: In Figured Specimen A, the shell is of moderate height with rapidly expanding whorls, although not as rapidly as is characteristic for *Naticopsis*. It is ornamented with well-marked, closely-spaced, fine transverse ribs. The sutures are distinct but not deep. The aperture is long and oval but the details are not visible.

Figured Specimen B is an internal impression and shows only that the shell is of a similar height and the whorls expand at a similar rate to Figured Specimen A. It could represent, however, another species.

Dimensions (in mm.):

	Height	*Width*	*Apical Angle*
Figured Specimen A	18 (estimated)	12	78° (estimated)
Figured Specimen B	21	14	70° (estimated)

Occurrence: Figured Specimen A, UWA Type No. 45459 (Reg. No. 23389), Fossil Cliff Formation at Fossil Cliff; Figured Specimen B, UWA Type No. 45460 (Reg. No. 33769) basal part of High Cliff Sandstone at Old Glendevon Homestead, Woolaga Creek.

OTHER GASTROPODS

In addition to the species that have already been described, at least one species of a high-spired *Loxonema*-like gastropod is represented in the material from the Nura Nura Member. The specimens, however, are so poor that they do not warrant description or illustration.

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APPENDIX

The Base of the Fossil Cliff Formation

Previous workers (see McWhae et al., 1958, p. 76) have shown that there is no sharp boundary between the Holmwood Shale and the Fossil Cliff Formation. In Becketts Gully, Clarke et al. (1951, p. 53) placed the boundary immediately below the distinct fossiliferous limestones. Below these, however, two-fifths of a mile upstream from the road crossing, is a bed with distinct ferruginous leached nodules which contains abundant fossils of the Fossil Cliff type. Originally it may be assumed that this bed contained shelly limestone. The bed also contains coarse quartz grains and in stratigraphical position and appearance (lithology) is similar to the bed occurring at the base of the Fossil Cliff Formation at High Cliff, Irwin River, and the fossiliferous bed in Caryngirnia Gully considered by Clarke et al. (1951, p. 66) to be in the Caryngirnia Formation, but now regarded as being part of the Fossil Cliff Formation (see next section). In Becketts Gully it is proposed to place the base of the Fossil Cliff Formation immediately below the base of this bed with the nodules, the coarse quartz grains, and the Fossil Cliff type fauna.

Fossils in Caryngirnia Gully

Clarke et al. (1951, p. 66) recorded fossils from Caryngirnia Gully, which they regarded as being from the Caryngirnia Formation. Subsequent field work by Playford and Willmott (*in* McWhae et al., 1958, p. 78) suggested that these beds belonged in the Fossil Cliff Formation; and examination of the fossils (Dickins & Thomas, 1957) has confirmed this—the fauna of brachiopods, pelecypods and gastropods (about 30 species) is the same as that of the Fossil Cliff Formation. The occurrence of the pelecypods and gastropods is recorded in the main part of the text (Field Nos. PB 7 and IR 20). These beds also have many coarse and very coarse quartz grains and appear to be correlatable with the bed in Becketts Gully discussed in the immediately preceding section.

Fossils from near the Base of the High Cliff Sandstone at Woolaga Creek

Playford (1959, p. 18) has discussed the stratigraphical position of fossils which occur near the base of the High Cliff Sandstone. I have concluded (*in* Playford, 1959) that this fauna contains species younger than any found in the Fossil Cliff Formation.

According to the field data, fossil beds occur in the basal part of the High Cliff Sandstone, but as most of the fossil samples have been collected from loose boulders it is not possible to be certain that older forms have not been included. Playford (loc. cit.) considers the relationship between the High Cliff Sandstone and the immediately underlying Holmwood Shale to be conformable. My examination, although it supports the conclusion that there is no distinct angular discordance, affords evidence for a break in sedimentation, possibly with subaerial erosion. On the south bank of Woolaga Creek, where the creek cuts through the strike ridge formed by the basal part of the High Cliff Sandstone (approx. 633825 Pintharuka 1-mile Sheet), a small outcrop shows a sharp boundary between the thin-bedded soft micaceous sandy siltstone of the Holmwood Shale and the sandstone of the High Cliff with coarse grains at the base. The basal bed weathers out distinctly and above it, in place, are marine fossils with which are associated at least one fragment of sandstone. No macro-fossils could be found in the Holmwood Shale exposed near the contact.

Corroborative evidence for a break below the High Cliff Sandstone is shown in Becketts Gully, on the south side at Round Hill immediately upstream from where the gully cuts through the Fossil Cliff Formation (see map in Clarke et al. 1951). The top part of the Fossil Cliff Formation of grey, thin-bedded, soft, micaceous, sandy siltstone is slightly channelled; the channels are filled by medium-grained quartz sandstone of the High Cliff Sandstone.

Correlation of the Caryngينia Formation with the Sequence in the Wooramel River Area

Playford & Willmott (*in* McWhae et al., 1958, p. 78) tentatively correlate the Caryngينia Formation with the Madeline Formation, the basal formation of the Byro Group in the Wooramel River area. My examination, however, suggests that, in lithology, the Caryngينia Formation resembles the Keogh Formation rather than the Madeline Formation, and that, with the exception of the Mingenew Formation, the Byro type of sedimentation is not found exposed at the surface in the Irwin River area. The Caryngينia Formation, like the Keogh Formation, is characterized by interbedded, thin-bedded and laminated quartz greywacke, sandstone, and siltstone and, on the whole, the sand-size sediments are cleaner (better sorted) and less micaceous than those of the Madeline Formation and the Byro Group (Konecki, Dickins, & Quinlan, 1958). Lithologically the Caryngينia Formation is similar to the arenite sequence which makes up the Wooramel Group in the Carnarvon Basin and it seems natural to group it with the underlying High Cliff Sandstone and the Irwin River Coal Measures rather than with the Byro Group. The Caryngينia Formation also resembles the Keogh Formation in the scarcity of marine macro-fossils. Reliable correlation of the Caryngينia Formation seems likely only by means of spores.

Relationship of the Nalbia, Norton, and Coolkilya Greywackes

The superpositional relationship of the formations of the upper part of the Byro and the lower part of the Kennedy Groups in the Minilya River area near Wandagee is not as clear as at the north end of the Kennedy Range and this has been partly responsible for the duplication of terminology and the use of the name Coolkilya in quite different senses. The two sets of nomenclature are that first used by Teichert (1950) and that proposed by Condon (1954). This problem has been discussed by Condon (1954, p. 85) and Teichert (1957) and the relationship of the two sets of nomenclature is shown by Thomas & Dickins (1954, text-fig. 1).

The top part of the Coolkilya Sandstone of Teichert (1950), as shown in figure 2 of Teichert (1952), corresponds to the bottom 58 feet of Condon's section

(1954, p. 92); i.e. at Wandagee Hill, the top of the Coolkilya Greywacke of Condon is about 250 feet above the top of the Coolkilya Sandstone of Teichert. The two red-brown horizons, the upper of which is marked by the last *Calceolispongia robusta* Teichert, are contained in the bottom 58 feet of Condon's (1954) Wandagee Hill section. At the north end of the Kennedy Range, the top of Teichert's Coolkilya Sandstone can be placed above the second pelecypod coquinite, 406 feet above the base of Condon's section (1954, p. 94) and 244 feet below the top. At Wandagee Hill, the top of the *Chonetes-Streptorhynchus* band is 67 feet above and at the north end of the Kennedy Range 74 feet above the second pelecypod coquinite. These thicknesses illustrate the remarkable uniformity of the Coolkilya Greywacke in the Kennedy Range-Minilya River area, a uniformity confirmed by the measurement of a number of sections along the north end of the Kennedy Range by P. J. Jones of the Bureau of Mineral Resources and the author.

The boundary of the Norton Greywacke and the Baker Formation corresponds to the base of Teichert's Coolkilya Sandstone; so the Baker Formation represents the bottom part of Teichert's Coolkilya Sandstone. Because of lack of information the position of the top of the Baker Formation is not clear.

The Nalbia and Norton Greywackes therefore occupy a similar stratigraphic position and, as I propose to show below, a faunal examination suggests that the Nalbia and the Norton are to be equated and both are to be separated from the Coolkilya Greywacke, which lithologically they resemble. The definition of the top boundary of the Nalbia Greywacke (=Nalbia Sandstone) given by Teichert (1952, p. 129) is equally satisfactory for the Norton Greywacke. In many places a *Strophalosia-Cleiothyridina* coquinite is developed near the top of both. However, the top of the Nalbia may not have always been placed consistently with this definition.

The fauna recorded from definite Nalbia Greywacke is not very large; it consists of 13 species, eight of which occur also in the Coolkilya Greywacke. Of these eight, seven are recorded also in the Norton Greywacke and the eighth occurs also in the Wandagee and Baker Formations and is therefore of no consequence in comparing the Nalbia and Norton Greywackes. Of the remaining five species, three (*Streblopteria*? sp. nov., *Stutchburia* sp. nov. B, and *Astartila blatchfordi*) are found in the Norton Greywacke, one occurs only in the Nalbia Greywacke, and the other only in beds older than the Norton Greywacke. The Coolkilya Greywacke on the other hand is distinguished from both the Nalbia and the Norton by a number of forms which, on the basis of a comparison with the Canning Basin and Timor, indicate a younger age (see discussion in main part of monograph). Especially important in this regard are *Parallelodon subtilistriatus, Atomodesma exaratum*, and *Ptychomphalina* sp. nov. A. Other forms which distinguish the Coolkilya Greywacke are *Phestia thomasi, Pseudomyalina obliqua, Middalya johnstonei, Stutchburia* sp. nov. D, Pectinid gen. et sp., and *Euphemites* sp. nov. B.

This evidence seems to be so definite that the Nalbia and Norton Greywackes are the same formation that the retention of the younger name, Norton, hardly seems any longer necessary.

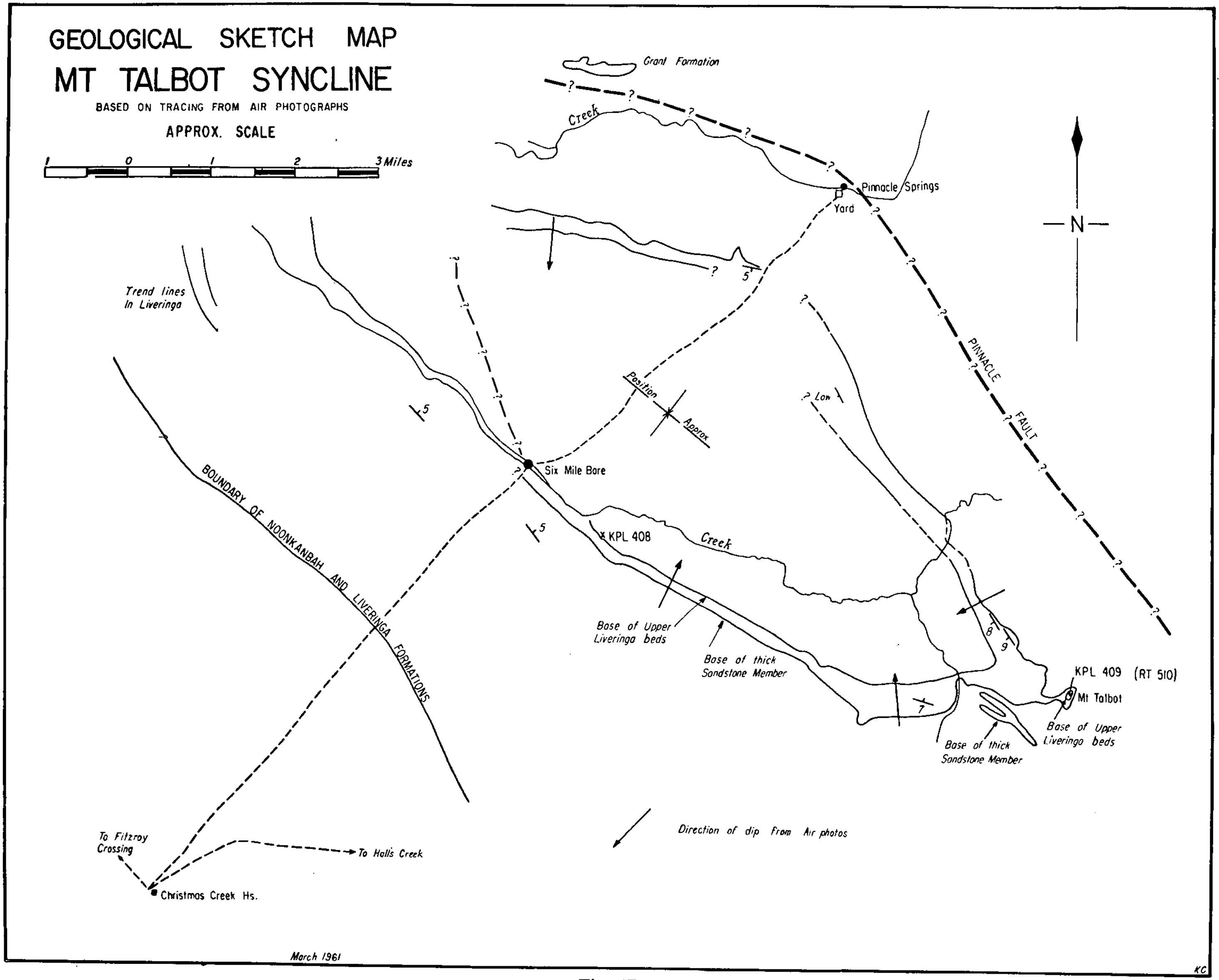
GEOLOGICAL SKETCH MAP
MT TALBOT SYNCLINE
BASED ON TRACING FROM AIR PHOTOGRAPHS
APPROX. SCALE
1 0 1 2 3 Miles
Grant Formation
Creek
Pinnacle Springs
Yard
N
PINNACLE FAULT
Trend lines
In Liveringa
Position Approx
Low
Six Mile Bore
BOUNDARY OF NOONKANBAH AND LIVERINGA FORMATIONS
KPL 408
Creek
Base of Upper
Liveringa beds
Base of thick
Sandstone Member
KPL 409 (RT 510)
Mt Talbot
Base of Upper
Liveringa beds
Base of thick
Sandstone Member
Direction of dip From Air photos
To Fitzroy
Crossing
To Halls Creek
Christmas Creek Hs.
March 1961
KC

Fig. 17

Relationship of the Lower and Upper Marine Parts of the Liveringa Formation

The faunas of the Liveringa Formation and differences between those of the lower and upper marine parts have been discussed in the main part of this monograph. Thomas & Dickins (1954) consider that this gap in the faunas may represent up to one third of Permian time. The evidence which has come to hand since this time has confirmed the distinctiveness of the two faunas. Information is now presented from the Mount Talbot Syncline which may indicate a disconformity (i.e. a considerable break in sedimentation without marked angular discordance). This evidence is based on the field work of G. A. Thomas and the author, and the accompanying map has been compiled from these data, unpublished map compilations in the Bureau of Mineral Resources, and air-photograph interpretation.

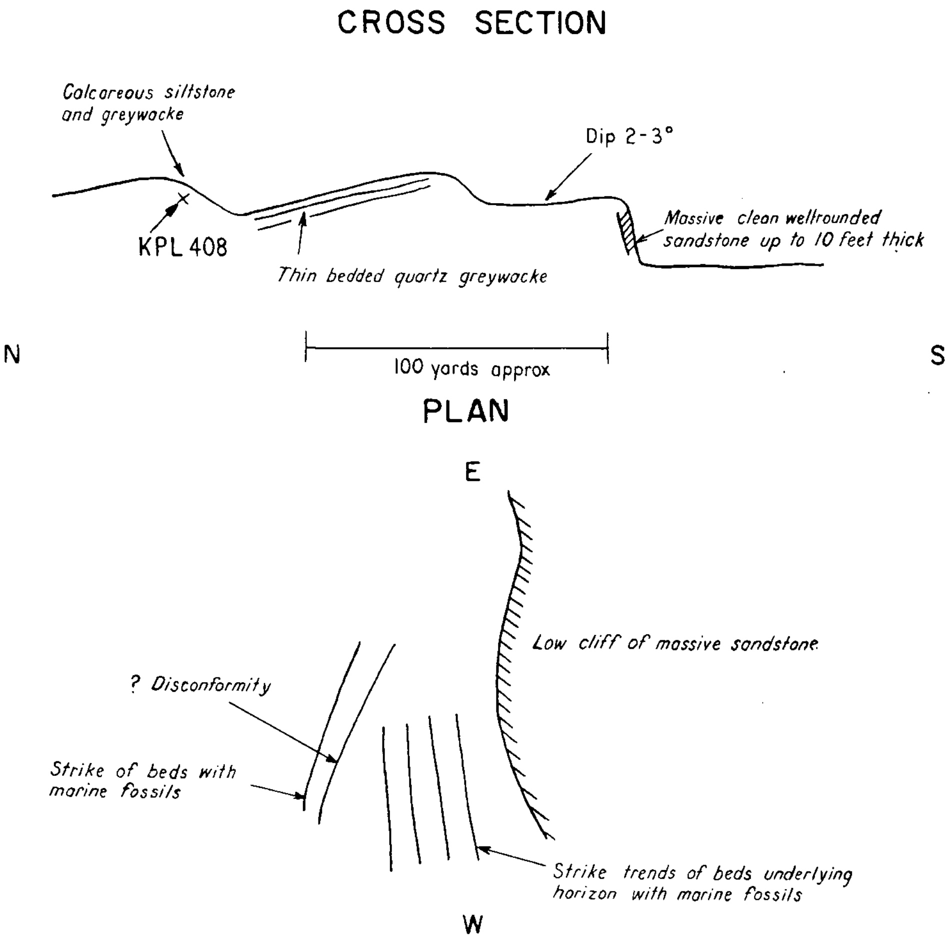

Fig. 18

The relationship of the beds at KPL 408 is shown in the accompanying figures (17 & 18). This suggests that the upper beds with the marine fossils were laid down on the slightly irregular surface of the lower thin-bedded greywackes and the massive sandstone bed.

At KPL 409 the massive sandstone, about 12 feet thick, is exposed in a steep section on the east side of Mount Talbot. The beds underlying this sandstone are irregular on top ('cut and fill structure') and the sandstone fills the irregularities. Above the sandstone are the thin-bedded greywackes the top of which form a dip slope. On this dip slope are found the beds with the marine fossils of the Upper Liveringa type.

Marine fossils identified at KPL 408 are:

Pelecypods

Glyptoleda? sp. nov.
Vosellina? sp. nov.
'*Allorisma*' sp. nov. A.
Aviculopecten? sp. nov. (small, *Lima*-like, but with aviculopectinid ears).
Oriocrassatella sp. nov. ('*Procrassatella* type').
Astartella sp. nov.

Gastropods

Warthia cf. *micromphala* (Morris) 1845.
Euphemites sp. (probably not identifiable specifically).
Pleurotomariidae gen. et sp. nov.
Mourlonia (*Mourlonia*) sp. nov. C.

Of these 10 species, seven are found elsewhere only in the Upper Liveringa beds.

The remaining three (*Aviculopecten*? sp. nov., *Glyptoleda*? sp. nov., and *Euphemites* sp.) are possibly restricted to the beds in the Mount Talbot Syncline.

At KPL 409 the following species, which also occur at KPL 408, are found:

Aviculopecten? sp. nov.
Oriocrassatella sp. nov. ('*Procrassatella* type').
Astartella sp. nov.

In some parts of the Fitzroy Basin, the lower and upper marine beds of the Liveringa are separated by a thick sequence lacking marine fossils (see Guppy et al., 1958). Perhaps this sequence is largely absent in the Mount Talbot area, where according to dip and distance, about 1,000 feet of strata intervene between the top of the Noonkanbah Formation and the beds with the Upper Liveringa marine fossils. This thickness would be unusual for the Lower Liveringa beds, for which a maximum thickness of 435 feet has been recorded by Guppy et al. (1958, p. 52). Possibly the Mount Talbot marine horizon is stratigraphically lower than that of the Hardman Member of the upper part of the Liveringa Formation, and represents an horizon which has not been recognized elsewhere in the Basin.

The relationship of the strata in the Mount Talbot area does, however, seem to afford evidence for a disconformity, which might be expected on the general grounds that a marine sequence is followed by a considerable thickness of beds with plants, without marine fossils and with coal in places, which in turn is succeeded by appreciably younger marine beds. The local unconformity recorded by Veevers & Wells (1961, p. 88) between the Lightjack Member and the overlying Condren Member in the Mount Bannerman area apparently corresponds to the disconformity suggested above.

PLATES

PLATE 1

FIGS. 1-6.—*Nuculopsis (Nuculopsis) darlingensis* sp. nov. × 4. .... Page 29

FIG. 1.—Paratype B, a left valve, side view.

FIGS. 2-5.—Holotype, a right valve. 2. Tilted side view. 3 Front view. 4 Dorsal view. 5. Side view.

FIG. 6.—Paratype A, a right valve, side view.

FIGS. 7-12.—*Nuculopsis (Nuculanella) bangarraensis* sp. nov. × 4. .... Page 31

FIG. 7.—Paratype B, a right valve, side view.

FIGS. 8-9.—Holotype. 8. Side view of left valve. 9. Dorsal view.

FIGS. 10-12.—Paratype A. 10. Side view of right valve. 11. Side view of left valve. 12. Front view.

FIGS. 13-15.—*Nuculopsis (Nuculanella) piedmontia* (Tasch) 1953. .... Page 31

FIG. 13.—State University of Iowa Catalogue No. (SUI) 10424, dorsal view. × 8.

FIG. 14.—SUI, 10425, side view of left valve. × 4.

FIG. 15.—SUI, 10426, side view of left valve. × 4.

FIGS. 16-24.—*Quadratonucula australiensis* gen. et sp. nov. × 4. .... Page 33

FIGS. 16-17.—Paratype B, a right valve. 16. Side view. 17. Front view.

FIGS. 18-20.—Paratype A, a right valve. 18. Side view of latex cast of external impression. 19. Side view of internal impression. 20. Dorsal view of internal impression.

FIGS. 21-22.—Holotype. 21. Tilted side view. 22. Side view.

FIG. 23.—Paratype D, a left valve, side view of latex cast of an external impression.

FIG. 24.—Paratype C, a left valve, side view.

FIGS. 25-29.—*Anthraconeilo* sp. nov. × 2. .... Page 35

FIGS. 25-27.—Figured Specimen B. 25. Latex cast showing dentition. 26. Dorsal view. 27. Side view.

FIGS. 28-29.—Figured Specimen A. 28. Front view. 29. Side view.

(Photographs in the plates, except where otherwise indicated, taken by the author, or by J. E. Zawartko, photographer of the Bureau of Mineral Resources, Geological Branch, working in collaboration with the author.)

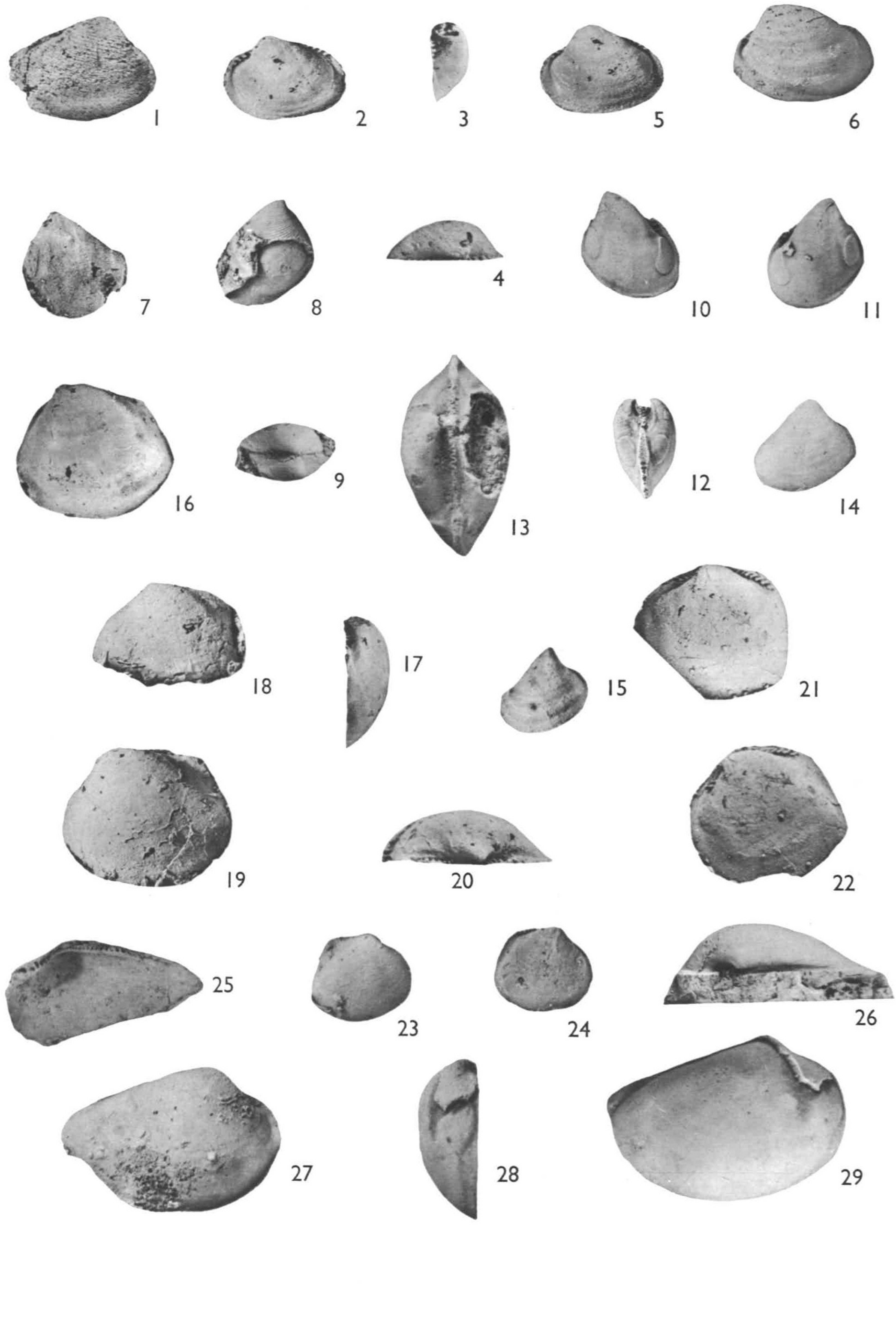
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PLATE 2

FIGS. 1-3.—*Anthraconeilo kansana* (Tasch) 1953. .... Page 34

FIG. 1.—State University of Iowa Catalogue No. (SUI) 10427, side view. × 4.

FIGS. 2-3.—SUI, 10428. 2. Dorsal view. × 8. 3. Side view. × 4.

FIGS. 4-11.—*Phestia darwini* (de Koninck) 1877. × 2. .... Page 38

FIG. 4.—Hypotype D, dorsal view showing ligament pit and pedal muscles.

FIGS. 5-8.—Hypotype A. 5. Front view. 6. Side view of left valve. 7. Side view of right valve. 8. Dorsal view.

FIG. 9.—Hypotype C, side view of left valve.

FIG. 10.—Hypotype E, side view of a left valve.

FIG. 11.—Hypotype B, side view of right valve.

FIGS. 12-18.—*Phestia lyonsensis* (Dickins) 1956. × 2. .... Page 37

FIG. 12.—Hypotype D, side view of a right valve.

FIGS. 13-15.—Hypotype A. 13. Front view. 14. Dorsal view. 15. Side view of left valve.

FIG. 16.—Hypotype C, side view of left valve.

FIGS. 17-18.—Hypotype B. 17. Side view of right valve. 18. Side view of left valve.

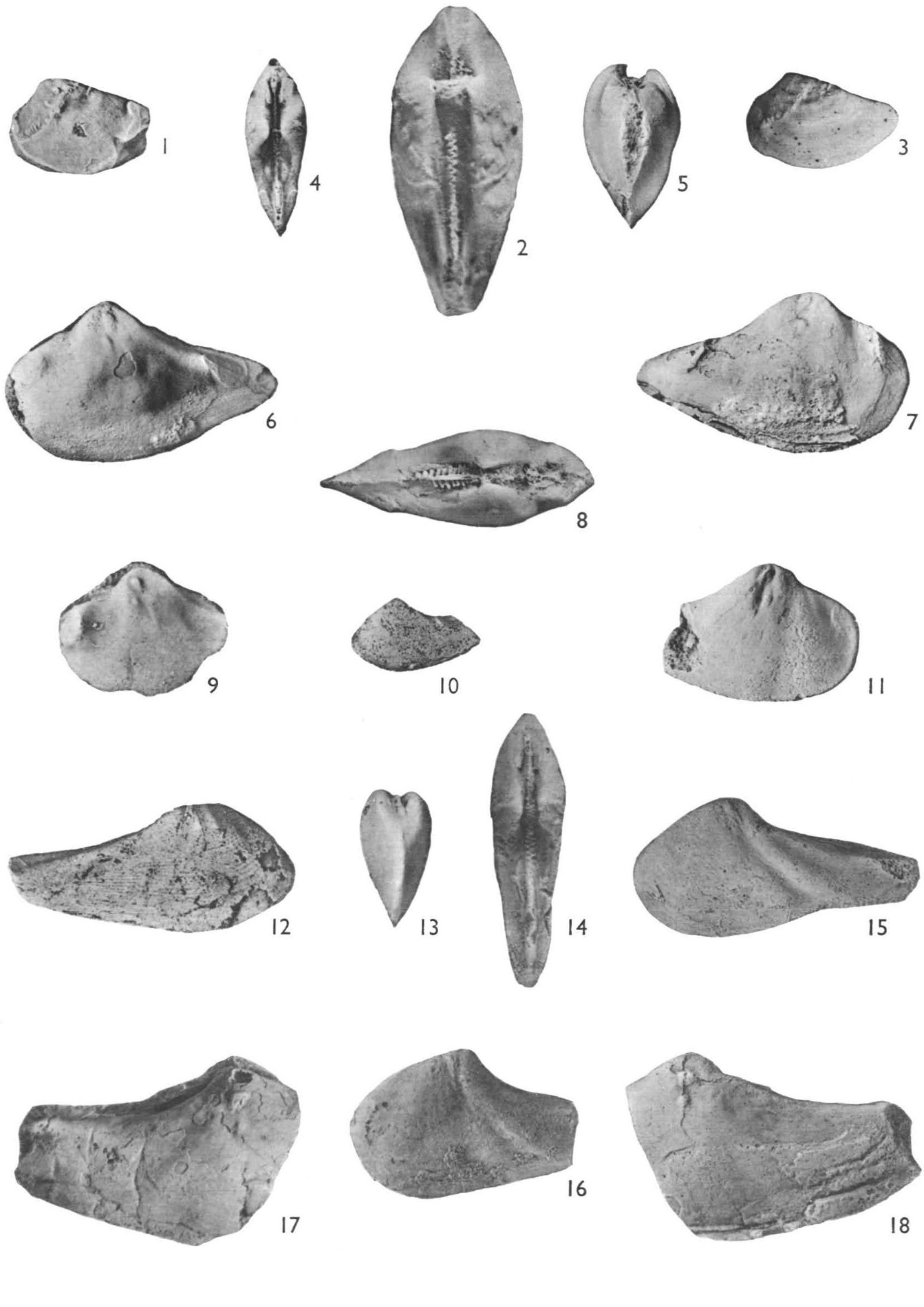
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Plate 3

Figs. 1-5.—*Parallelodon subtilistriatus* Wanner 1922. .... Page 40 from the Lower Liveringa marine beds; north-west of Mount Marmion, Western Kimberley. × 2.

Fig. 1.—Hypotype A, UWA Type No. 45358, side view of a right valve.

Figs. 2-3.—Hypotype B, UWA Type No. 45359, a left valve. 2. Internal view showing dentition. 3. Side view.

Figs. 4-5.—Hypotype C, UWA Type No. 45360, a left valve. 4. Tilted internal view to show ligament grooves. 5. View to show dentition.

Figs. 6-14.—*Parallelodon bimodoliratus* sp. nov. .... Page 40

Figs. 6-8.—Holotype, a left valve, latex cast. × 2. 6. Dorsal view. 7. Front view. 8. Side view.

Fig. 9.—Paratype C, side view of a left valve. × 1.

Fig. 10.—Paratype F, side view of a slightly crushed left valve, latex cast. × 2.

Fig. 11.—Paratype E, side view of a left valve to show the anterior adductor muscle. × 1.

Fig. 12.—Paratype A, a latex impression showing internal view of a right valve and the dentition. × 4.

Fig. 13.—Paratype B, side view of a left valve. × 1.

Fig. 14.—Paratype D, side view of a left valve (front part of shell is incomplete). × 1.

Figs. 15-23.—*Edmondia prichardi* sp. nov. .... Page 43

Fig. 15.—Paratype C, side view of a right valve. × 1.

Fig. 16.—Paratype E, latex impression made from an internal impression showing the internal 'ossicle' behind the umbo in a left valve. × 1.

Fig. 17.—Paratype D, side view of a left valve. × 1.

Figs. 18 and 23.—Paratype F, internal impression of a right valve. × ½. 18. Dorsal view. Note the impression of the internal 'ossicle' behind the umbo. 23. Side view.

Figs. 19-21.—Holotype, a left valve. × ½. 19. Side view. 20. Dorsal view. 21. Front view.

Fig. 22.—Paratype A, plasticene squeeze of an external impression of a left valve. × 1.

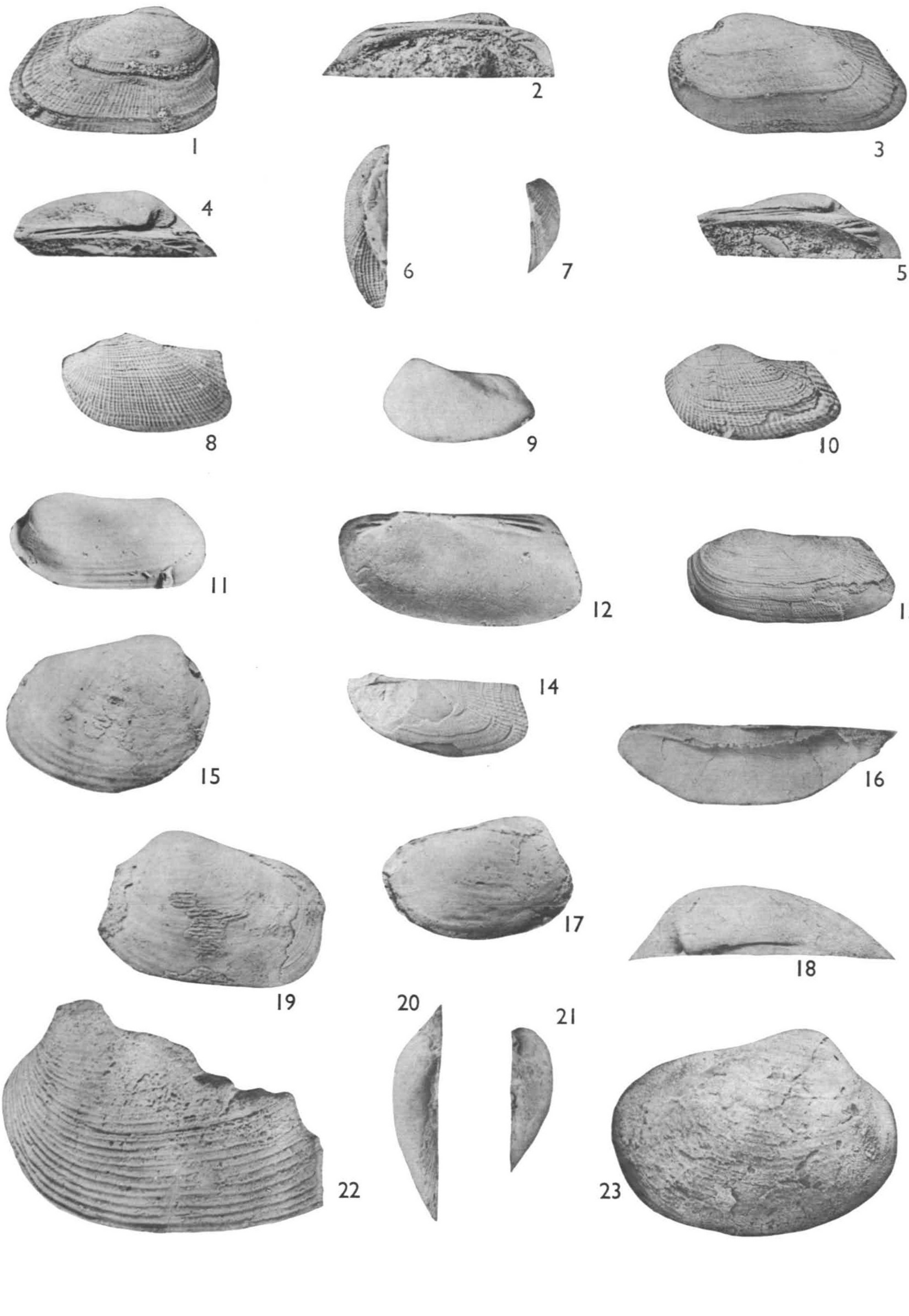
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Plate 4

Figs. 1-3.—*Megadesmus* sp. × ½. .... Page 45

Figured Specimen, CPC 3880. 1. Side view. 2. Dorsal view. 3. Front view.

Figs. 4-10.—*Astartila*? *tumida* sp. nov. .... Page 46

Figs. 4-7.—Holotype, a right valve. × 1. 4. Side view. 5. Front view. 6. Tilted side view to show posterior area. 7. Dorsal view.

Fig. 8.—Paratype A, side view of a left valve. × 1.

Fig. 9.—Paratype C, side view of a right valve. × ½.

Fig. 10.—Paratype B, side view of a left valve. × ½.

Figs. 11-14.—*Astartila*? sp. .... Page 47

Fig. 11.—Figured Specimen C, side view of left valve. × 1.

Figs. 12-13.—Figured Specimen B, a right valve. × 1. 12. Side view. 13. Dorsal view.

Fig. 14.—Figured Specimen A, a right valve, side view. × ½.

Figs. 15 and 16.—*Edmondia prichardi* sp. nov. .... Page 43

Fig. 15.—Part of shell of holotype showing the external ornament. × 4.

Fig. 16.—Paratype B, umbonal part of shell showing internal radiating ornament. × 2.

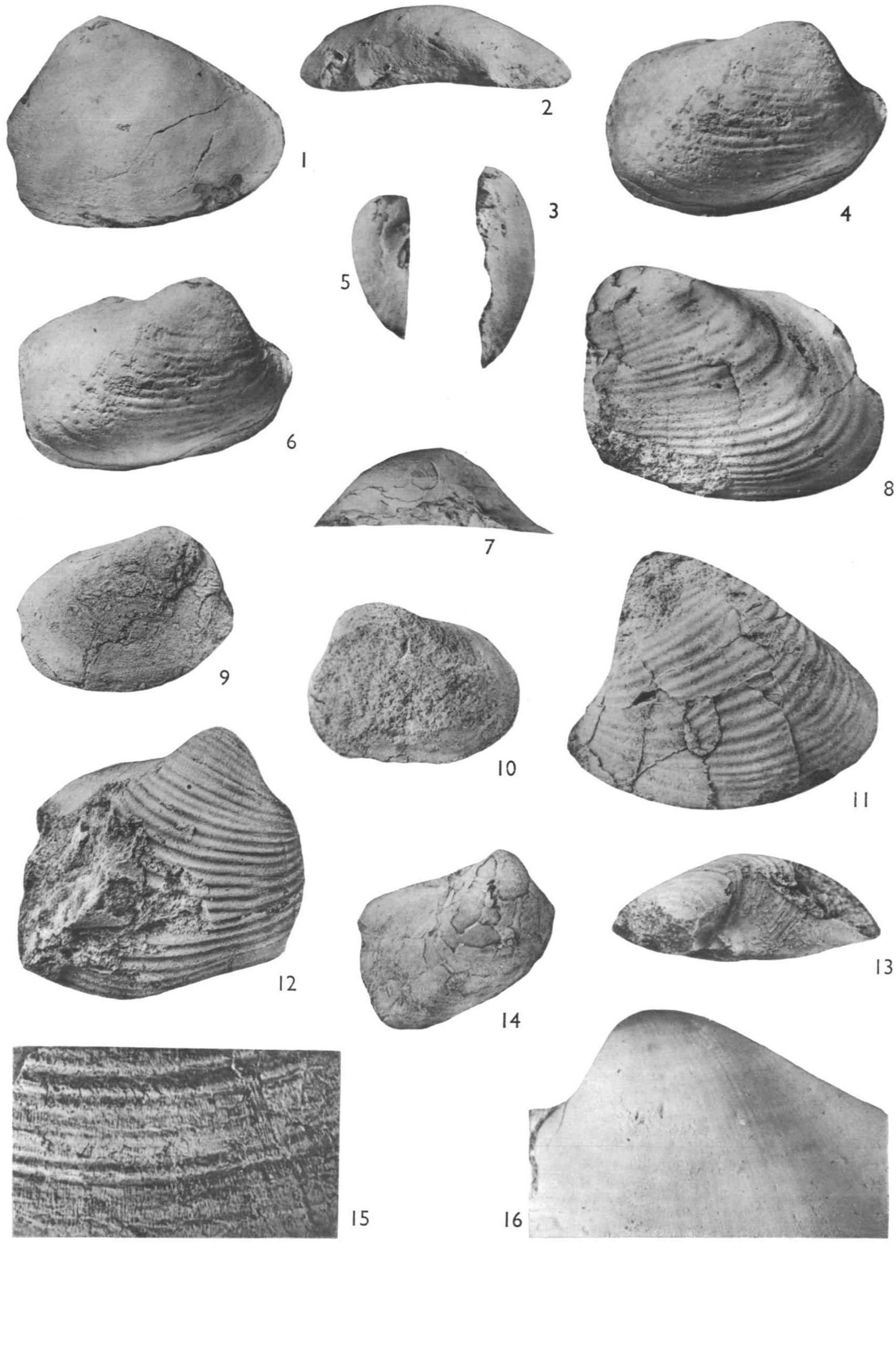
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PLATE 5

FIG. 1.—*Myonia* sp. × 1. .... Page 49
Australian Museum No. F 21384 from Wyro, near Ulladulla, N.S.W.

FIGS. 2-12; 22.—*Myonia subarbitrata* sp. nov. .... Page 48

FIGS. 2-3.—Paratype C. × 2. 2. Side view of right valve. 3. Side view of left valve.

FIG. 4.—Paratype E, side view of a right valve. × 2.

FIG. 5.—Paratype F, side view of a right valve. × 2.

FIGS. 6-7.—Holotype, a left valve. × 2. 6. Side view. 7. Front view.

FIGS. 8-10.—Paratype A, a crushed left valve. × 1. 8. Side view. 9. Dorsal view. 10. Front view.

FIGS. 11-12.—Paratype B, a right valve. × 2. 11. Side view. 12. Dorsal view.

FIG. 22.—Paratype F, external impression of a left valve showing the surface ornament. × 4.

FIGS. 13-19.—*Myonia* sp. nov. .... Page 50

FIG. 13.—Figured Specimen B, side view of a left valve. × 1.

FIG. 14.—Figured Specimen D, side view of a right valve. × 1.

FIGS. 15-17.—Figured Specimen A, a left valve. × 1. 15. Side view. 16. Dorsal view. 17. Front view.

FIG. 18.—Figured Specimen E, side view of a left valve. × 2.

FIG. 19.—Figured Specimen C, side view of a left valve. × 1.

FIGS. 20-21.—*Pachymyonia* cf. *occidentalis* Dickins 1957. .... Page 50
Figured Specimen, a left valve. 20. Enlargement to show rows of papillae on external surface. × 4. 21. Side view. × 1.

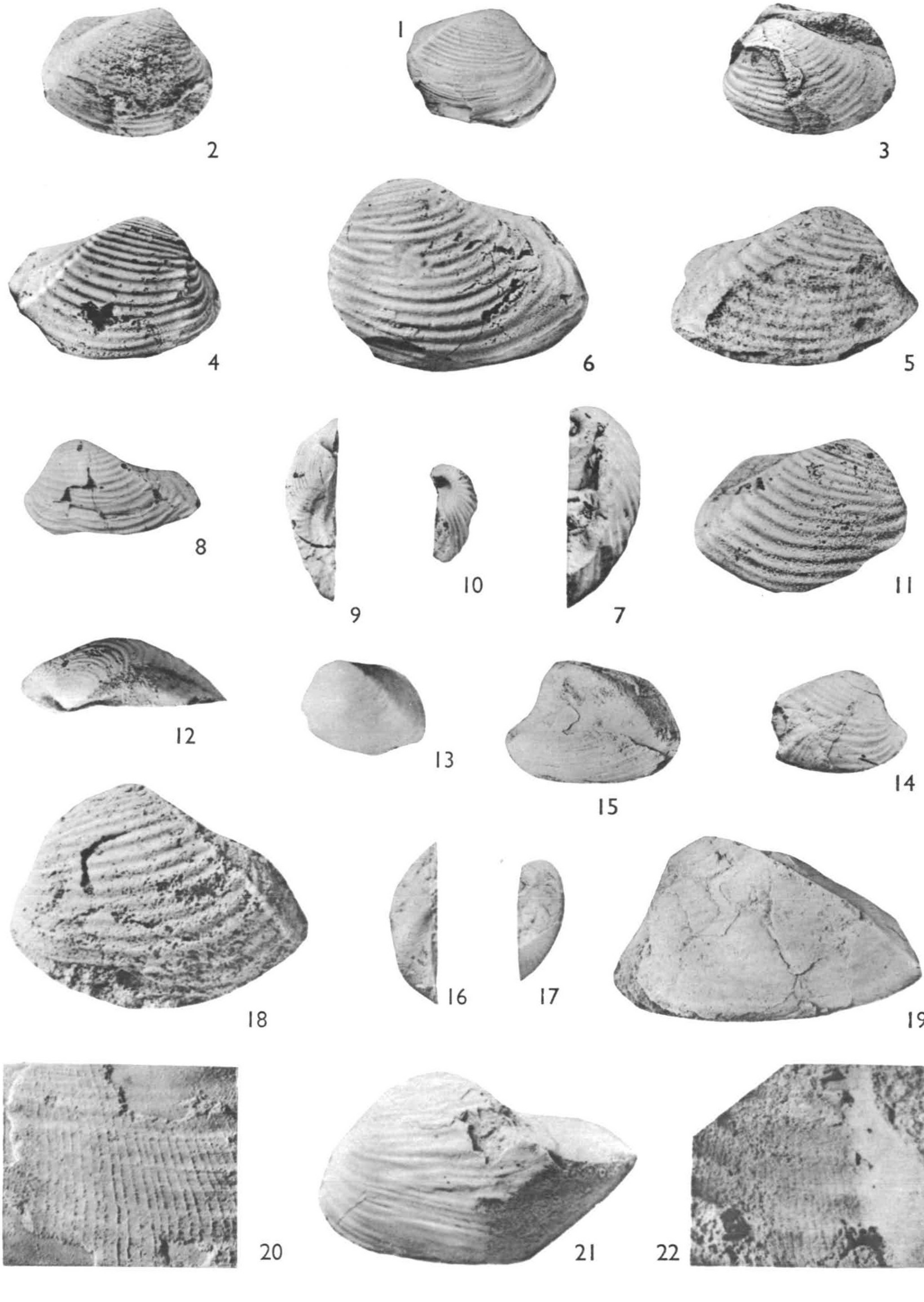
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PLATE 6

FIGS. 1-9.—*Palaeosolen*? *badgeraensis* sp. nov. .... Page 57

FIGS. 1-3; 5.—Latex cast of external impression of holotype, a left valve. × 1. 1. Side view, lighting normal. 2. Dorsal view. 3. Side view, lighting from below to show carina and radiating ornament. 5. Front view showing gape.

FIG. 4.—Latex cast of internal impression of holotype showing the elongated ligament groove. × 2.

FIG. 6.—Paratype A, side view of a right valve. × 1.

FIG. 7.—Paratype B, side view of a small right valve. × 1.

FIG. 8.—Paratype C, side view of a left valve. × 1.

FIG. 9.—Paratype D, side view of a left valve. × 1.

FIGS. 10-14.—*Chaenomya*? *nuraensis* sp. nov. .... Page 52

FIGS. 10-12.—Holotype, a left valve. × 1. 10. Dorsal view. 11. Side view. 12. Front view.

FIGS. 13-14.—Paratype, latex cast of an external impression of a left valve. 13. Side view. × 2. 14. Enlargement to show external granulation. × 4.

FIGS. 15-20.—*Praeundulomya subelongata* sp. nov. .... Page 54

FIGS. 15-18.—Holotype, a right valve. × $\frac{1}{2}$. 15. Side view, lighting normal. 16. Dorsal view. 17. Side view, lighting from below to show posterior grooves. 18. Front view.

FIG. 19.—Paratype A, side view of left valve. × $\frac{1}{2}$.

FIG. 20.—Paratype B, side view of left valve with umbo broken away. × 1.

FIGS. 21-22.—*Palaeocosmomya* sp. nov. .... Page 56

FIG. 21.—Figured Specimen A, side view of right valve. × 1.

FIG. 22.—Figured Specimen B, side view of a left valve. × 2.

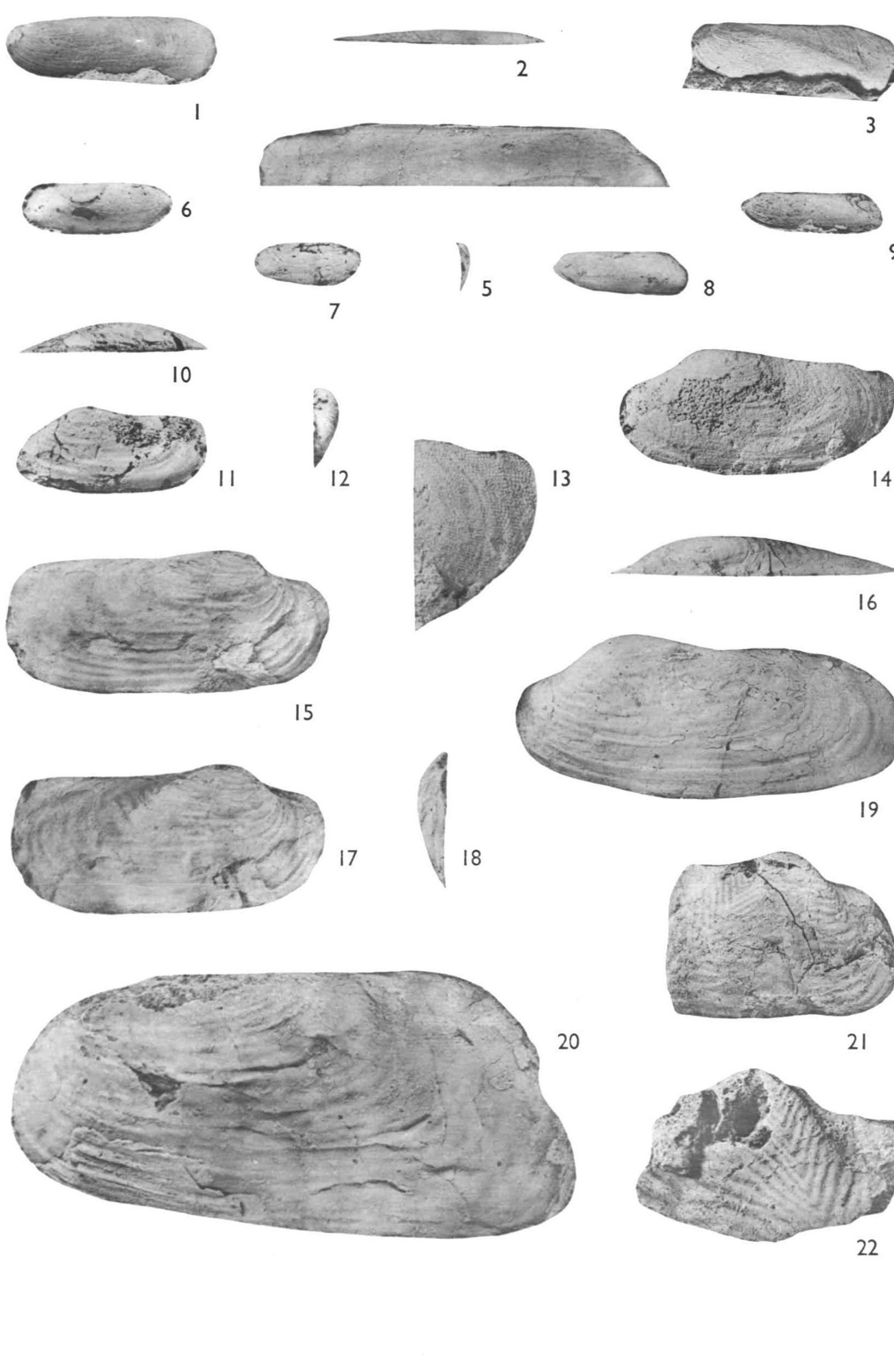
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Plate 7

Figs. 1-9.—*'Solemya' holmwoodensis* sp. nov. .... Page 59

Figs. 1-4.—Holotype. 1. Dorsal view of posterior part of shell showing the structure of the 'nymphs'. × 2. 2. Tilted dorsal view showing 'nymphs' and elongated ligament area of the long side. × 1. 3. Side view of right valve. × 2 approx. 4. Side view of left valve. × 1.

Fig. 5.—Paratype B, side view of a left valve. × 1.

Figs. 6-7.—Paratype C. × 1. 6. Dorsal view. 7. Front view.

Figs. 8-9.—Paratype A. 8. Dorsal view. × 1. 9. Surface ornament of ventral part of right valve below the umbo. × 4.

Fig. 10.—*Solemya australis* Lamarck. × 2 .... Page 59

Queensland University Geology Museum, No. F 36031, internal view of right valve.

Plate 7

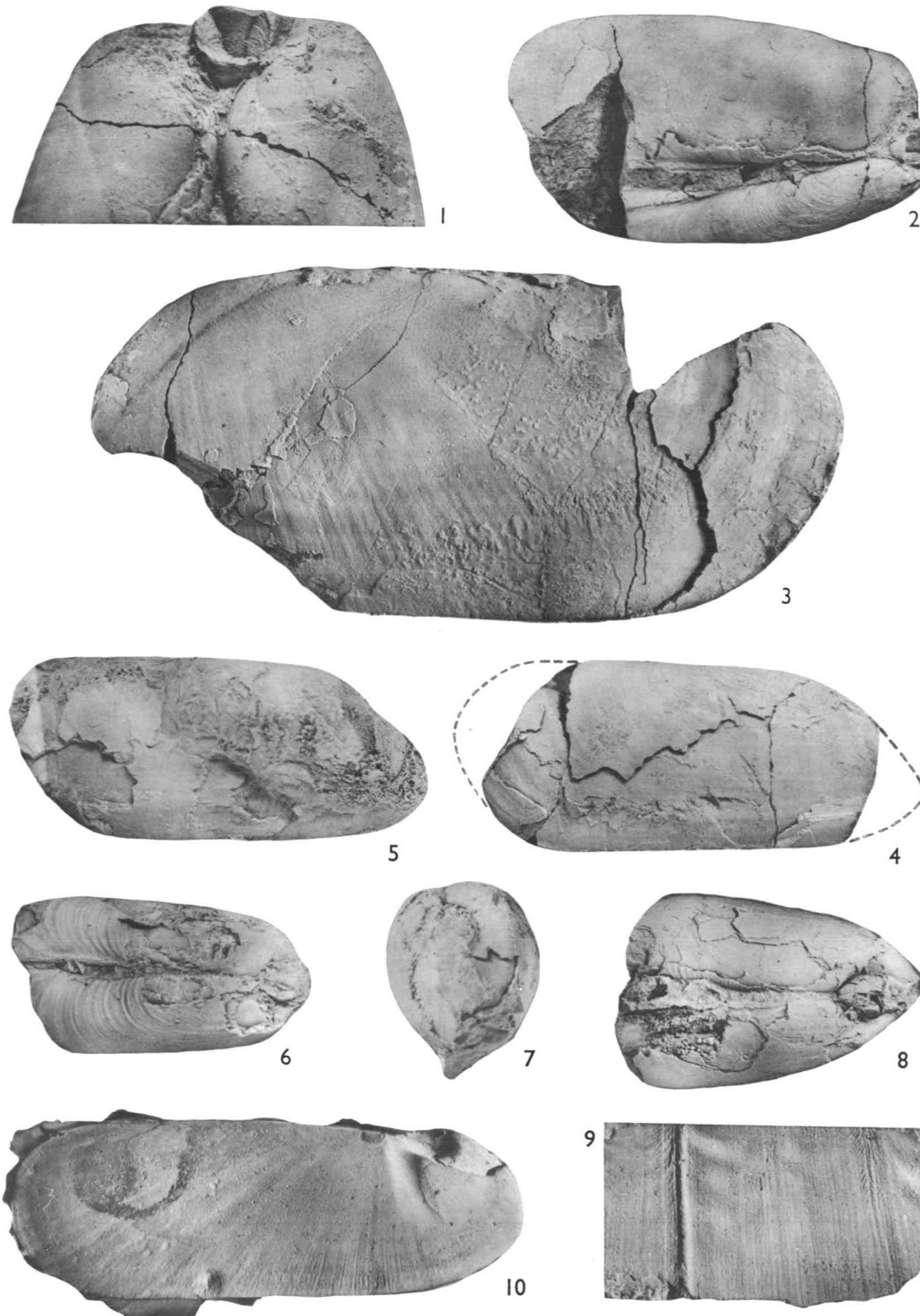

PLATE 8

FIGS. 1-4.—*Lithophaga*? sp. .... Page 63

FIGS. 1-2.—Figured Specimen B, a left valve. × 2. 1. Side view. 2. Front view.

FIGS. 3-4.—Figured Specimen A, a right valve. 3. Side view. × 1 (front part of shell is incomplete). 4. Back part of shell showing the external ornament. × 4.

FIG. 5.—*Modiolus koneckii* sp. nov.? .... Page 62

Figured Specimen, CPC 3901, side view of a right valve. × 2.

FIGS. 6-11.—*Modiolus koneckii* sp. nov. .... Page 61

FIG. 6.—Paratype D, a right valve. × 1.

FIG. 7.—Paratype B, a right valve. × 1.

FIG. 8.—Paratype A, a right valve. × 2.

FIG. 9.—Paratype C, a right valve. × 2.

FIGS. 10-11.—Holotype, a right valve. × 1. 10. Dorsal view. 11. Side view.

FIGS. 12-16.—*Chaenomya* sp. .... Page 51

FIGS. 12-13.—Figured Specimen A. × 1. 12. Side view of left valve. 13. Dorsal view.

FIG. 14.—Figured Specimen B, a left valve. × ½.

FIGS. 15-16.—Figured Specimen C. 15. External impression showing external ornament. × 4. 16. Dorsal view, the valves are sprung open so that the view of the left valve is a tilted side view. × 1.

FIGS. 17-18.—*'Solemya' holmwoodensis* sp. nov. .... Page 59

FIGS. 17 and 18.—Holotype showing internal ornament of shell. × 5½.

FIG. 19.—*Solemya australis* Lamarck .... Page 59

Queensland University Geology Museum, No. F 36031, showing internal ornament of shell. × 12.

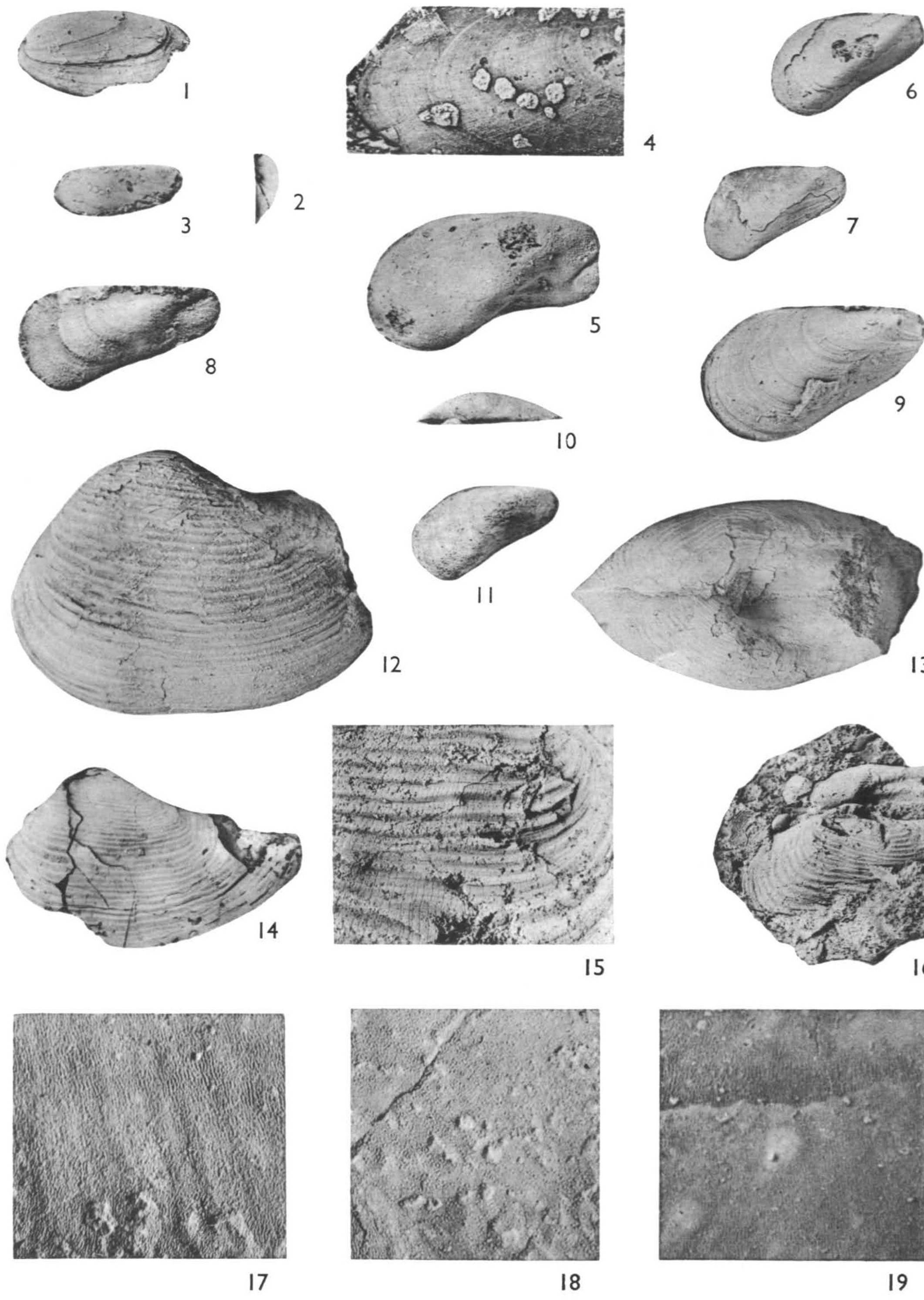
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PLATE 9

FIGS. 1-7; 9.—*Atomodesma mytiloides* Beyrich 1864. .... Page 67

FIGS. 1-4.—Figured Specimen A, a right valve. 1. Side view. × 1. 2. Latex cast of impression showing ligament groove. × 2. Note single deeply marked line regarded as a growth-line. 3. Front view. × 1. 4. Dorsal view. × 1.

FIGS. 5-6.—Figured Specimen D. × 1. 5. Dorso-posterior view showing relative convexity of valves. 6. Side view of right valve.

FIG. 7.—Figured Specimen C, side view of a left valve. × 2.

FIG. 9.—Figured Specimen B, side view of a left valve. × 1.

FIGS. 8; 10-12.—*Atomodesma* cf. *timorense* Wanner 1922 .... Page 69

FIG. 8.—Figured Specimen B, side view of a left valve. × 1.

FIGS. 10-12.—Figured Specimen A, a left valve. × 1. 10. Dorsal view. 11. Side view. 12. Front view.

FIGS. 13-17.—*Atomodesma mitchelli* (McCoy) 1847. × 1. .... Page 64

FIGS. 13-15.—Australian Museum, No. F 48885. 13. Side view of left valve. 14. Side view of right valve, showing also the impression of the hinge and the inequality of valves. 15. Dorso-posterior view.

FIGS. 16-17.—Australian Museum, No. F 2170. 16. Front view showing impression of septum and possibly a small anterior ear. 17. Side view of right valve.

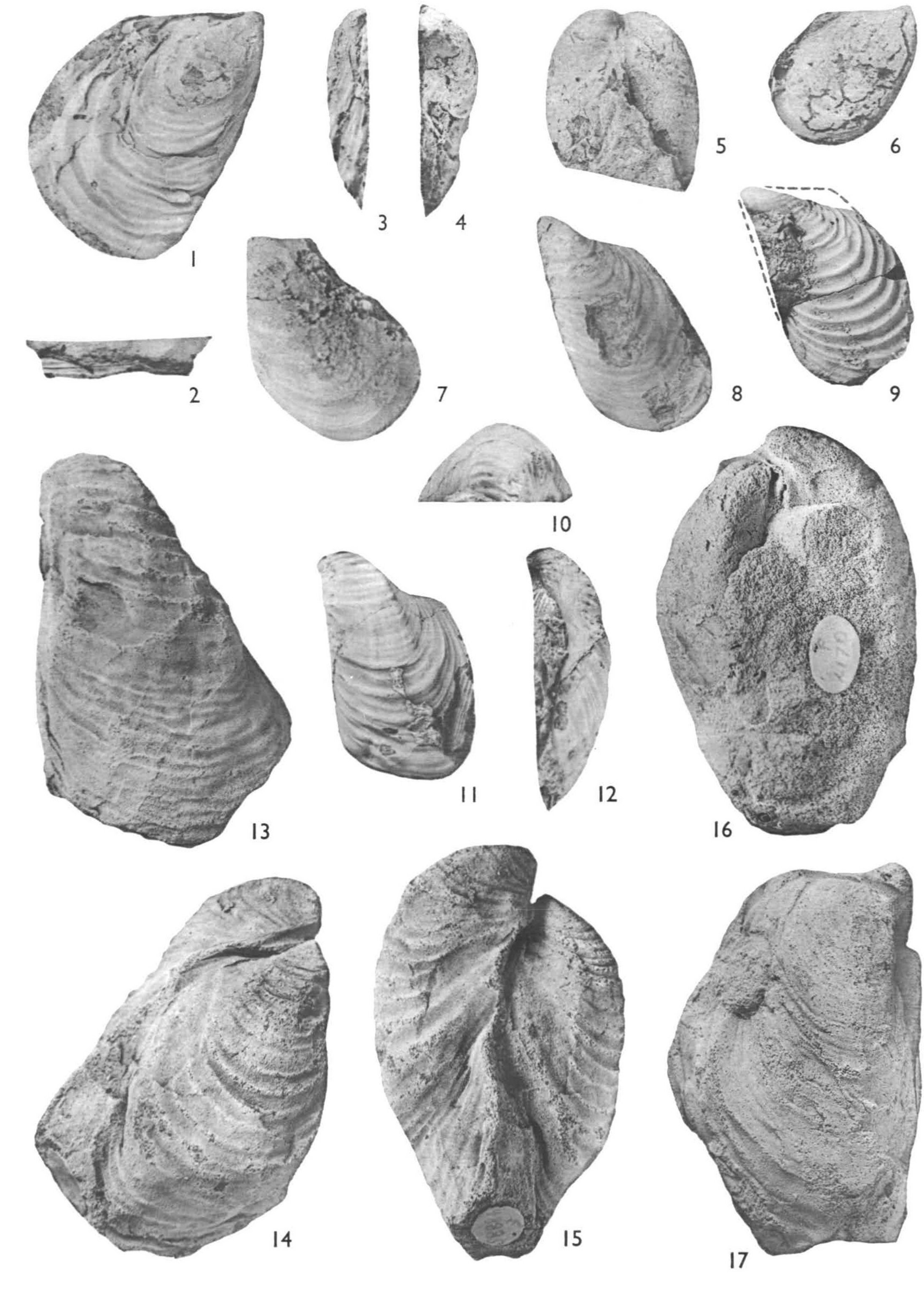
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PLATE 10

FIG. 1.—*Atomodesma trechmanni* (Marwick) 1935 .... Page 64
Ligament of a plaster cast made from holotype. × 1.

FIGS. 2-9.—*Atomodesma mytiloides* Beyrich 1864, var. nov. .... Page 68

FIGS. 2-5.—Figured Specimen A. 2. View showing ligament groove of right valve. × 2. 3. Side view of right valve. × ½ (none of left valve visible). 4. Front view. × ½ (valves may be slightly apart at front). 5. View showing anterior ear of right valve. × 1.

FIGS. 6-7.—Figured Specimen C. 6. Side view of right valve. × 1. 7. View showing ligament groove of right valve. × 2.

FIGS. 8-9.—Figured Specimen B. 8. View showing ligament groove of left valve. × 2. 9. Side view of right valve showing also partly preserved umbonal part of left valve. × 1.

FIGS. 10-15.—*Pseudomyalina* sp. .... Page 69

FIG. 10.—Figured Specimen B, part of internal impression of a large left valve showing the longitudinal ligament grooves. × ½.

FIGS. 11-13.—Figured Specimen A, plasticene impression of a left valve. × ½. 11. Side view. 12. Dorsal view. 13. Front view.

FIGS. 14-15.—Figured Specimen C, a left valve. × 1. 14. Side view without ammonium chloride coating to show nacreous layer on inside part of shell—shiny darker layer. 15. Tilted side view showing faint impression of adductor muscle.

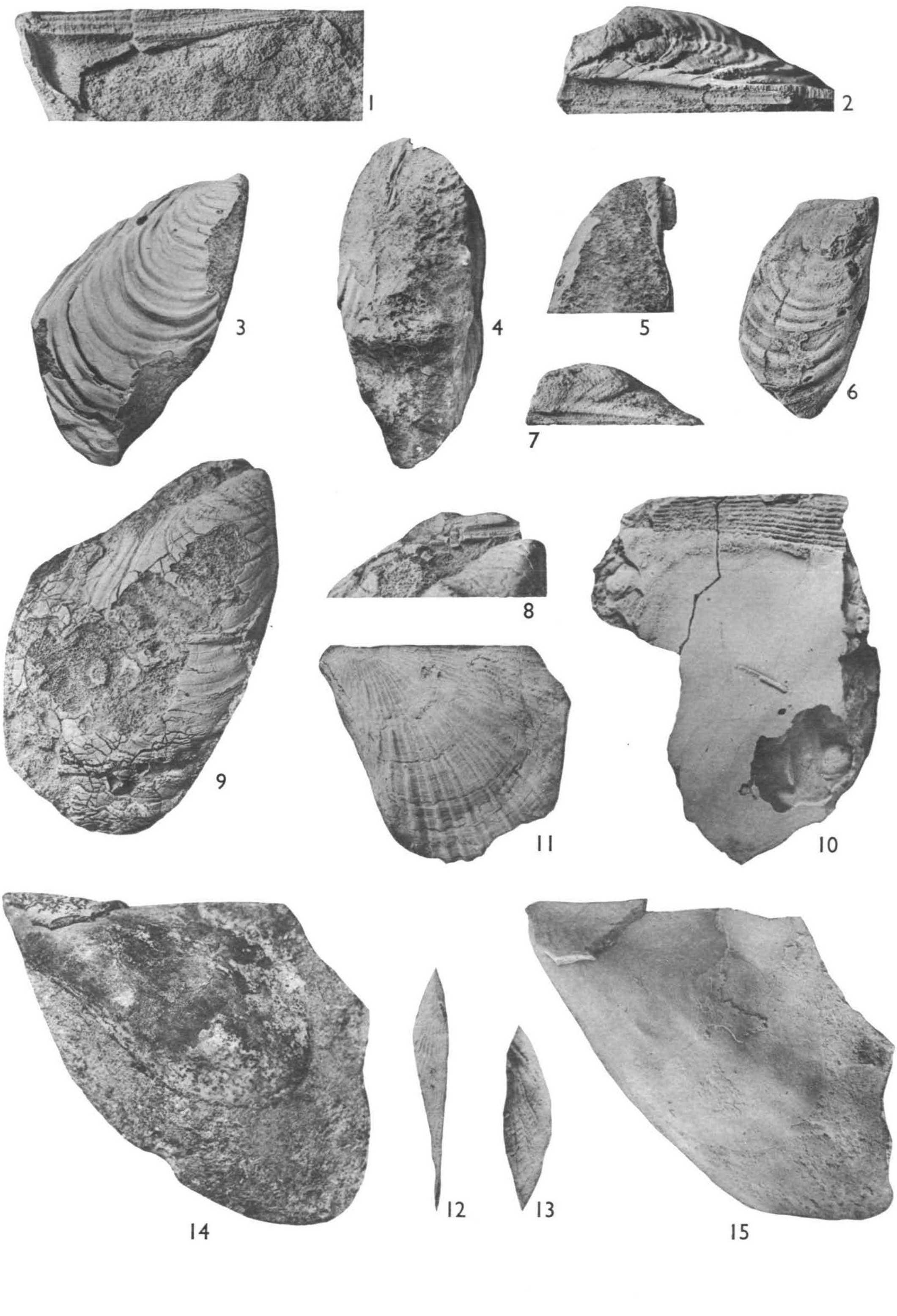
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PLATE 11

FIGS. 1-3.—*Aviculopecten* sp. nov. .... Pages 78, 81

FIG. 1.—Queensland University Geology Museum, No. F 21062, a right valve showing increase in ribbing by both subdivision and intercalation. × 1.

FIGS. 2-3.—Geological Survey of Queensland, No. F 1498—a left valve figured by Etheridge (1892, pl. 43, fig. 2) as *Deltopecten illawarensis*. 2. Latex cast showing the hinge. × 1. 3. Side view. × ½.

FIG. 4.—*Pinctada chemnitzi* (Phillipi), Hynd 1955 .... Page 77

Left and right valves of a single specimen. × 1.

FIG. 5.—*Aviculopecten tenuicollis* (Dana) 1847. .... Page 82

Hypotype E, inside of shell showing concentric interlocking lamellae. × 8.

FIGS. 6-8.—*Maccoyella barkleyi* (Moore) 1870. .... Page 74

FIG. 6.—Queensland University Geology Museum, No. F 27411, inside of a left valve from Bungeworgorai Creek, Roma District, showing radiating structure. × 6.

FIG. 7.—Queensland University Geology Museum, No. 27413, concentric lamellar layer of left valve near outside of valve. × 3. Locality not known.

FIG. 8.—Queensland University Geology Museum, No. 27412, concentric lamellar layer of a left valve near umbo. × 3. Locality not known.

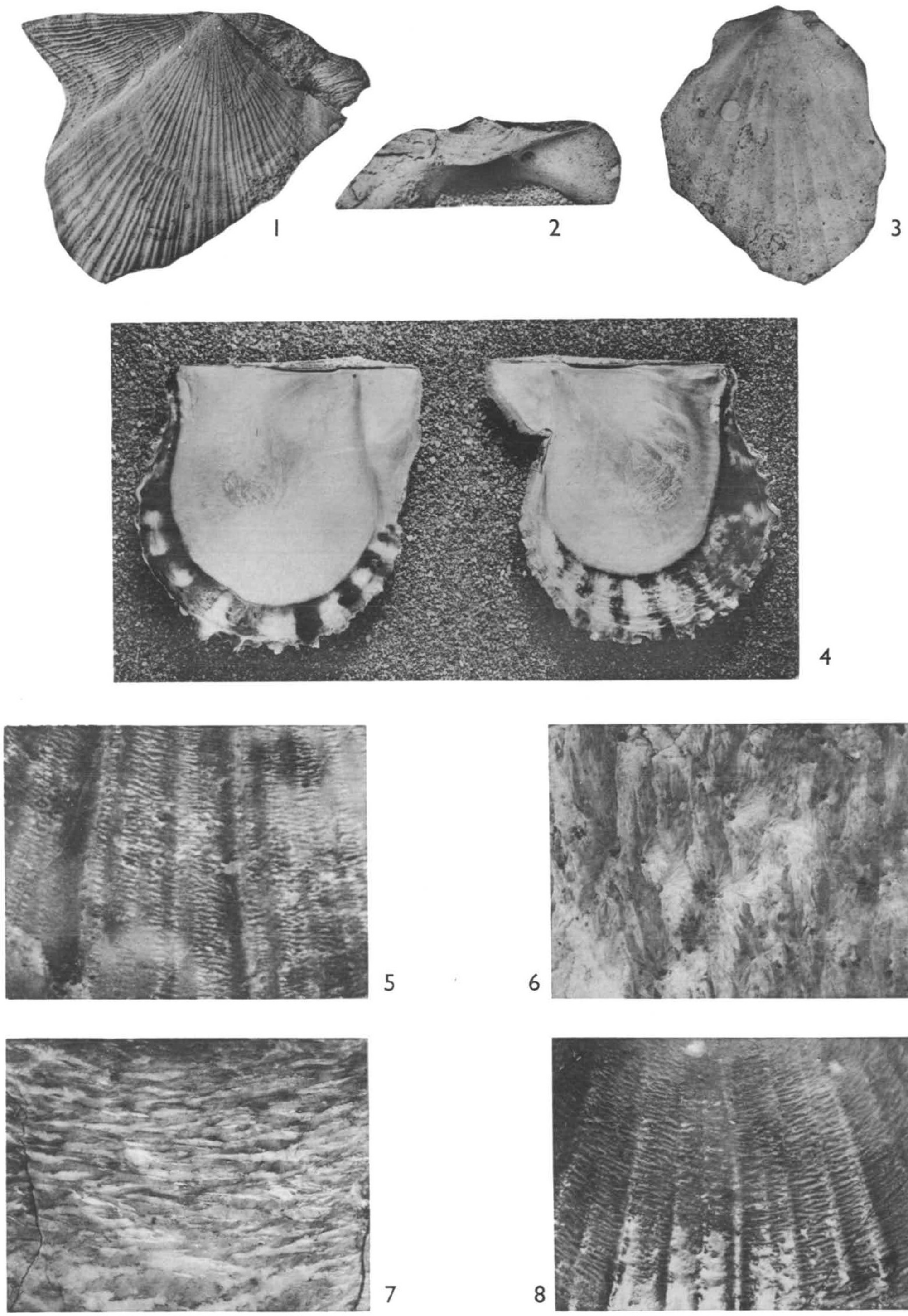

PLATE 12

FIGS. 1-3.—*Deltopecten limaeformis* (Morris) 1845. × ½ .... Page 78

FIGS. 1-2.—Geological Survey of Queensland, No. F 1500, figured by Etheridge, Jnr. (1892, pl. 41, fig. 3) as *Deltopecten illawarensis*. 1. Side view of left valve. 2. Dorsal view showing biconvexity.

FIG. 3.—Queensland University Geology Museum, No. F 20791, side view of a left valve, more completely preserved but comparable with Etheridge's figured specimen.

FIG. 4.—*Deltopecten* sp. × ½. .... Page 81

Side view of external impression of a right valve.

FIGS. 5-11.—*Deltopecten waterfordi* sp. nov. .... Page 79

FIG. 5.—Paratype C, a right valve, showing hinge. × 1.

FIG. 6.—Paratype B, side view of a large left valve. × ½.

FIG. 7.—Paratype A, side view of a left valve. × ½.

FIGS. 8-11.—Holotype, a right valve. 8. Front view. × ½. 9. Side view. × ½. 10. Dorsal view. × ½. 11. Ribs showing incipient subdivision of primary ribs. × 1.

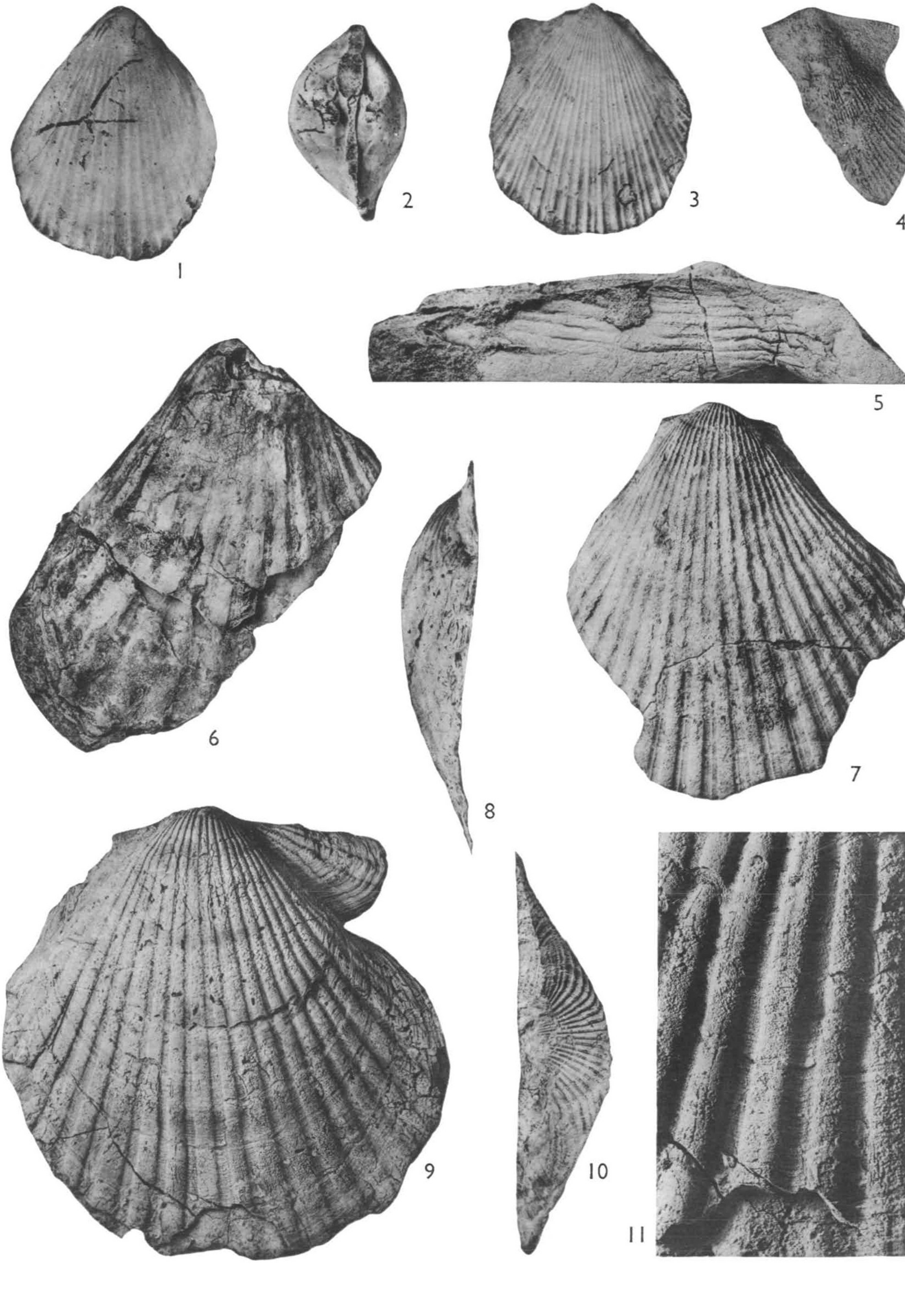
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Plate 13

FIGS. 1-4.—*Girtypecten ovalis* sp. nov. × 2. .... Page 85

FIGS. 1-2.—Holotype, a left valve. 1. Dorsal view. 2. Side view.

FIG. 3.—Paratype B, side view of a right valve.

FIG. 4.—Latex cast of Paratype A, an external impression of part of a left valve.

FIGS. 5-9.—*Acanthopecten*? sp. .... Page 86

FIG. 5.—Figured Specimen D, side view of a left valve. × 1.

FIG. 6.—Figured Specimen B, side view of latex cast from external impression. × 2.

FIGS. 7-8.—Figured Specimen A, a left valve. 7. Side view. × ½. 8. Natural cross-section of a spine. × 2.

FIG. 9.—Figured Specimen C, side view of a left valve. × 1.

FIGS. 10-11.—*Aviculopecten*? sp. .... Page 84

Figured Specimen, a left valve. 10. Side view. × 1. 11. Plasticene cast of external impression showing details of the ribbing. × 2.

FIGS. 12-17.—*Aviculopecten tenuicollis* (Dana) 1847. .... Page 82

FIG. 12.—Hypotype E, a right and left valve with the proximal part of left valve broken away and showing the right valve tucked inside the left. × 1.

FIGS. 13-14.—Hypotype A, a left valve—latex cast. × 1. 13. Dorsal view. 14. Side view.

FIG. 15.—Hypotype C, internal view showing ligament with chondrophore. × 1.

FIG. 16.—Hypotype D, side view of a left valve. × 2.

FIG. 17.—Hypotype B, side view of a left valve. × 1

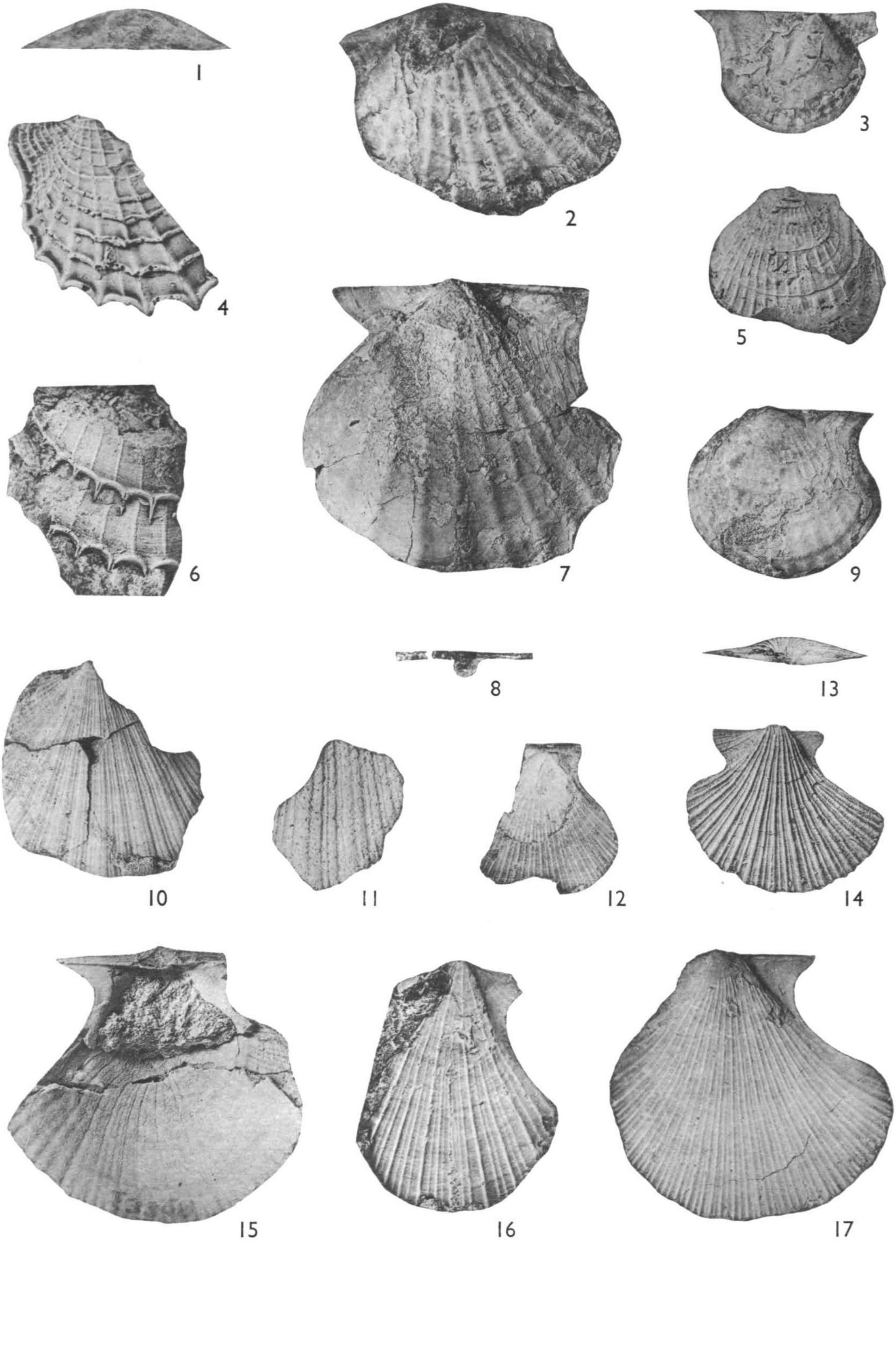
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Plate 14

Fig. 1.—*Aviculopecten tenuicollis* (Dana) 1847. × 1. .... Page 83
Type specimen from Harper's Hill, New South Wales, figured by Dana (1849, pl. 9, figs. 7; 7a). Negative provided by courtesy of Remington Kellogg, Director, and Porter M. Keir of the United States National Museum, Washington, D.C.

Figs. 2-8.—*Euchondria callytharraensis* sp. nov. .... Page 89
Fig. 2.—Paratype C, a right valve—side view of a plasticene squeeze. × 2.
Figs. 3-5.—Holotype, a left valve—latex cast. × 1. 3. Side view. 4. Dorsal view. 5. Front view.
Fig. 6.—Paratype B, side view of a left valve. × 1.
Figs. 7-8.—Paratype A, a right valve. 7. Side view. × 2. 8 Details of hinge. × 4.

Figs. 9-12.—*Streblopteria* sp. .... Page 88
Fig. 9.—Figured Specimen C, side view of a right valve. × 1.
Fig. 10.—Figured Specimen B, side view of a left valve. × 2.
Fig. 11.—Figured Specimen D, side view of a left valve. × 2.
Fig. 12.—Figured Specimen A, side view of a left valve. × 2.

Figs. 13-16.—*Palaeolima* sp. nov. .... Page 92
Figs. 13-15.—Figured Specimen B, a left valve. 13. Dorsal view. × 1. 14. Back view. × 1. 15. Side view. × 2.
Fig. 16.—Figured Specimen A, side view of a right valve. × 2.

Fig. 17.—*Streblopteria*? sp. .... Page 88
Side view of a presumed left valve.

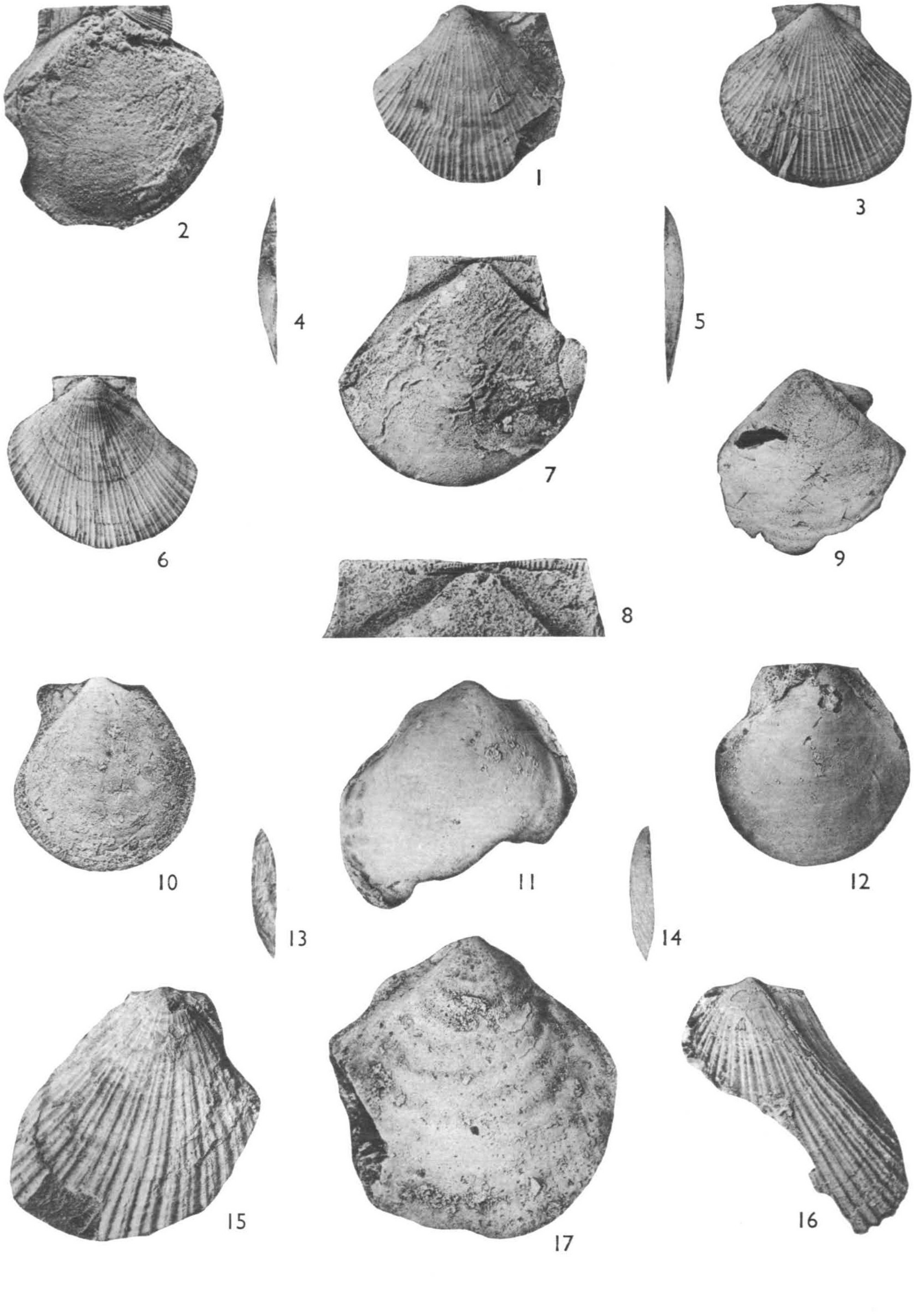
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PLATE 15

FIGS. 1-5.—*Plagiostoma*? sp. nov. .... Page 93

FIG. 1.—Figured Specimen A, side view of a left valve. × 2.

FIGS. 2-3.—Figured Specimen C, a left valve. × 2. 2. Side view. 3. Back view.

FIG. 4.—Figured Specimen D, side view of a left valve. × 4.

FIG. 5.—Figured Specimen B, tilted dorsal view of a left valve—impression of ligament pit can be seen as a small projection slightly towards the front of the dorsal commissure. × 2.

FIGS. 6-13.—*Elimata guppyi* gen. et sp. nov. .... Page 94

FIG. 6.—Paratype A, side view of a left valve. × 3.

FIG. 7.—Paratype B, side view of right valve. × 2.

FIGS. 8; 13.—Paratype C, a right valve. 8. Dorsal view. × 2. 13. Side view. × 3.

FIG. 9.—Paratype D, side view of right valve. × 2.

FIGS. 10-12.—Holotype, a left valve. × 2. 10. Side view. 11. Back view. 12. Dorsal view.

FIGS. 14-15.—*Stutchburia randsi* (Etheridge Jnr.), 1892. × 2. .... Page 97

Geological Survey of Queensland, No. F 943, type specimen figured by Etheridge Jnr. (1892, pl. 14, fig. 14). 14. Dorsal view. 15. Side view.

FIGS. 16-23.—*Stutchburia hoskingae* sp. nov. .... Page 96

FIG. 16.—Paratype D, side view of a right valve. × 1.

FIG. 17.—Paratype B, a left valve, side view of plasticene squeeze. × 1.

FIG. 18.—Paratype C, side view of a left valve. × 2. Note impression of posterior lateral tooth.

FIG. 19.—Paratype E, side view of part of a right valve. × 1.

FIGS. 20-22.—Paratype A, a left valve. × 1. 20. Dorsal view. 21. Front view. 22. Side view.

FIG. 23.—Holotype, side view of right valve. × 1.

FIG. 24.—*Stutchburia variabilis* Dickins 1957. × 1. .... Page 96

Side view of plasticene squeeze of a right valve.

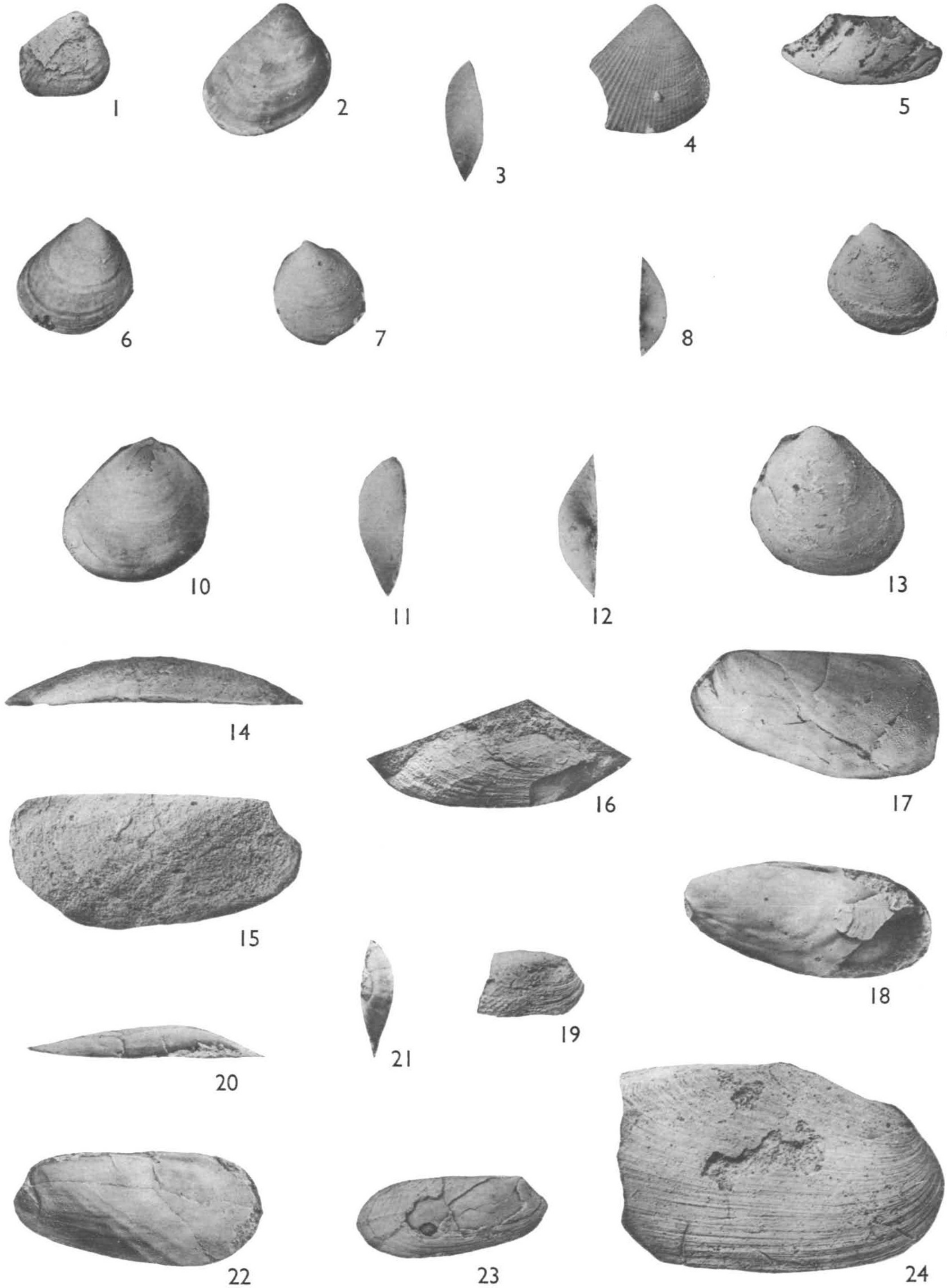
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PLATE 16

FIG. 1.—*Conocardium* sp. × 2. .... Page 105
Side view of a partly preserved valve.

FIGS. 2-9.—*Astartella obliqua* sp. nov. .... Page 104

FIG. 2.—Paratype B, internal view of a left valve. × 4.

FIGS. 3-6.—Holotype, a right valve. × 2. 3-5. Latex cast made from external impression; front, dorsal and side views. 6. Latex cast made from internal impression.

FIGS. 7-8.—Paratype A, a left valve. × 2. 7. Internal impression. 8. Latex cast of internal impression.

FIG. 9.—Paratype C, side view of a right valve. × 2.

FIGS. 10-19.—*Cypricardinia*? *elegantula* sp. nov. .... Page 98

FIGS. 10-12.—Paratype A. × 1. 10. Side view of right valve. 11. Front view. 12. Side view of left valve.

FIG. 13.—Paratype C, side view of a left valve. × 1.

FIGS. 14-15.—Paratype E. × 2. 14. Dorsal view. 15. Latex cast showing dentition of left valve.

FIG. 16.—Paratype D, a left valve, showing the dentition, ligament and shape. × 2.

FIGS. 17-18.—Holotype, a left valve. 17. Side view. × 1. 18. Umbonal part of shell showing details of the ornament. × 4.

FIG. 19.—Paratype B, internal impression of part of a left valve showing posterior lateral teeth. × 1.

FIGS. 20-21.—*Cypricardinia*? *gregarius* (Etheridge Jnr.) 1900. × 2. .... Page 98
Australian Museum, No. F 29507, latex casts to show dentition. 20. Left valve. 21. Right valve.

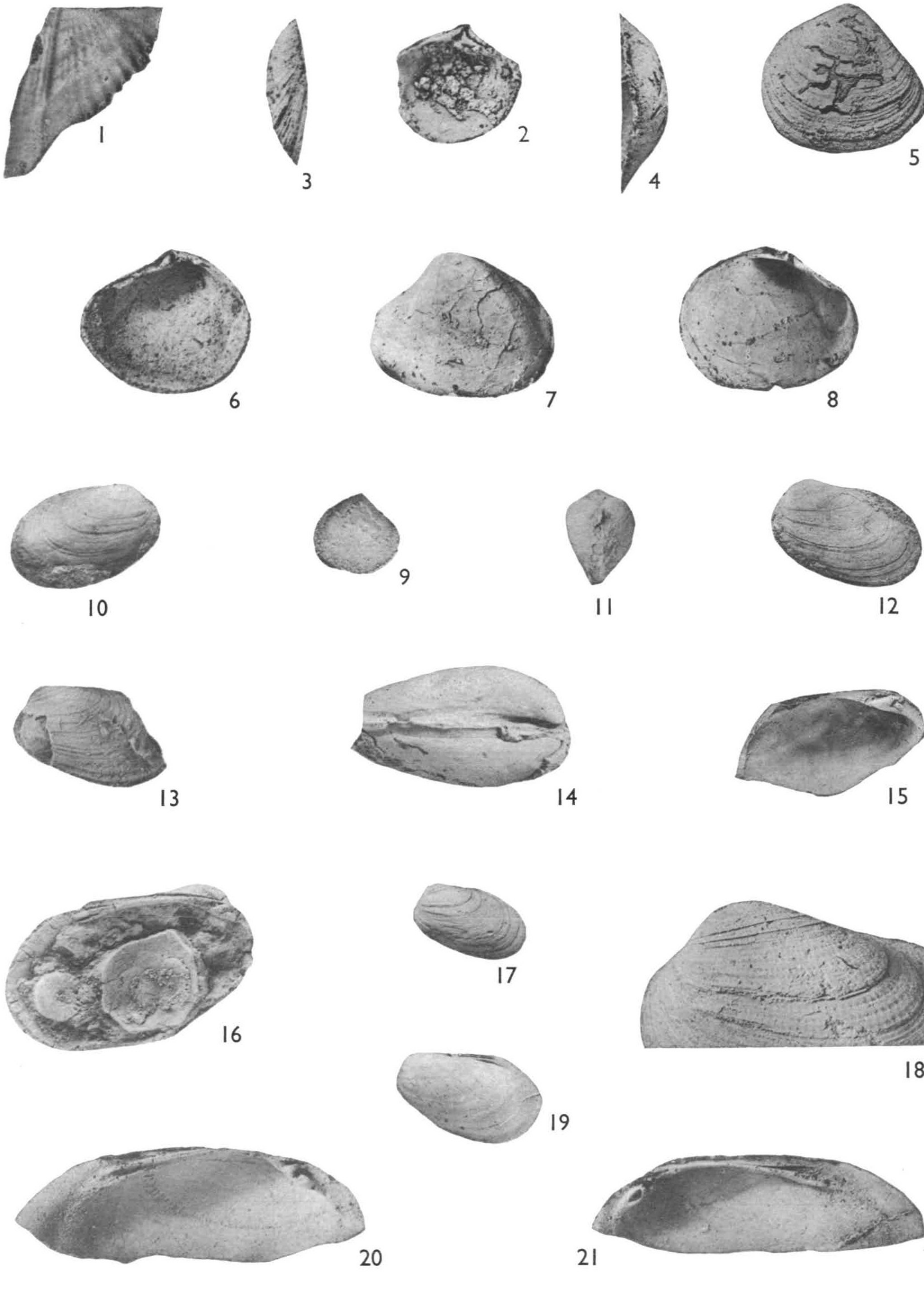
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PLATE 17

FIGS. 1-9.—*Schizodus sandimanensis* sp. nov. .... Page 101

FIG. 1.—Paratype D, side view of left valve. × 2.

FIG. 2.—Paratype B, latex cast made from internal impression of a right valve. × 2.

FIGS. 3-5.—Holotype, a right valve. × 1. 3. Side view. 4. Front view. 5. Dorsal view.

FIG. 6.—Paratype A, internal impression of a left valve. × 1.

FIGS. 7-8.—Paratype E, a left valve. × 2. 7. Side view. 8. Tilted to show posterior adductor scar.

FIG. 9.—Paratype C. × 1.

FIGS. 10-19.—*Schizodus fitzroyensis* sp. nov. .... Page 100

FIG. 10.—Paratype D, side view of a left valve. × 1.

FIG. 11.—Paratype C, side view of a left valve. × 1.

FIG. 12.—Paratype B, side view of a left valve. × 1.

FIG. 13.—Paratype E, side view of a left valve. × 2.

FIGS. 14-17.—Holotype, internal impression of a right valve. 14. Front view. × 1. 15. Dorsal view. × 1. 16. Latex cast showing dentition. × 2. 17. Side view. × 1.

FIGS. 18-19.—Paratype A, internal impression of a left valve. 18. Latex cast showing hinge. × 2. 19. Side view. × 1.

FIG. 20.—*Schizodus* sp. × 1. .... Page 102

CPC 4018, side view of a left valve.

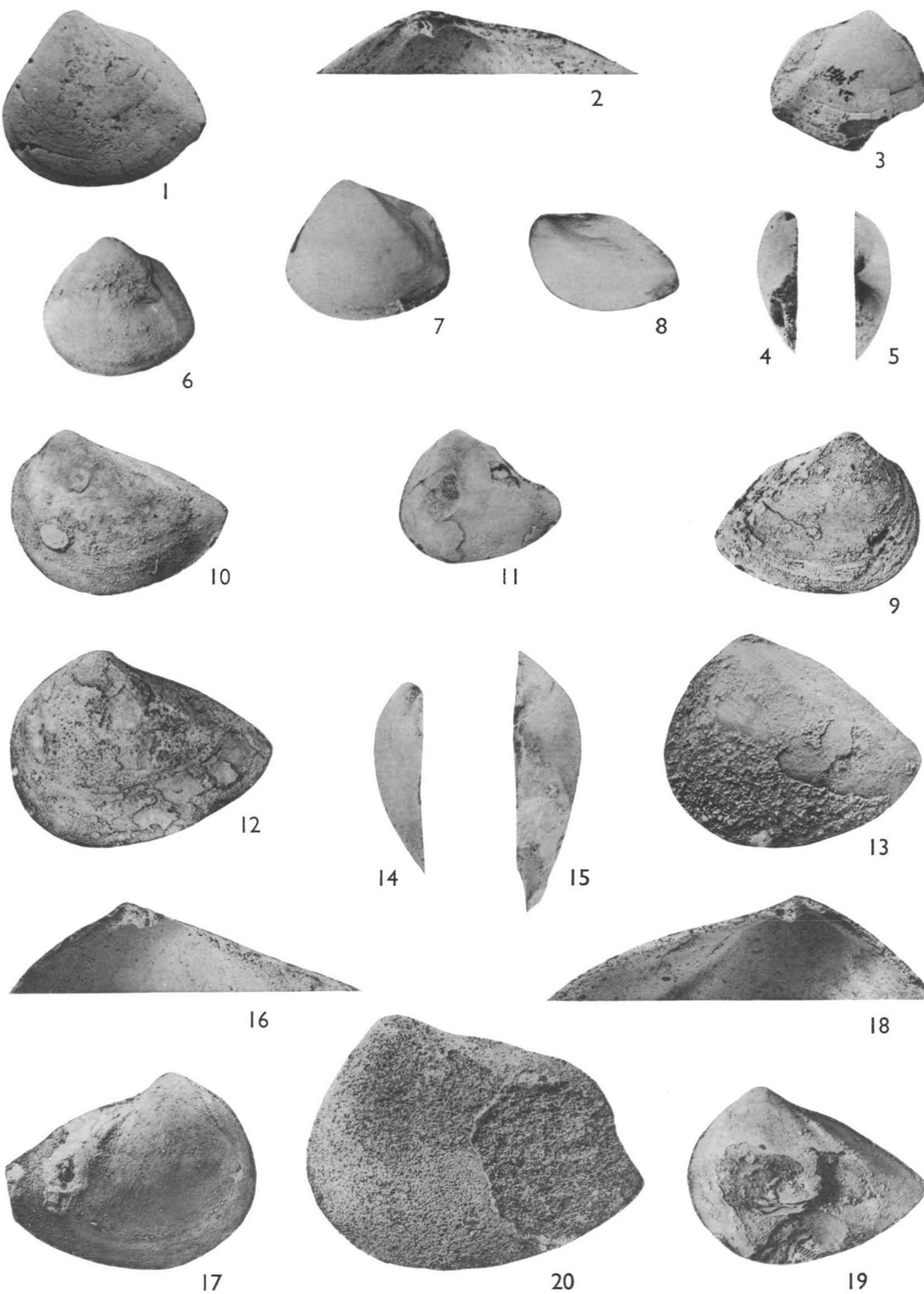
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PLATE 18

FIGS. 1-5.—*Oriocrassatella* sp. .... Page 103

FIG. 1.—Figured Specimen C, internal impression of a right valve. × 1.

FIG. 2.—Figured Specimen B, latex cast of external impression of left valve. × 1.

FIGS. 3-4.—Figured Specimen A, a right valve. 3. Latex cast of internal impression. × 2. 4. Plasticene squeeze of external impression. × 1.

FIG. 5.—Figured Specimen D, side view of a left valve. × 1.

FIGS. 6-15.—*Oriocrassatella stokesi* Etheridge Jnr., 1907. .... Page 103

FIG. 6.—Hypotype E (UWA Type No. 45421), part of a right valve showing the dentition. × 2.

FIG. 7.—Type specimen figured by Etheridge Jnr. (1907a, pl. 6, figs. 4; 5), borrowed from the South Australian Museum, Adelaide, by courtesy of Mr. H. M. Hale, Director, and Dr. B. Daily. × 2.

FIG. 8.—Plaster replica from the Australian Museum, Sydney, of the other original type specimen figured by Etheridge Jnr. (1907a, pl. 6, figs. 2, 3). × slightly less than 2. Australian Museum photograph.

FIG. 9.—Hypotype A (CPC 3962), hinge of a right valve. × 2.

FIGS. 10-12.—Hypotype B. (CPC 3963), a right valve. × 1. 10. Hinge. 11. Side view. 12. Front view.

FIG. 13-14.—Hypotype C (CPC 3964), a right valve. × 1. 13. Dorsal view. 14. Side view.

FIG. 15.—Hypotype D. (CPC 3965), internal view of a right valve. × 1.

This series of specimens shows clearly how variable preservation can affect the appearance of the dentition.

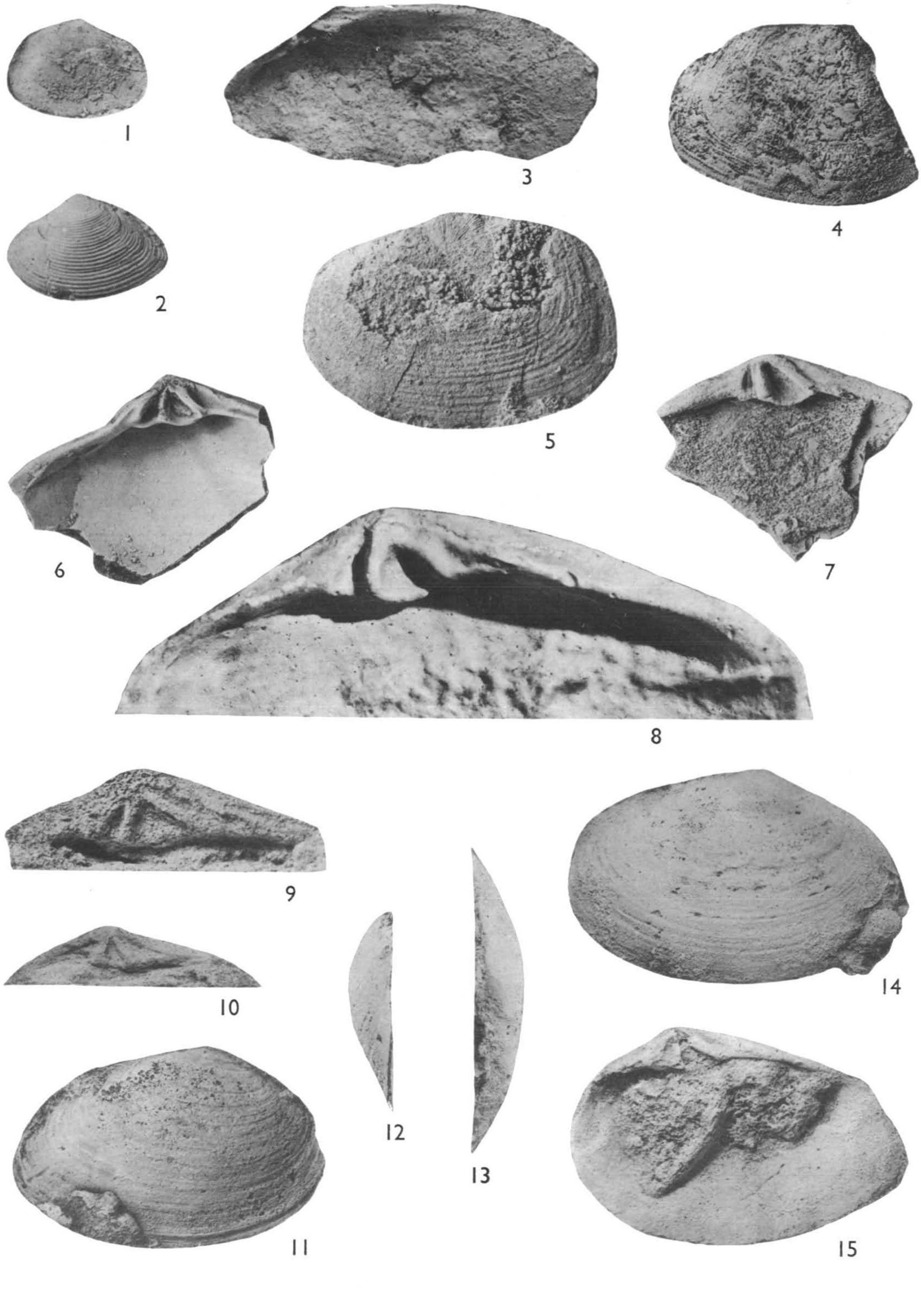
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PLATE 19

FIGS. 1-4.—*Bellerophon* sp. nov. × 1. .... Page 113

FIGS. 1-3.—Figured Specimen A. 1. Adapertural view. 2. Apertural view. 3. Side view.

FIG. 4.—Figured Specimen B, adapertural view.

FIGS. 5-13.—*Bellerophon* cf. *formani* .... Page 112

FIG. 5.—Figured Specimen D, adapertural view. × 2.

FIGS. 6-7.—Figured Specimen E. × 2. 6. Apertural view. 7. Adapertural view.

FIGS. 8-10.—Figured Specimen C. × 1. 8. Apertural view. 9. Side view. 10. Adapertural view.

FIGS. 11-12.—Figured Specimen B. × 1. 11. Adapertural view. 12. Side view.

FIG. 13.—Figured Specimen A, adapertural view. × 1.

FIGS. 14-22.—*Bellerophon formani* sp. nov. .... Page 111

FIGS. 14-15.—Paratype C. × 1. 14. Adapertural view. 15. View to show impression of the slit.

FIG. 16.—Paratype B, adapertural view. × 1.

FIGS. 17-18.—Paratype E, latex cast from external impression. × 2. 17. Side view. 18. Adapertural view.

FIG. 19.—Paratype A, latex cast from external impression, adapertural view. × 1.

FIGS. 20-22.—Holotype. × 1. 20. Side view. 21. View to show impression of slit. 22. Adapertural view.

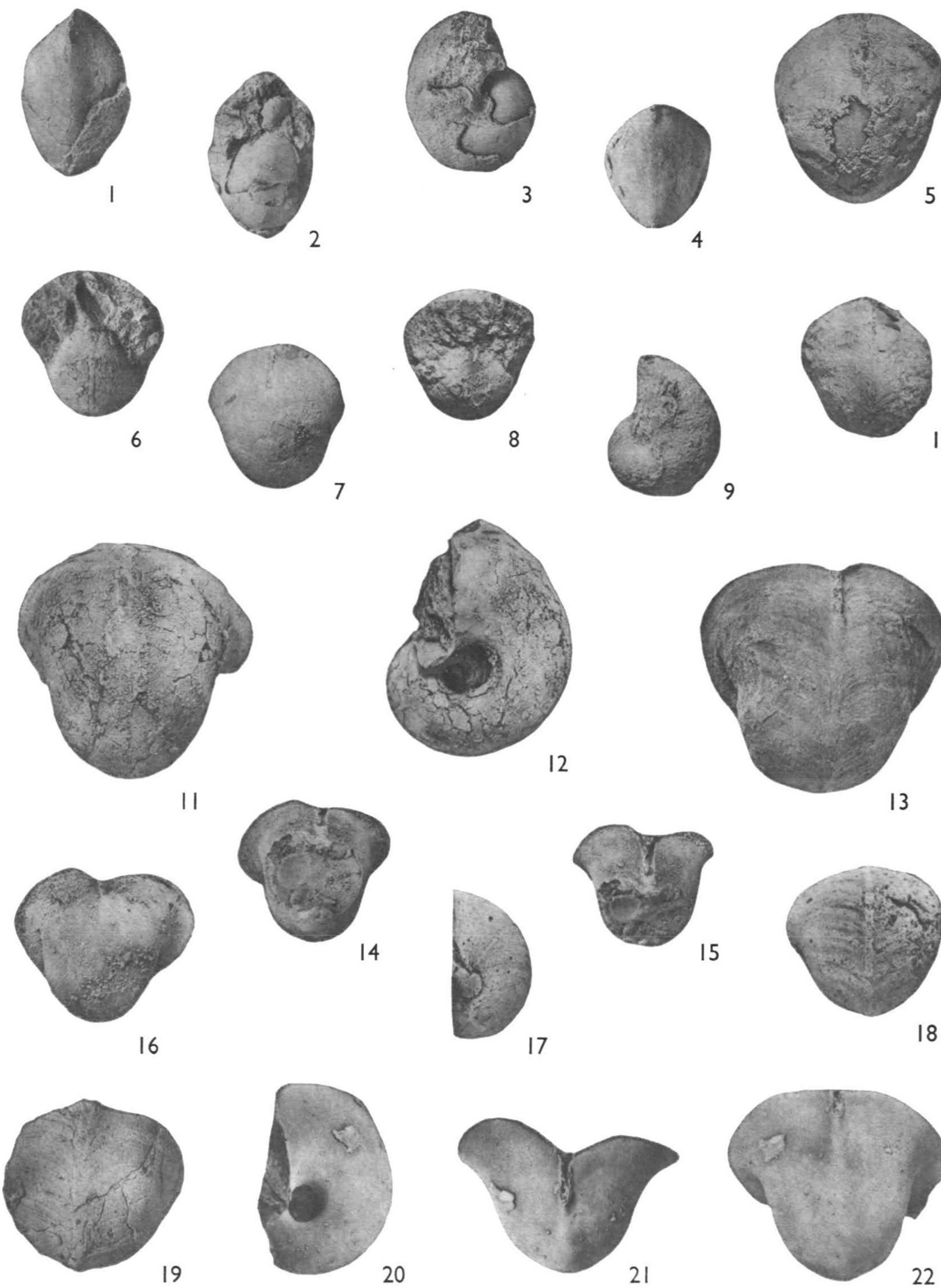
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Plate 20

Figs. 1-13.—*Stachella crucilirata* sp. nov. .... Page 116

Figs. 1-4.—Holotype. 1-3. Internal impression. × 1: adapertural view, side view and view to show impression of slit-band. 4. Latex cast of external impression. × 2.

Figs. 5-6.—Paratype B. × 1. 5. Adapertural view. 6. Apertural view.

Fig. 7.—Paratype D, adapertural view. × 2.

Figs. 8-11.—Paratype A. 8. Internal impression, adapertural view. × 1. 9-11. Latex cast of external impression. × 2: adapertural, side and tilted adapertural views.

Figs. 12-13.—Paratype C. × 2. 12. Apertural view. 13. Adapertural view.

Figs. 14-19.—*'Retispira' clarkei* sp. nov. .... Page 114

Figs. 14-15.—Paratype—latex cast. × 2. 14. Side view. 15. Adapertural view.

Figs. 16-19.—Holotype. × 2. 16-17. Internal impression: adapertural and tilted adapertural views. 18-19. Latex cast of external impression: adapertural and side views.

Figs. 20-24.—*Retispira irwinensis* sp. nov. × 2 .... Page 114

Fig. 20.—Paratype A, adapertural view.

Figs. 21-22.—Paratype B. 21. Adapertural view. 22. Side view.

Figs. 23-24.—Holotype. 23. Side view. 24. Adapertural view.

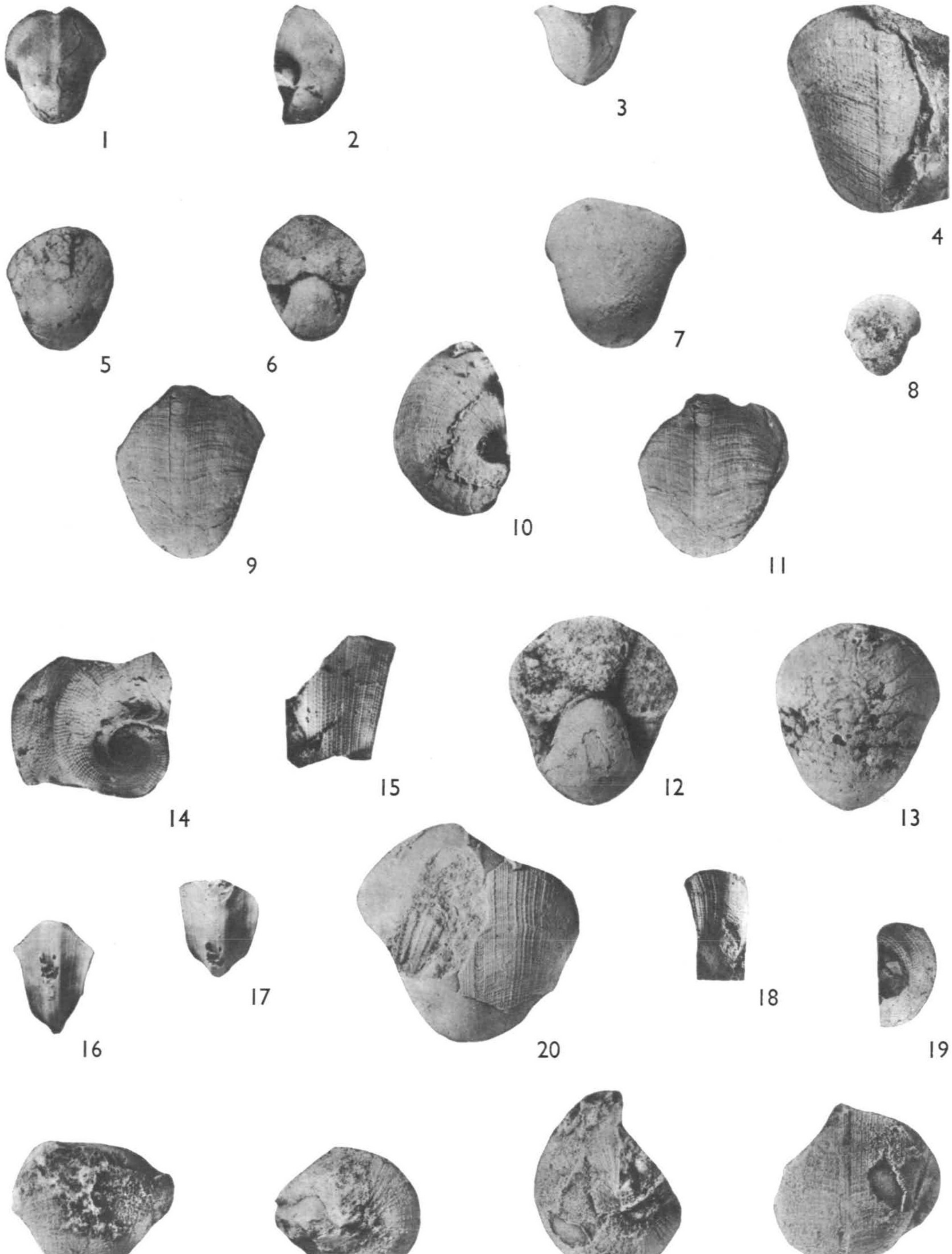
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Plate 21

Figs. 1-9.—*Euphemites wynnensis* sp. nov. × 2. .... Page 107

Fig. 1.—Paratype E, plasticene squeeze.

Fig. 2.—Paratype A, adapertural view.

Fig. 3.—Paratype D, plasticene squeeze.

Figs. 4-6.—Holotype. 4. Adapertural view. 5. Side view. 6. Apertural view.

Fig. 7.—Paratype C, adapertural view.

Figs. 8-9.—Paratype B. 8. Adapertural view. 9. Side view.

Figs. 10-11.—*Warthia intermedia* sp. nov.? × 2. .... Page 110

Figured Specimen (CPC 3983). 10. Side view. 11. Adapertural view.

Figs. 12-19.—*Warthia intermedia* sp. nov. .... Page 109

Fig. 12.—Paratype A, side view. × 4.

Figs. 13-14.—Paratype B. × 4. 13. Adapertural view. 14. Side view.

Figs. 15-16.—Paratype C. × 4. 15. Side view. 16. Apertural view.

Figs. 17-19.—Holotype. × 2. 17. Adapertural view. 18. Apertural view. 19. Side view.

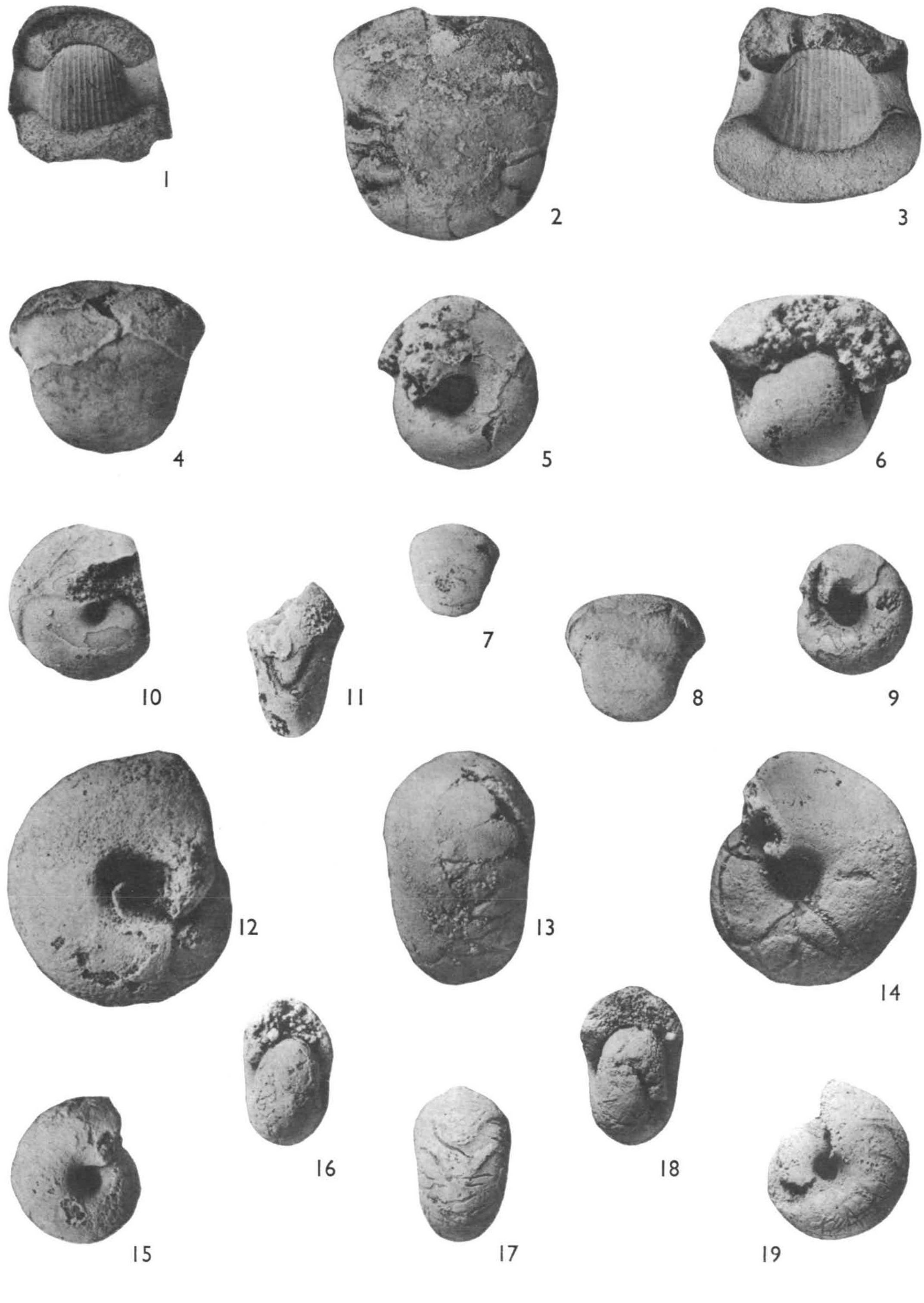
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Plate 22

Figs. 1-8.—*Warthia*? *carinata* sp. nov. .... Page 110

Fig. 1.—Paratype A, side view. × 2.

Figs. 2-4.—Holotype. × 4. 2. Adapertural view. 3. Apertural view. 4. Side view.

Figs. 5-6.—Paratype C. × 4. 5. Side view. 6. Apertural view.

Figs. 7-8.—Paratype B. × 4. 7. Adapertural view. 8. Side view.

Figs. 9-12.—*Warthia* cf. *micromphala* (Morris) 1845. × 1. .... Page 109

Figs. 9-11.—Figured Specimen A (CPC 3984—Field No. FL 178) from the Upper Liveringa beds, exact locality not clear but from Dry Corner Syncline, within 300 feet of top of formation. 9. Side view. 10. Tilted adapertural view showing slit and slit-band. 11. Adapertural view.

Fig. 12.—Figured Specimen B (CPC 3985 — Field No. FL 81) from the Lower Liveringa beds, 3¼ miles on a bearing of 131° from Sandfly Yard and 1½ miles on a bearing of 342° from Victory Bore, Luluigui Station (Mount Anderson 4-mile Sheet), showing the faint impression of the slit-band.

Figs. 13-21.—*Mourlonia*? *obscura* sp. nov. × 4. .... Page 124

Figs. 13-14.—Holotype—latex cast. 13. Tilted apical view. 14. Side view.

Figs. 15-16.—Paratype A—latex cast. 15. Tilted apical view. 16. Side view.

Fig. 17.—Paratype D, apertural view.

Fig. 18.—Paratype C, side view.

Fig. 19.—Paratype E, apertural view.

Figs. 20-21.—Paratype B. 20. Apertural view. 21. Tilted basal view.

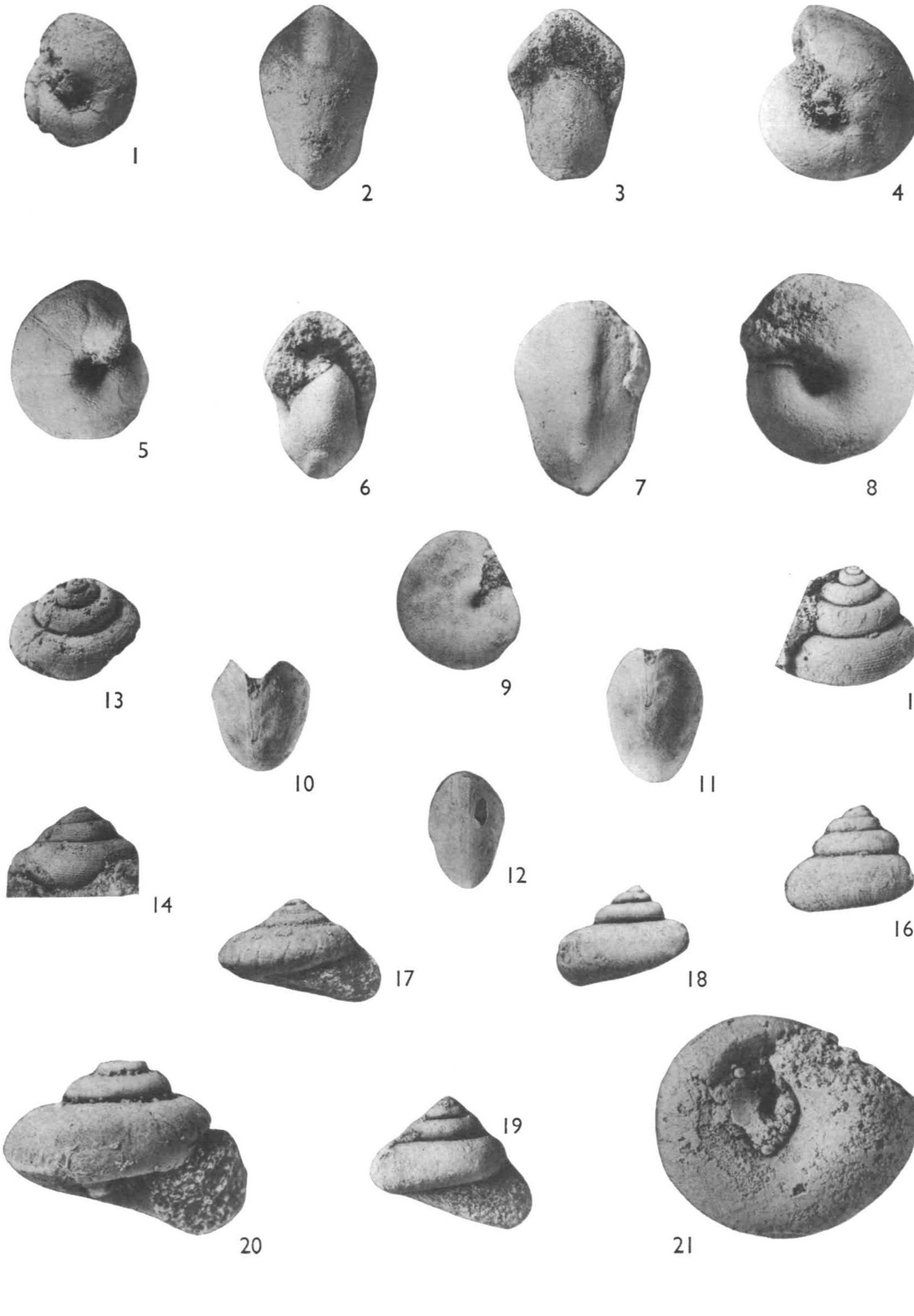
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PLATE 23

FIGS. 1-11.—*Mourlonia (Pseudobaylea) freneyensis* sp. nov. .... Page 121

FIG. 1.—Paratype C, apertural view. × 2.

FIGS. 2; 6.—Paratype A. × 1. 2. Tilted apical view. 6. Apertural view.

FIG. 3.—Paratype B, side view. × 1.

FIG. 4.—Paratype D, apertural view. × 2.

FIG. 5.—Paratype E, side view of latex cast. × 2.

FIGS. 7-9.—Holotype. × 2. 7. Apertural view. 8. Tilted apical view. 9. Side view.

FIGS. 10-11.—Paratype F, latex cast. × 2. 10. Tilted apical view. 11. Side view.

FIGS. 12-17.—*Mourlonia (Woolnoughia) angulata* sp. nov. .... Page 123

FIGS. 12-13.—Holotype. × 1. 12. Side view. 13. Basal view.

FIG. 14.—Paratype C, showing details of ornament. × 4.

FIGS. 15-16.—Paratype A. × 1. 15. Apertural view. 16. Side view.

FIG. 17.—Paratype B, side view. × 1.

FIGS. 18-21.—*Mourlonia (Mourlonia)* sp. nov. .... Page 119

Figured Specimen, latex cast. 18. Tilted apical view. × 2. 19. Side view. × 4. 20. Apical view. × 4. 21. Apertural view. × 4.

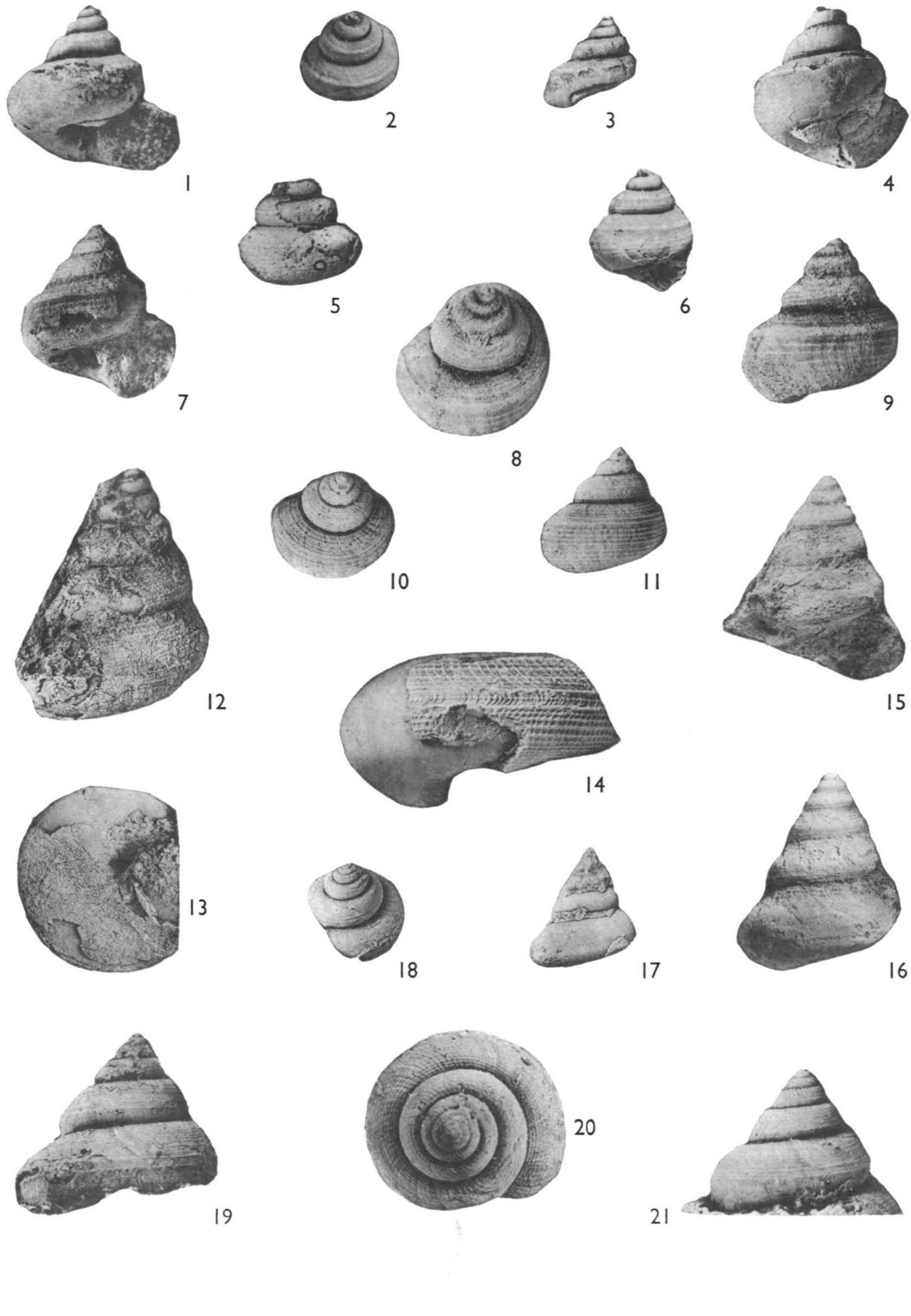
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PLATE 24

FIGS. 1-4.—*Straparolus* (*Leptomphalus*) *besselensis* sp. nov. × 4. .... Page 129

FIG. 1.—Holotype, apical view of latex cast.

FIG. 2.—Paratype B, basal view of latex cast.

FIG. 3.—Paratype A, apical view of latex cast.

FIG. 4.—Paratype C, basal view of latex cast.

FIGS. 5-6.—*Mourlonia* (*Mourlonia*) *lyndonensis* (Dickins) 1957. × 4. ...... Page 119

Hypotype. 5. Side view. 6. Tilted apical view.

FIGS. 7-8.—*Peruvispira* cf. *umariensis* (Reed) 1928. × 4. .... Page 126

Figured Specimen, latex cast. 7. Tilted basal view. 8. Side view.

FIGS. 9-11.—*Ptychomphalina maitlandi* Etheridge 1903. × 1. .... Page 126

From south of Wandagee Station, Wandagee, Carnarvon Basin, W.A. (UWA Reg. No. 28292), Bulgadoo Shale or Cundlego Formation.

FIG. 9.—Hypotype A, UWA Type No. 45443, side view.

FIG. 10.—Hypotype B, UWA Type No. 45444, apertural view.

FIG. 11.—Hypotype C, UWA Type No. 45445, side view.

FIGS. 12-19.—*Ptychomphalina talboti* sp. nov. .... Page 125

FIGS. 12-13.—Paratype D. 12. Early whorls. × 3. 13. Apertural view. × 1.

FIGS. 14-15.—Paratype B. × 1. 14. Side view. 15. Apertural view.

FIG. 16.—Holotype, side view. × 1.

FIGS. 17-18.—Paratype A. 17. Apertural view. × 1. 18. View of base showing shell structure. × 4.

FIG. 19.—Paratype C, base. × 2.

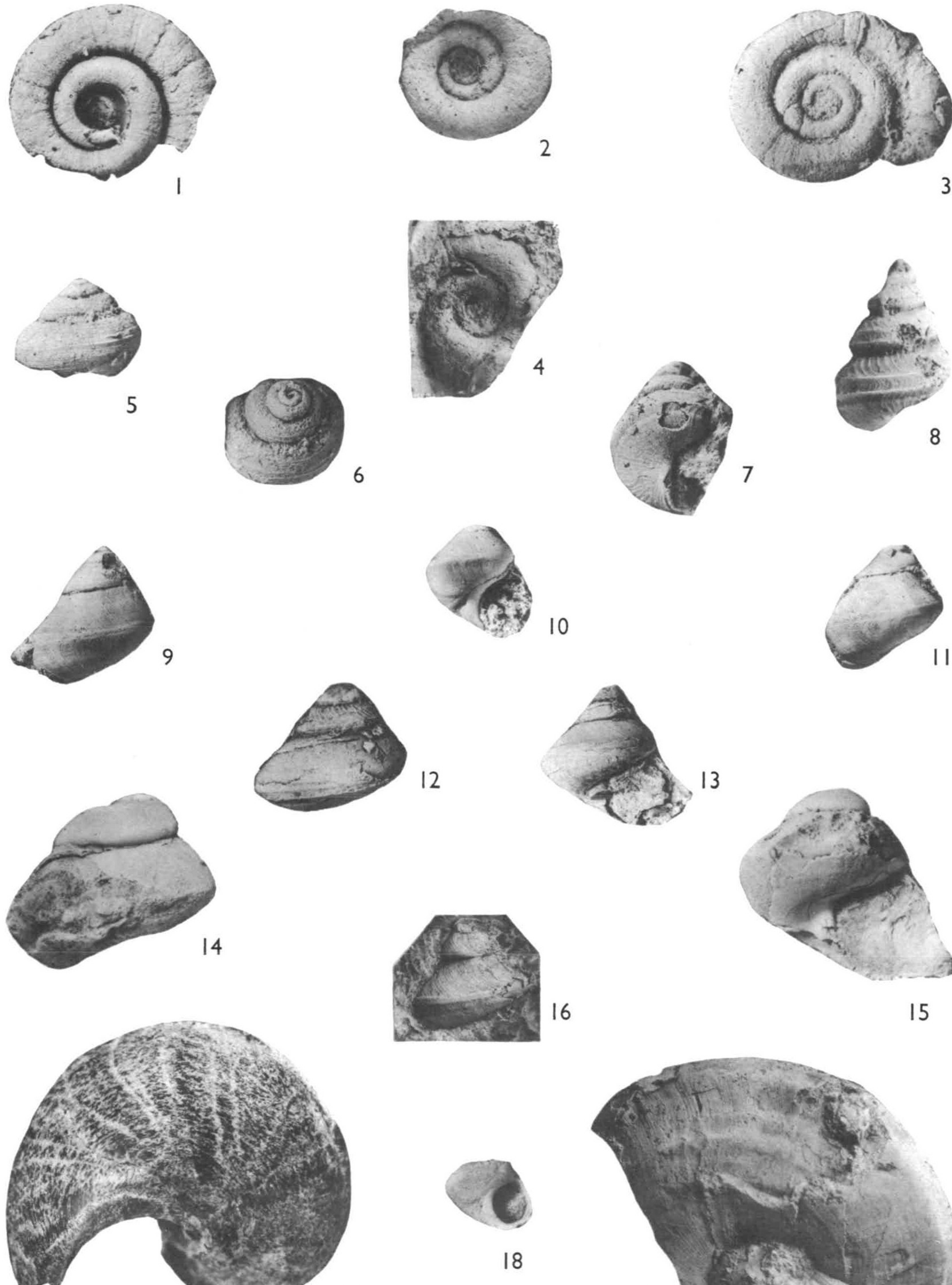

Plate 25

Figs. 1-3.—*Straparolus* (*Leptomphalus*) sp. nov. × 4. .... Page 130
Figured Specimen. 1. Apical view. 2. Apertural view. 3. Tilted basal view.

Figs. 4-6.—*Platyceras* sp. nov. × 1. .... Page 133
Figs. 4-5.—Figured Specimen B. 4. Adapertural view. 5. Side view.
Fig. 6.—Figured Specimen A, adapertural view.

Figs. 7-18.—*Platyceras* cf. *abundans* (Wanner) 1922. .... Page 131
Figs. 7-8.—Figured Specimen A. × 1. 7. Side view. 8. Adapertural view.
Fig. 9.—Figured Specimen D, side view. × 1.
Figs. 10-12.—Figured Specimen B. × 1. 10. Apertural view. 11. Side view. 12. Adapertural view.
Figs. 13-15.—Figured Specimen C. × 1. 13. Apertural view. 14. Adapertural view. 15. Side view.
Figs. 16-18.—Figured Specimen E. 16. Apertural view. × 1. 17. Side view of apical part of shell. × 4. 18. Side view. × 1.

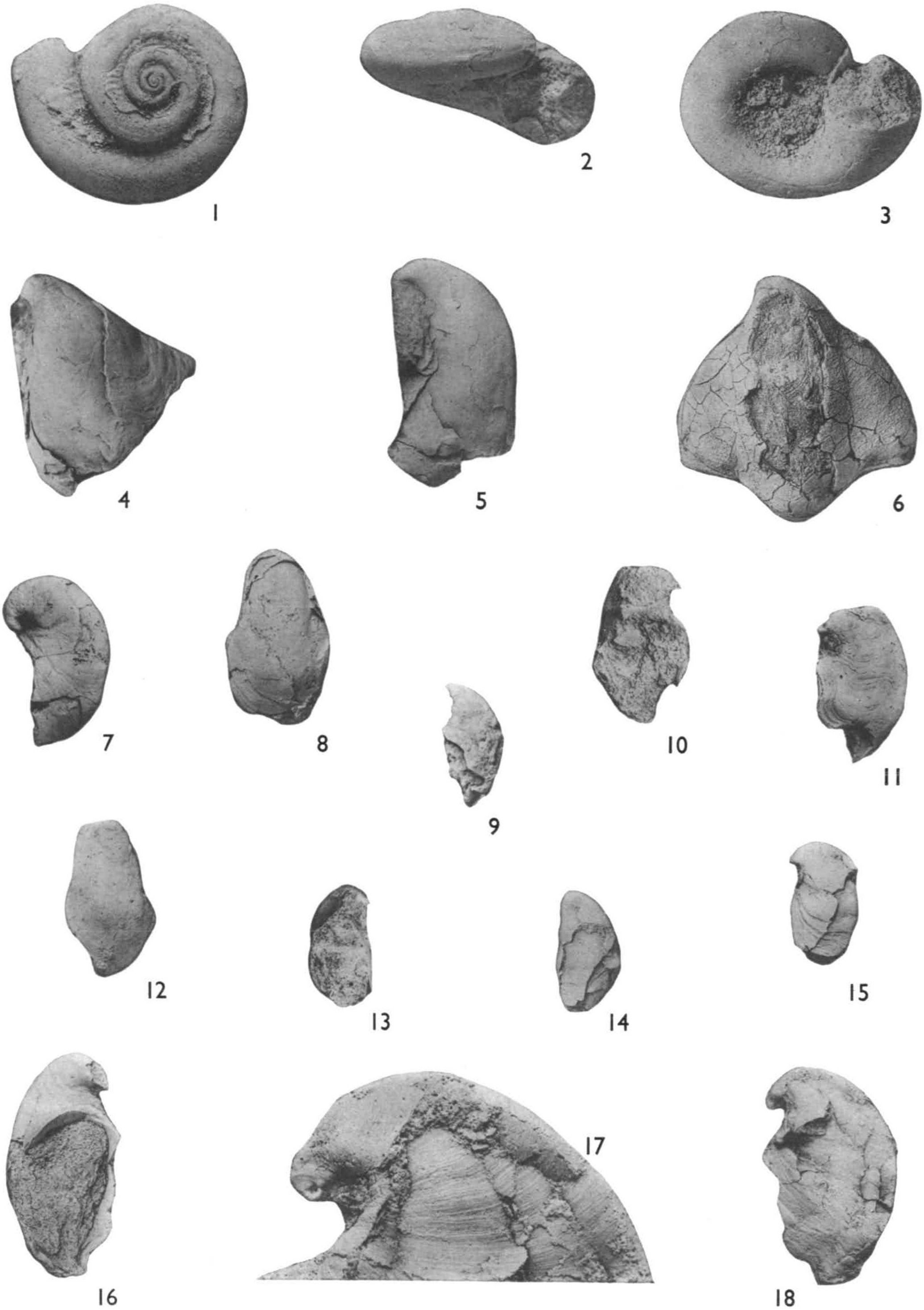
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PLATE 26

FIGS. 1-7.—*Macrochilina winensis* sp. nov. .... Page 134

FIG. 1.—Paratype A, apertural view. × 4.

FIGS. 2-3.—Paratype C, oblique apertural view. 2. × 4. 3. ×,8.

FIGS. 4-5.—Paratype B. × 2. 4. Apertural view. 5. Side view.

FIGS. 6-7.—Holotype. × 4. 6. Apertural view. 7. Side view.

FIGS. 8-9.—*Naticopsis*? sp. nov. × 1. .... Page 135

FIG. 8.—Figured Specimen B, apertural view.

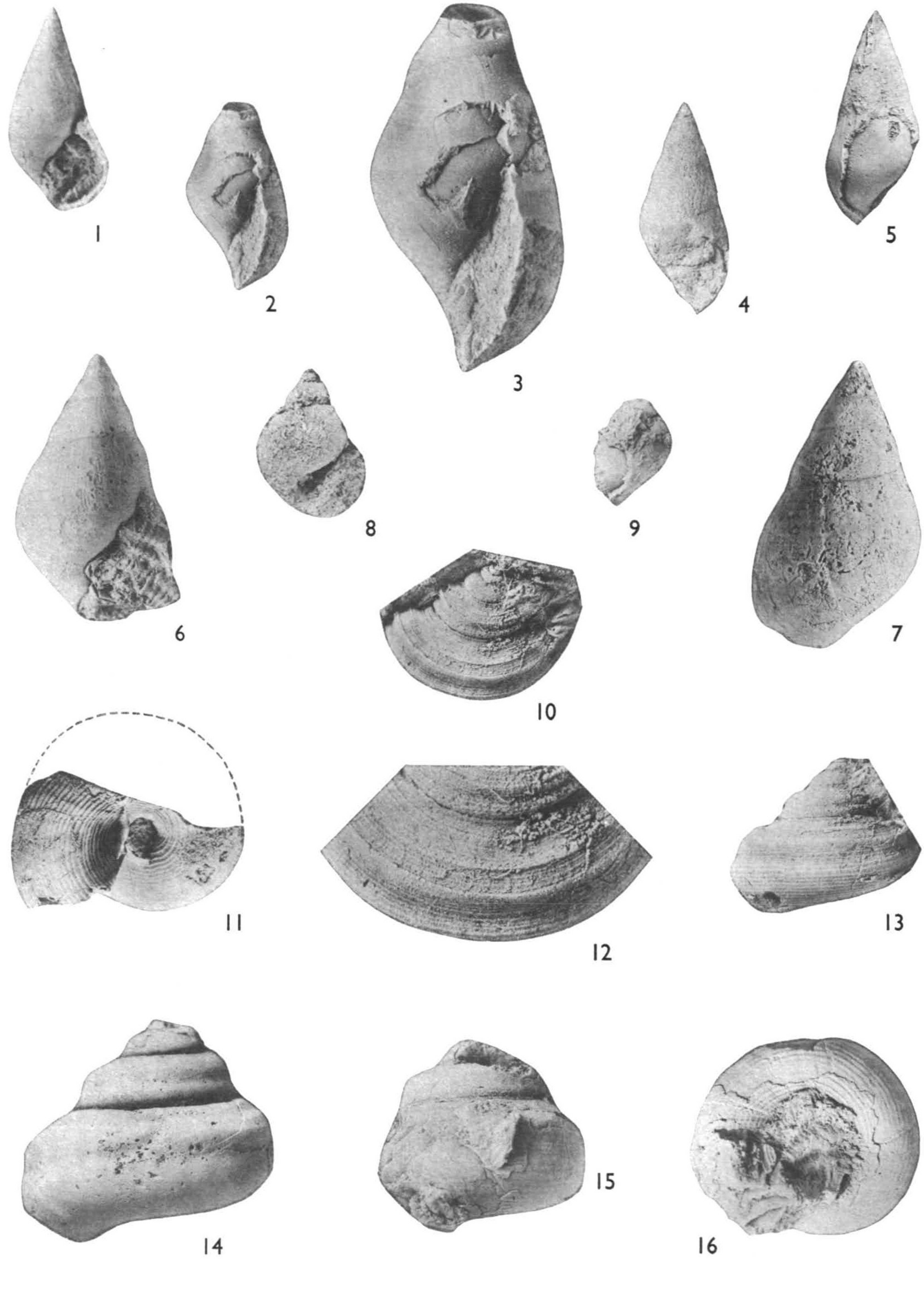
FIG. 9.—Figured Specimen A, side view.

FIGS. 10-16.—*Baylea perthensis* sp. nov. .... Page 127

FIGS. 10-13.—Holotype. 10. Tilted apical view. × 4. 11. Basal view. × 4. 12. Part of tilted apical view. × 8. 13. Side view. × 4.

FIG. 14.—Paratype B, side view. × 4.

FIGS. 15-16.—Paratype A. × 4. 15. Side view. 16. Basal view.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