LATE EOCENE MOLLUSCA
and
related composite species
from
SOUTHERN AUSTRALIA

by

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(Volume I)

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To my Mother,

of whose grey hairs
not a few
were from myself.

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any University or previously published works by other people, except where due reference is made in the text of this thesis, to the best of my knowledge and belief.

Massimo F. Buonaiuto.

SUMMARY

Late Eocene Mollusca and related Tertiary composite species from Southern Australia mainly from the Maslin and Aldinga Bays outcrops (Willunga SubBasin, St. Vincent Basin, South Australia), are discussed here. They include Gastropoda, Bivalvia, and Scaphopoda only.

SYSTEMATICS. Of the 215 species dealt with here, 81 previously known forms are revised, 82 are newly instituted, and 52 informally described. Also recognized for the first time are 7 new genera, *Allasinazella* (Striarcinae), *Kaurnacteon* (Acteonidae), *Kosugeia* (Triphoridae), *Cottonella* and *Kaurnaginella* (Marginellidae), *Cycloliotia* (Liotiinae), and *Campylothyrsos* (Siliquariidae); 1 new subgenus *Ludbrookella* (Grammatodontinae); and the two subfamilies, Siliquariinae Gray and Stephopominae subfam. nov. Several genera and subgenera have been recorded for the first time in Australia and several others have had their stratigraphic range extended as far back as the Late Eocene.

The following groups are discussed in more detail: *Pseudomalaxis* Fischer (Buonaiuto, 1975; this study), *Crossea* A. Adams, *Liotina* Fischer and its subgenus *Austroliotia* Cotton, Siliquariidae Gray, Orbitestellidae Iredale, Pyramidellacea d'Orbigny, Marginellidae Jousseaume, Pteropoda Cuvier, Pleurotomariidae Swainson, Triphoracea Kosuge, *Limopsis* Sassi, and Striarcinae McNeil.

BIOSTRATIGRAPHY. As shown in the following synoptic table, an informal zonation is based on the stratigraphic distribution of the species in the Tortachilla Limestone, Blanche Point Formation, Lower Port Willunga Formation (St. Vincent Basin), and in the Knight Group and Buccleuch Beds (Murray Basin).

EPOCH	Standard Foraminiferal Zones	Molluscan zonation		Molluscan assemblages	BASINS		
		Zones	Subzones		St. Vincent		Murray
LATE EOCENE	P.17	*Orbitestella rugosa*		to define	ALDINGA M.	Pt. WILLUNGA F.	Buccleuch Beds
	P.16	*Orbitestella spinosa*					?
			Barren		Chinaman Gully F.		
		Orbitestella margaritata	*Dimya asseretoi*	*Ledella-Pectunculina-Zeacolpus*	"Soft Marl" M.	BLANCHE POINT F.	UPPER KNIGHT GROUP
				Spirocolpus-Dimya-Ledella	Gull Rock M.		
			Barren	(*Bryoza*)			
			Phygraea tarda	*Phygraea*			
			Barren				
	Hantkenina primitiva		*Vulsella laevigata*	*Spirocolpus-Trophon* *Dimya-Chlamys* *Chlamys-Pycnodonte* *Spirocolpus-Dimya* *Turritella-Dosina*	"Transitional Marl" M.		
				Barren	Lacuna		
	P.15	*Chlamys aldingensis*		*Dosina-Turritella-Chlamys* *Dimya* *Chlamys-Hiatella* Barren	'TORTACHILLA LIMESTONE'.		?

PALAEOECOLOGY. The quantitative analysis of the Molluscan faunas of the Tortachilla Limestone and the Blanche Point Formation revealed a number of distinct assemblages, as shown in the table above.

The succession of these assemblages suggests a supralittoral to subtidal environment of deposition for the Tortachilla Limestone. In the Blanche Point Formation the assemblages indicate a gradual transition from subtidal to shallow-medium sublittoral conditions in the 'Transitional Marl' Member, a medium to possibly deep sublittoral-shallow bathyal environment, for the lower Gull Rock Member; a return to shallow medium sublittoral in the upper Gull Rock Member; and again, a reversal to deeper conditions in the 'Soft Marl' Member. Two continental to supralittoral episodes are recognized here: the older represented by the lacuna between Tortachilla Limestone and Blanche Point Formation; the younger by the Chinaman Gully Formation.

The higher diversity indexes of the assemblages suggest that biologically accommodated conditions for Mollusca persisted almost continuously throughout both Tortachilla Limestone and Blanche Point Formation, with the exception of the Phygraea tarda assemblage and the overlying Bryozoa assemblage, which indicate biologically stressed conditions.

The molluscan faunas indicate warm temperate to subtropical climatic conditions persisting throughout the Late Eocene, with a climatic optimum in the middle 'Transitional Marls' (Roughly late zone P15-early P16), and less warm conditions in the Gull Rock and 'Soft Marl' Members. Climatic minima seems to coincide with regressive events at the Tortachilla Limestone/Blanche Point Formation boundary (roughly middle zone P15)and at the Chinaman Gully Formation continental episode (roughly middle zone P16).

PALAEOBIOGEOGRAPHY. The 169 taxa hitherto recorded in the Late Eocene of Southern Australia suggest a high degree of endemism (~ 39%) and a high affinity with the Boreal Proto Atlantic (~24%) and with New Zealand (~8%) faunas. Cosmopolitan elements are heavily represented (~18%). A very low affinity with the Central and Eastern Tethysis is indicated. A north-south ProtoAtlantic-ProtoSouthern Ocean route is suggested as the most active for the dispersal of the Mollusca during the Late Eocene. The analysis of the Australian forms endemic in the Late Eocene suggests post Eocene dispersal patterns toward the Indo Pacific and the Eastern Tethys.

LITHOSTRATIGRAPHY. The Tortachilla Limestone and the Blanche Point Formation of the Eastern St. Vincent Basin and their relationships are discussed and revised here. The Bucchleuch Beds (Murray Basin) are correlated with the Aldinga Member of the Port Willunga Formation, on the basis of Molluscan data.

INTRODUCTION

PREVIOUS INVESTIGATIONS

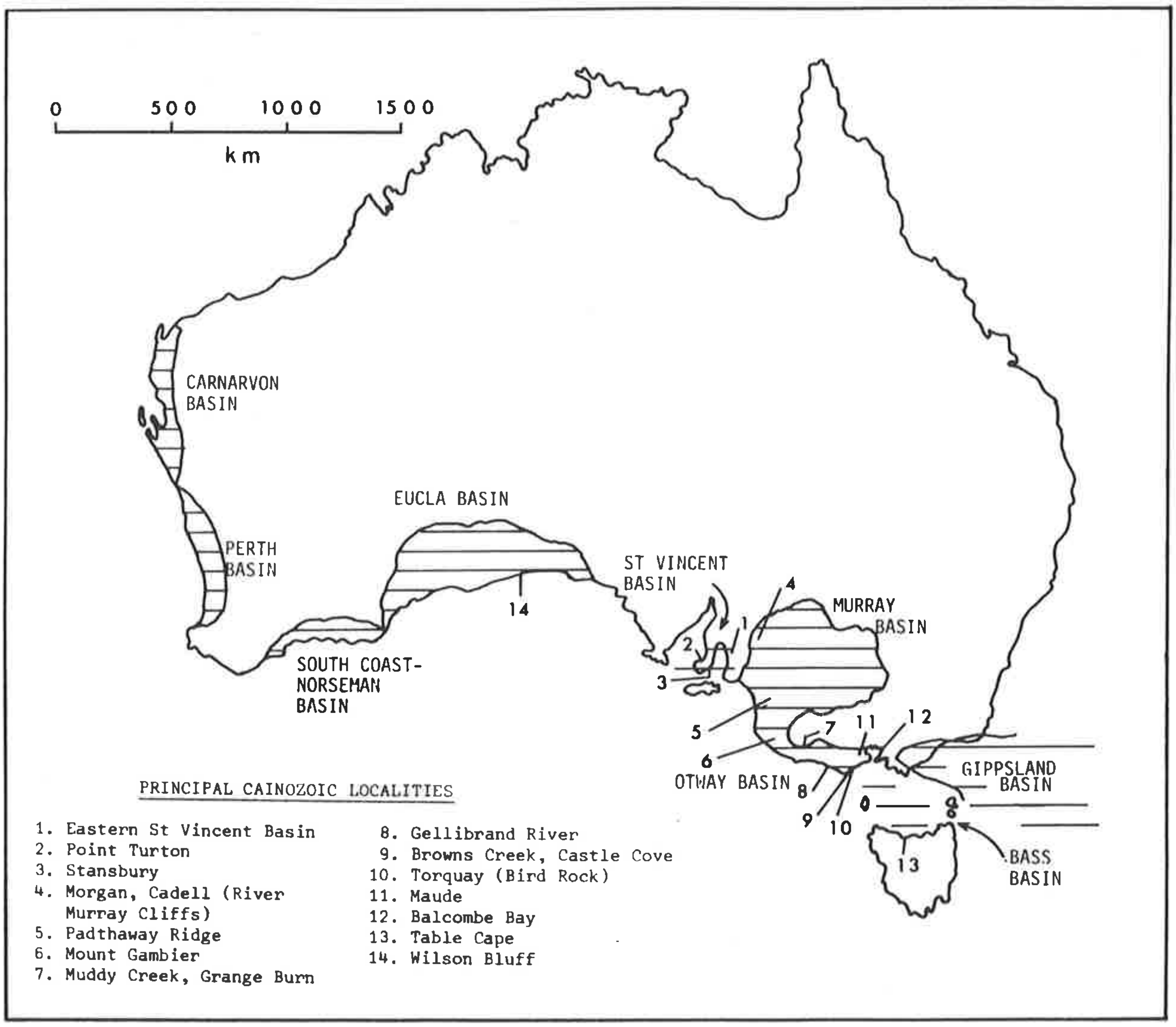
The studies of the Cainozoic Mollusca from the Southern Australian Basins began, at about the same time as the early geological investigations, with McCoy (1866-1877) who described the first Victorian fossil Mollusca, Such studies continued to flourish until the turn of the century. Prominent were the works of T. Woods (1867-79), Johnston (1880-1888), Hall & Pritchard (1895, 1897, 1902), Pritchard (1895-1913), and especially, Tate (1878-1899), whose writings were by far the most important. Tate's works still remain the main reference for the Late Eocene Mollusca.

These various studies, synthesized in the check-list of Dennant & Kitson (1903), dealt with forms from the Cainozoic St. Vincent, Murray, Otway, Bass and Gippsland Basins and, in minor measure, from the Eucla Basin. Almost all the major works, including the living forms, date back to this pioneering period which represents the golden age of the Australian Molluscan studies. The vitality of the period are also evinced by the intensive collaboration between Tate and the outstanding French palaeontologist Maurice Cossmann. This collaboration resulted in the 1897 paper on the Australian Tertiary Opisthobranchia by Cossmann, and led to the incorporation and revision of the then known Australian fossil Mollusca in his Essays (1895-1925). Cossmann's illustrations of these species still remain among the best.

The other main contribution by an overseas scholar is that of Harris (1893) on Tertiary Australasian Mollusca kept in the British Museum Collections.

It was also during Tate's professorship that the molluscan collections in the Department of Geology, University of Adelaide, were built up with material from the Anglo-Paris, Proto-Adriatic, North American

FIG. 1 Australian Cainozoic Basins and main localities (after Ludbrook, 1973; McGowran, 1978b).



PRINCIPAL CAINOZOIC LOCALITIES

1. Eastern St Vincent Basin
2. Point Turton
3. Stansbury
4. Morgan, Cadell (River Murray Cliffs)
5. Padthaway Ridge
6. Mount Gambier
7. Muddy Creek, Grange Burn
8. Gellibrand River
9. Browns Creek, Castle Cove
10. Torquay (Bird Rock)
11. Maude
12. Balcombe Bay
13. Table Cape
14. Wilson Bluff

and New Zealand basins. At the same time, collections of valuable reference works were assembled in South Australia. These are now distributed throughout the S.A. Museum, the Barr Smith, the S.A. State, and, in particular, the Royal Society Libraries. The only other major additions to these collections were made by Verco, a distinguished amateur malacologist at the turn of the century. These additions contain works dating from pre-Linnean to the early 1800s which are vital to the present taxonomic and nomenclatural studies.

In the first part of this century, studies on molluscan palaeontology were mainly carried out by Chapman (1903-1929), Chapman & Crespin (1928-34), Chapman & Gabriel (1914-1923), Chapman & Singleton (1925, 1927), Singleton (1932-1945), May (1919-1922), Cotton (1934-1958) etc. The works of this period are generally on the Neogene species and the main contribution on the Late Eocene Mollusca is that of Chapman & Crespin (1934).

A number of species were further studied by New Zealand workers such as Finlay, Marwick, Marshall, Suter, Fleming, etc., but chiefly in relation to the New Zealand fauna or in the context of broad taxonomic revision.

During the fifties and the sixties, the studies on Cainozoic Mollusca again received a new and great impetus through the research and work of Ludbrook (née Woods) (1931-1954-1978) who, together with Tate, is the main contributor in this field. Other active molluscan workers include T.A. Darragh, National Museum of Victoria (1965 to date) and the author (Buonaiuto, 1975; 1977a,b).

Geological and stratigraphical investigations of the St. Vincent Basin, the main basin dealt with here, were initiated at the same time as palaeontological studies by Tate (1878-1899) and Tate & Dennant (1893-96), and were extended by Chapman (1914a,b) and Howchin (1923). Mawson (1953) offered a detailed historical picture of these studies from pioneering times to the end of the 1940's and for more details the reader is referred to it.

During the 1950's the lithostratigraphic and biostratigraphical knowledge of the Eastern St. Vincent Basin was furthered through contributions by Reynolds (1953), Crespin (1954), Glaessner (1951-1957), Glaessner & Wade (1958), Cochrane (1956), Wade (1952,1958) and Ludbrook (1956-1977). The 1960's and 1970's have seen a similar wave of studies by Brown (1960), Wade (1964), Lindsay (1967 to date), Stuart (1969, 1970); McGowran _et al_., (1971); Ludbrook (1967,1969,1973) etc. More recent contributions are given by: Jenkins (1974); Daily, Firman & Lindsay (1976); Cooper (1977a,b; 1978); and Buonaiuto (1977a).

McGowran (1977,1978a,b,c) places the Eocene deposits of the St. Vincent Basin within the regional biostratigraphical framework of the Late Cretaceous-Palaeogene evolution of the Indian Ocean and the Southern Australian margin, in relation to Australia/Antarctica break-up.

Further biostratigraphical investigations are at present also being carried out by J.M. Lindsay, S.A. Department of Mines & Energy, on foraminifera; by W.K. Harris, S.A. Department of Mines & Energy, on spores, pollen and dinoflagellates; and by Samir Shafik, Bureau of Mineral Resources, Geology and Geophysics, Canberra, on nannofossils.

PURPOSE OF THIS STUDY

The aims of this research are two-fold.

A) To describe and revise Late Eocene molluscan faunas from Southern Australian localities, primarily from the Willunga and the Adelaide Plains SubBasins (St. Vincent Basin) and, to a minor measure, from the Murray Basin. Particular attention to be given to Cainozic composite species with Late Eocene representatives.

B) To extract biostratigraphical, palaeoecological and palaeobiogeographical interpretations from the described species and assemblages. Particular attention to be given to the distribution of the faunas in relation to the lithostratigraphy of the Late Eocene units investigated, principally the Tortachilla Limestone and the Blanche Point Formation exposed in the Tertiary Embayments to the South of Adelaide.

LIMITATIONS OF THIS STUDY

At present, the number of Cainozoic molluscan species known in Australia reaches and, probably exceeds, four thousands (Darragh, 1970; Ludbrook, 1973, 1978), of which only about a hundred are from the Late Eocene (Ludbrook, 1973). Although this figure might seem impressive, it only represents a small fraction in comparison with the number of forms still to be described, especially among the micromollusca, which are the least known of all (Ponder, 1976).

Investigations conducted during this study, by means of the sampling method adopted, have shown that the Late Eocene faunas are much richer in forms than hitherto thought, and that the undescribed species, excluding those dealt with in this study, still number from a minimum of 100 to about a maximum of 400.

The systematic part of this thesis has extended beyond the study of the fauna from the Aldinga Bay and Maslin Bay sections, for the following reasons. First, a proper review of the previously known species from the southern Australian Late Eocene was necessary. Second, it appears that faunal gaps, due primarily to solution, are present in the sections just mentioned, and it seemed appropriate to study other sections to bridge the gaps.

Third, the recognition of numerous composite species with Late Eocene representatives required taxonomic studies spanning a wider time range than the Eocene. Finally, the diversity of the discovered fauna meant that the taxonomic work had to be selective.

ACKNOWLEDGEMENTS

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The completion of this research was made possible through the assistance and cooperation of many people and organizations to whom I am indebted.

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I acknowledge the following persons and organizations for the loan of specimens and valuable assistance: The Director of the S.A. Museum and the Curators, Mr. W. Ziedler and Mr. N. Pledge; the Director of the S.A. Department of Mines and Energy; the Director of the British Museum (Natural History) and Dr. C.P. Nuttall; the Director of the Auckland Museum and Institute and Dr. W.O. Cernohorsky; the Director of the New Zealand Geological Survey and Mr. I.W. Keyes; the Director of the National Museum of Victoria and Dr. T.A. Darragh; the Director of the Australian Museum, Sydney, and Dr. W. Ponder; Professor J.F. Lovering, Head of the School of Geology, University of Melbourne and Dr. M. Cooper.

I am very grateful to Dr. C.A. Fleming and Dr. P.A. Maxwell, New Zealand Geological Survey, and to Dr. J. Le Renard, Institute National

de la Recherche Agronomique, Versailles, for their comments and kind cooperation on some taxonomic aspects of my thesis.

Thanks should also go to Roswitha Hurst of the Department of German at the University of Adelaide, who undertook the monumental task of proof reading my English and to Mrs. Angela Nash who was given the no less monumental task of typing the final version of this work.

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PART 1

LITHOSTRATIGRAPHY
BIOSTRATIGRAPHY
PALAEOECOLOGY
PALAEOBIOGEOGRAPHY

CHAPTER 1

LITHOSTRATIGRAPHY

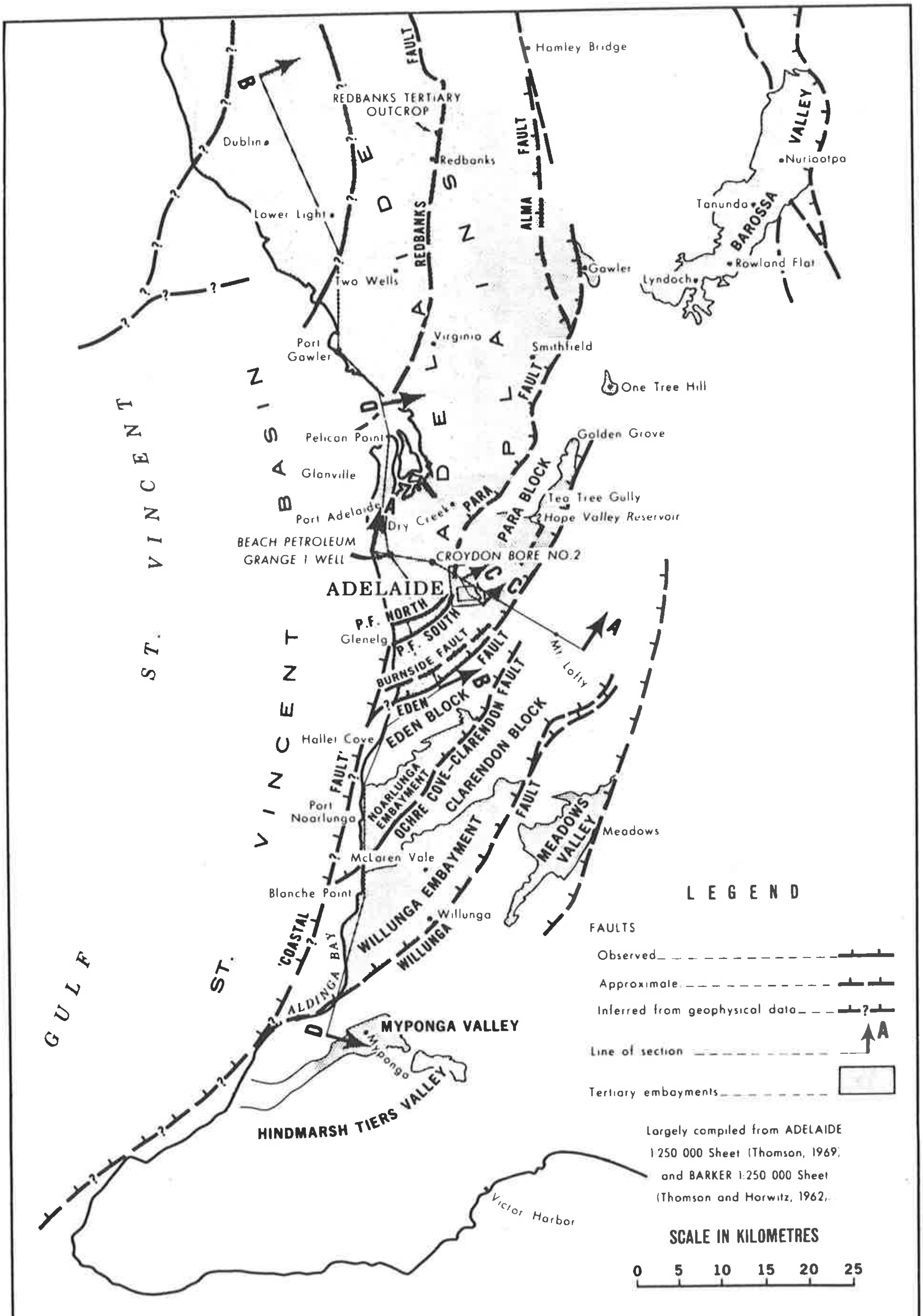
In this study the Late Eocene Tortachilla Limestone and Blanche Point Formation of the Eastern St. Vincent Basin (South Australia) are described in detail, since the majority of the species with which this thesis is concerned, are from these two units. They play a special role in the stratigraphy of the Lower Tertiary in Southern Australia, because their outcrops in Maslin and Aldinga Bays are part of the type section of the Aldingan Stage (Late Eocene), as instituted by Hall & Pritchard (1902) and redefined by Ludbrook and Lindsay (1966) "as representing the time-interval required for the deposition at Aldinga and Maslin Bays of the Tortachilla Limestone, the Blanche Point Marls, the Chinaman's Gully beds, and the lower half of the Port Willunga Beds".

The framework of this chapter is heavily based upon Reynolds (1953) and Crespin (1954) who described the outcrops in the cliffs of Maslin and Aldinga Bays (the Lower Aldinga Series of Tate, 1879) and distinguished within these deposits the formations indicated in the following table (Condon, in Crespin, 1954):

Reynolds (1953)	Crespin (1954)
Port Willunga Beds	Aldinga Limestone
Chinaman's Gully Beds	
Blanche Point Marls	Blanche Point Limestone
Tortachilla Limestone	
South Maslin Sands	Maslin Sandstone
North Maslin Sands	

Reynolds' subdivision, since it is more detailed, has been adopted by the subsequent authors and is generally adopted here (Fig.6).

FIG. 2 Eastern St. Vincent Basin: Tertiary basinal sediments and tectonic setting (from Daily, *et al.*, 1976).



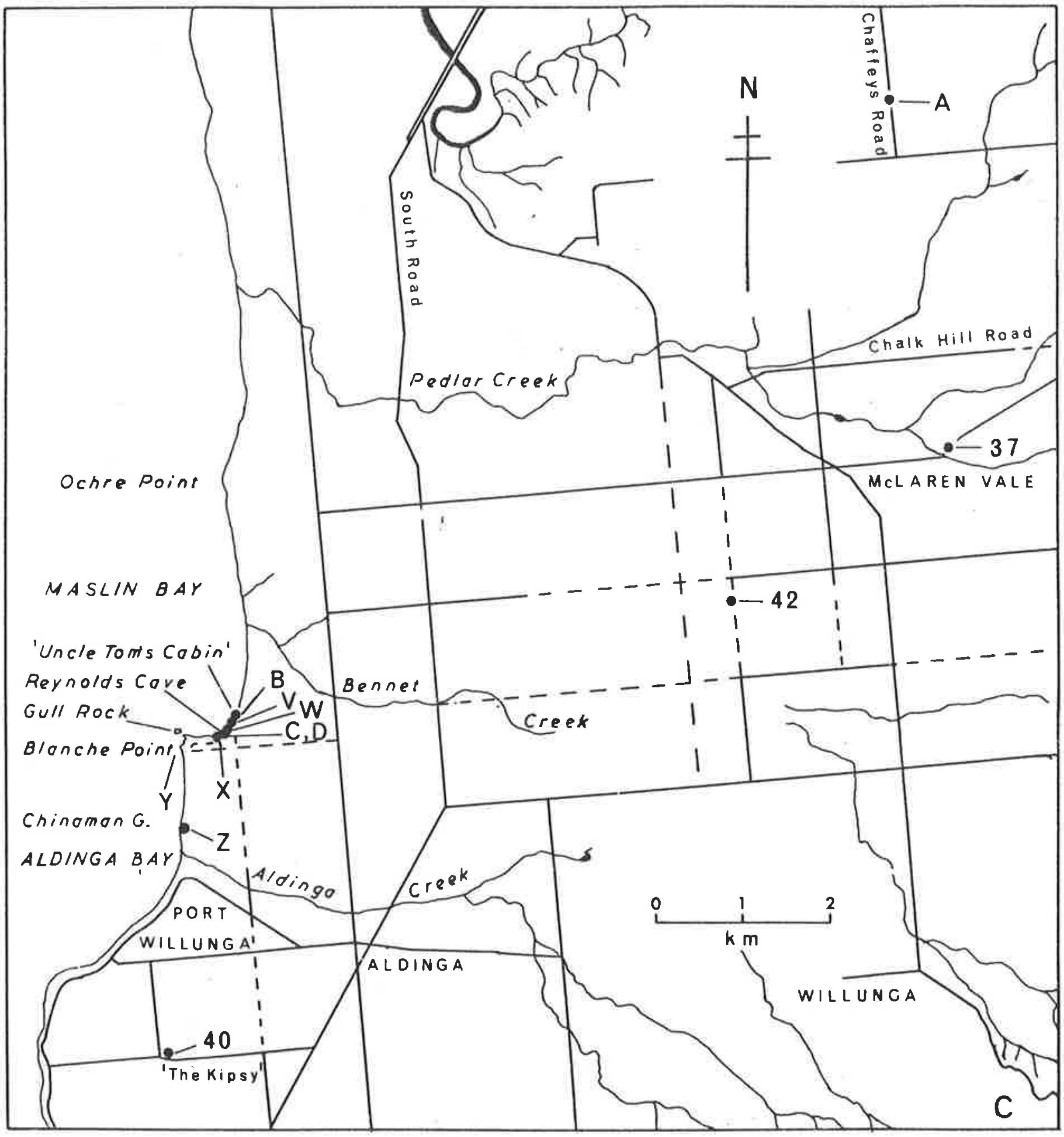
Largely compiled from ADELAIDE 1:250 000 Sheet (Thomson, 1969) and BARKER 1:250 000 Sheet (Thomson and Horwitz, 1962).

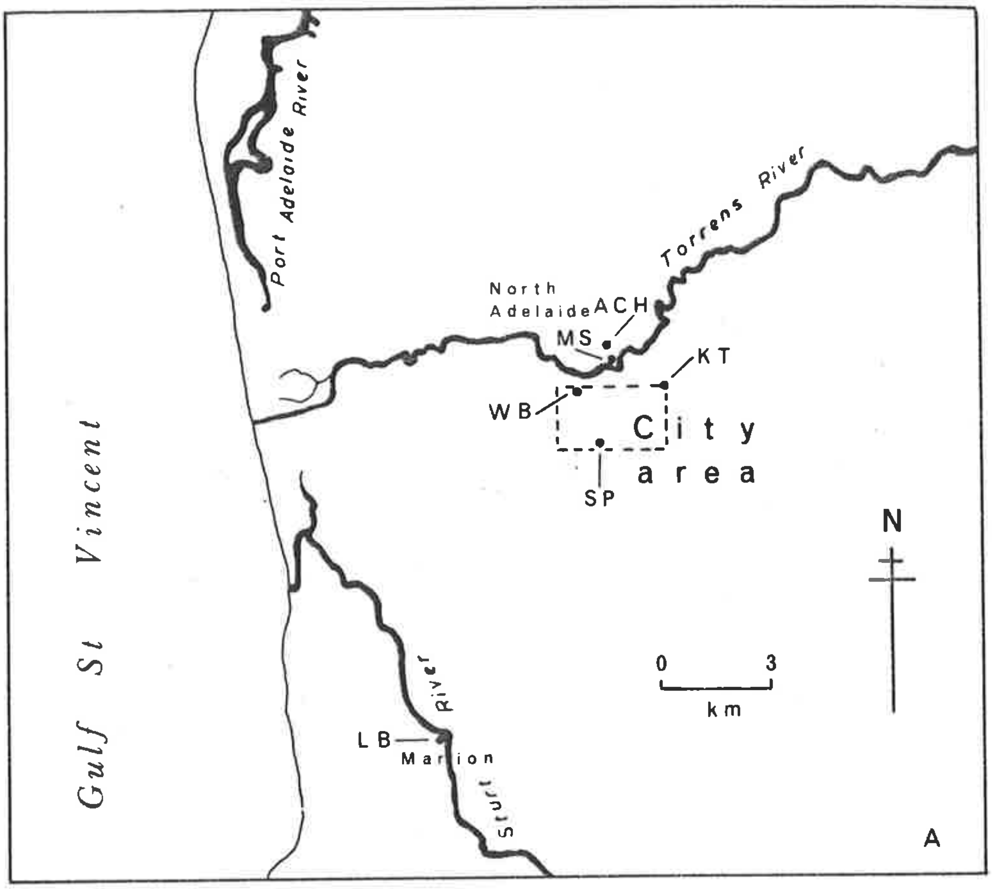
FIG. 3 Localities of the Eastern St. Vincent Basin:

A) Adelaide region, Adelaide Plains SubBasin

B) Noarlunga SubBasin

C) Willunga SubBasin.


N
Chaffeys Road
A
South Road
Pedlar Creek
Chalk Hill Road
37
McLAREN VALE
Ochre Point
MASLIN BAY
42
'Uncle Toms Cabin'
Reynolds Cave
Gull Rock
Blanche Point
B
V
W
C,D
X
Y
Bennet
Creek
Chinaman G.
Z
ALDINGA BAY
Aldinga
Creek
PORT
WILLUNGA
ALDINGA
0
1
2
km
WILLUNGA
40
'The Kipsy'
C


Port Adelaide River
Torrens River
North Adelaide
ACH
MS
KT
WB
City area
SP
Gulf St Vincent
N
0
3
km
LB
Marion
Sturt River
A

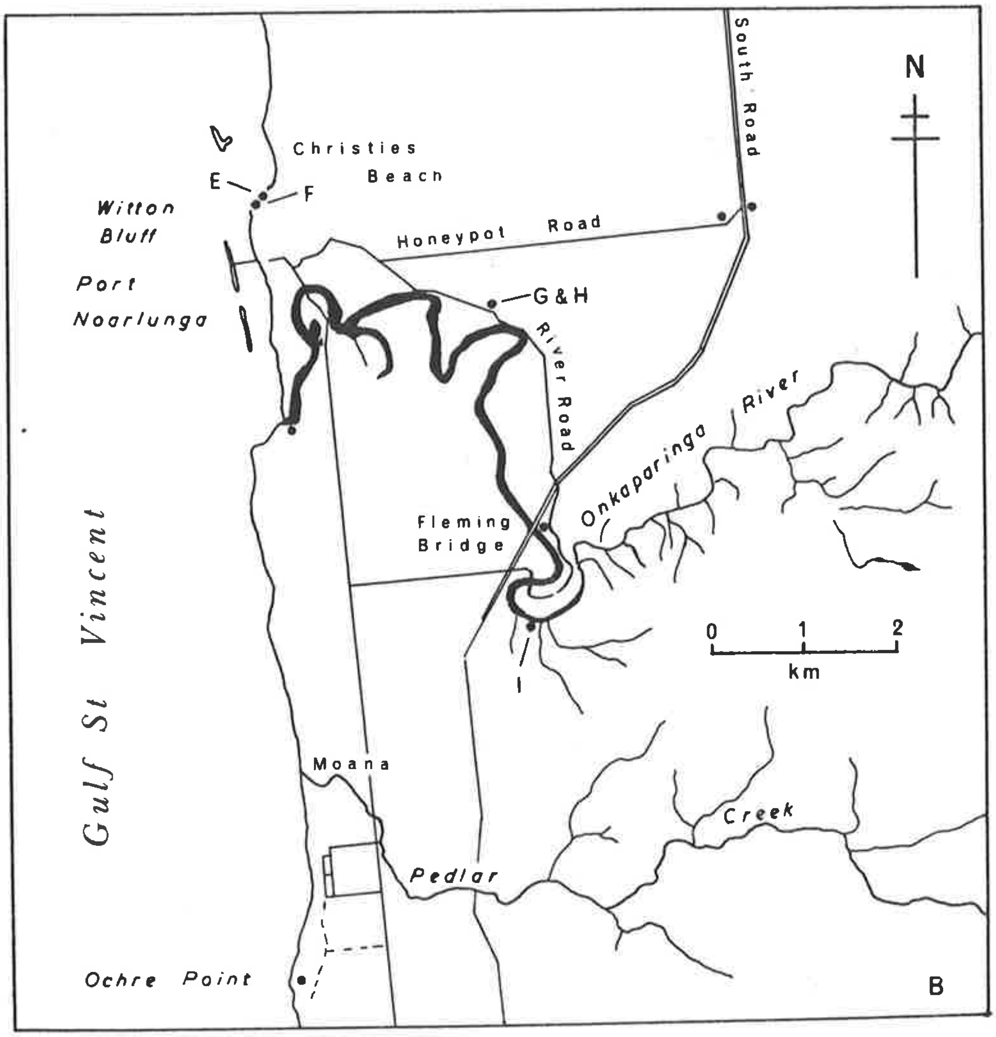

South Road
N
Christies Beach
E
F
Witton Bluff
Honeypot Road
Port Noarlunga
G&H
River Road
Onkaparinga River
Fleming Bridge
I
0
1
2
km
Gulf St Vincent
Moana
Creek
Pedlar
Ochre Point
B

FIG. 4 Localities of the Murray Basin.

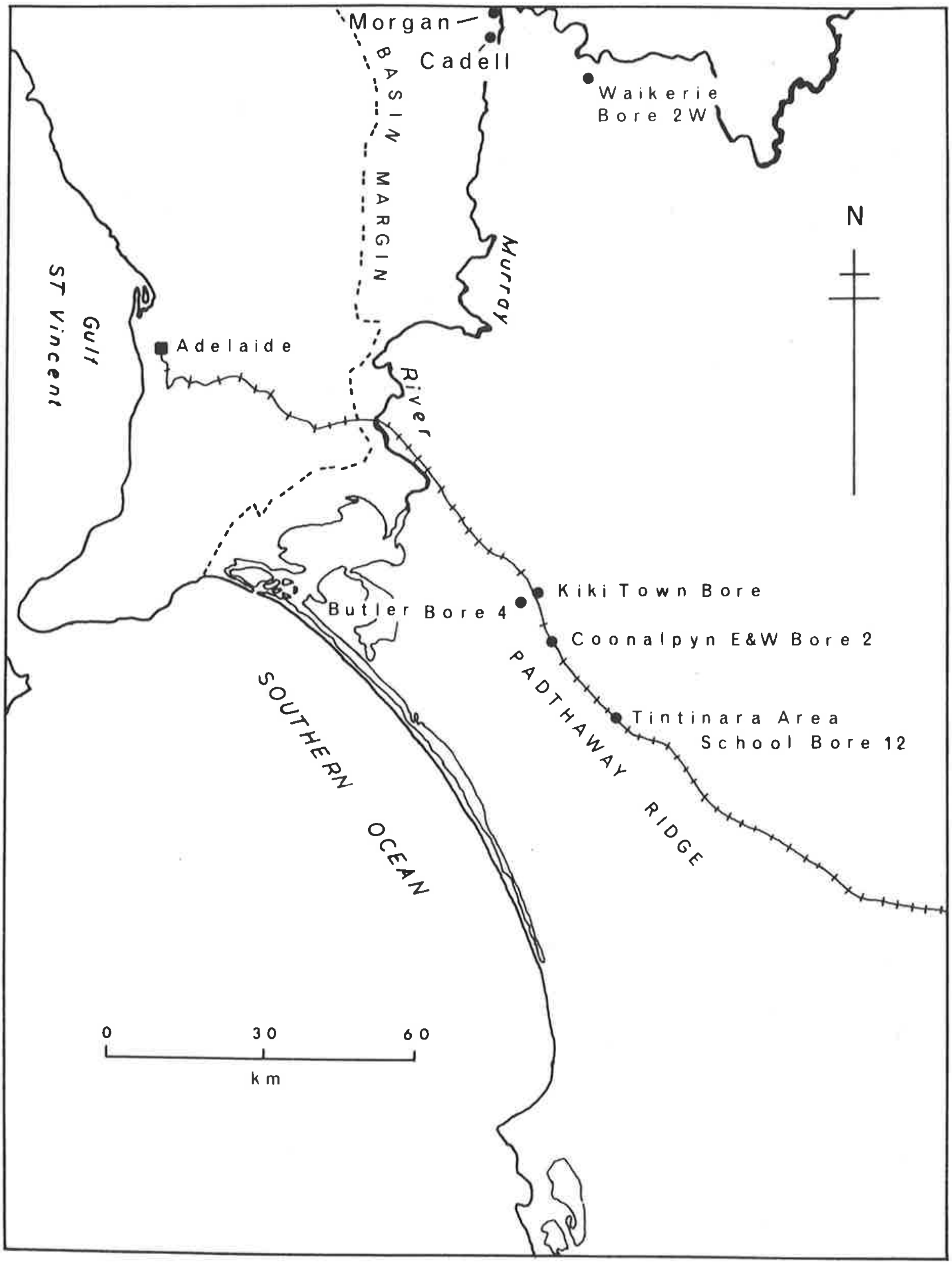

Morgan
Cadell
Waikerie Bore 2W
BASIN MARGIN
Murray River
N
Gulf ST Vincent
Adelaide
Kiki Town Bore
Butler Bore 4
Coonalpyn E&W Bore 2
Tintinara Area School Bore 12
PADTHAWAY RIDGE
SOUTHERN OCEAN
0
30
60
km

FIG. 5 Localities of the Eucla Basin.

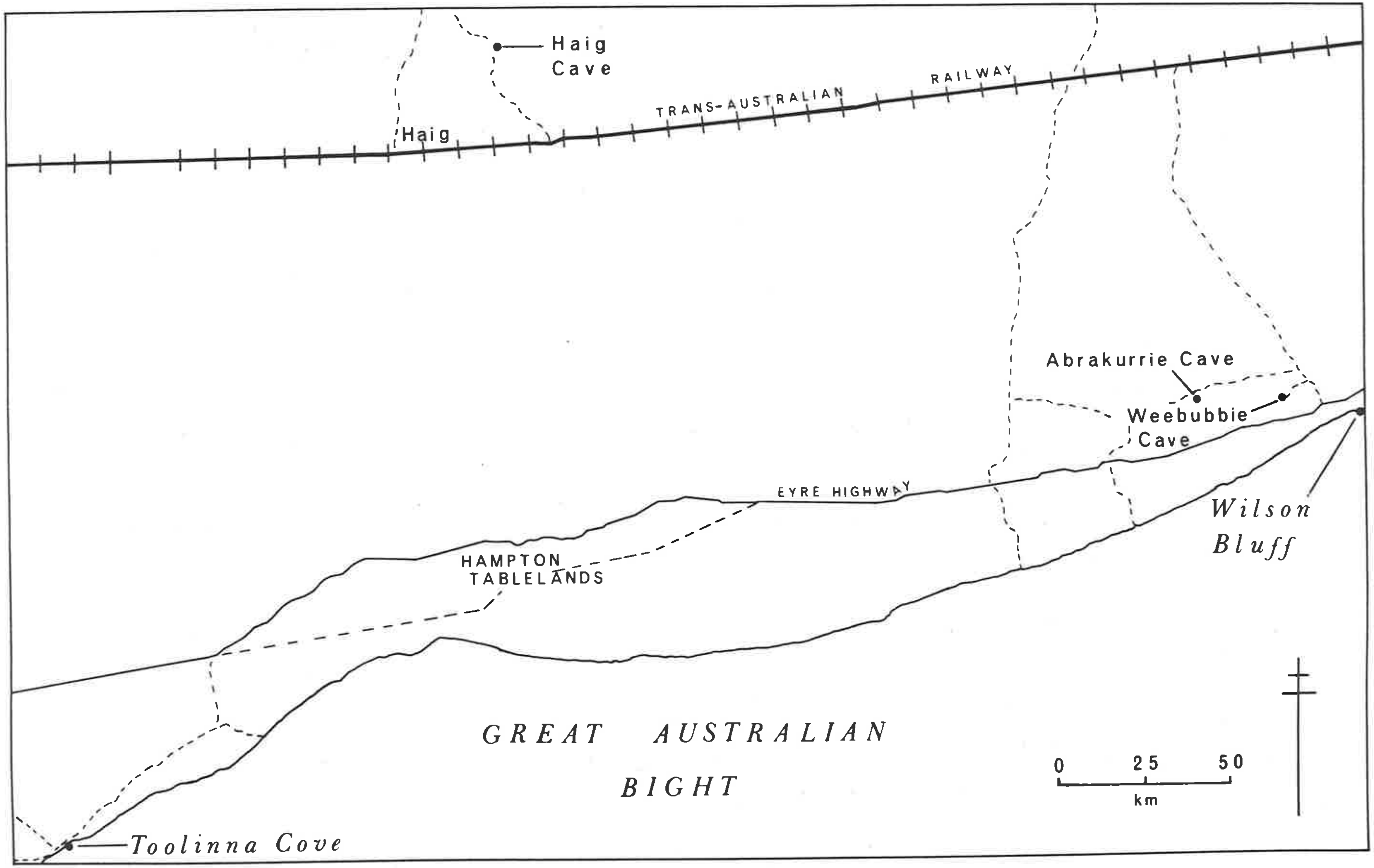

Haig Cave
Haig
TRANS-AUSTRALIAN RAILWAY
Abrakurrie Cave
Weebubbie Cave
EYRE HIGHWAY
Wilson Bluff
HAMPTON TABLELANDS
GREAT AUSTRALIAN BIGHT
0
25
50
km
Toolinna Cove

FIG. 6 Historical synopsis of the stratigraphic nomenclature of the formations instituted by the various authors at Maslin and Aldinga Bays (St. Vincent Basin, Willunga SubBasin).

TATE, 1879	GLAESSNER, 1951	REYNOLDS, 1953	CRESPIN, 1954; CONDON, 1954	BROWN, 1960; STUART, 1969	BUONAIUTO, 1977a	COOPER, 1977b	THIS STUDY
LOWER ALDINGA SERIES	Austrotrillina Beds	PORT WILLUNGA BEDS	ALDINGA LIMESTONE	PORT WILLUNGA BEDS	PORT WILLUNGA BEDS	PORT WILLUNGA F. unnamed member	PORT WILLUNGA F. unnamed member
	Polyzoal Beds of Aldinga Bays					Ruwarung Member	Ruwarung Member
						Aldinga Member	Aldinga Member
	Red Sands	CHINAMAN GULLY BEDS		CHINAMAN GULLY BEDS	CHINAMAN GULLY BEDS	CHINAMAN GULLY FORMATION	CHINAMAN GULLY FORMATION
	Turritella Clays and Marls	BLANCHE POINT Soft Marls	BLANCHE POINT LIMESTONE	BLANCHE POINT MARLS Soft Marls	BLANCHE POINT MARLS Soft Marls	BLANCHE POINT FORMATION Soft Marls	BLANCHE POINT FORMATION 'Soft Marl' Member
		Banded Marls		Banded Marls	Banded Marls	Gull Rock Member	Gull Rock Member
	Glauconitic Marls with Hantkenina	Transitional Marls		Transitional Marls	Transitional Marls	Transitional Marls	'Transitional Marl' Member
	Greensands	TORTACHILLA LIMES. Glauconitic Limestone		TORTACHILLA LIMEST. Glauconitic Limestone	Palaeokarst		Palaeosol/Karst
		Polyzoal Limestone		Polyzoal Limestone	TORTACHILLA LIMESTONE	TORTACHILLA LIMESTONE	TORTACHILLA LIMESTONE
		SOUTH MASLIN SANDS	MASLIN SANDSTONE	SOUTH MASLIN SANDS	SOUTH MASLIN SANDS	MASLIN SANDS South Maslin Sand Member	'SOUTH MASLIN' SAND
		NORTH MASLIN SANDS		NORTH MASLIN SANDS	NORTH MASLIN SANDS	North Maslin Sand Member	'NORTH MASLIN' SAND

The presentation of the units is according to the International Stratigraphic Guide (Hedberg, 1976) and Gelati's 1968 model, but within the Australian Code of Stratigraphy (1973). The geological terminology is consistent with the Glossary of Geology (Gary, McAfee, et al., 1974). The nomenclature and the approach to the interpretation of the unconformities is after Wheeler (1957, 1958a,b; 1959a,b; 1964a,b) and after Ki Hong Chang (1975).

Reynolds' nomenclature and subdivisions are at present maintained, although some of his names are still informal, in order not to unbalance a thesis, essentially palaeontological, with further discussion However, a revision of these units already in progress will be presented separately.

TORTACHILLA LIMESTONE

SYNONYMS

- Glauconitic Limestone (lower part), Lower Aldinga Series (Tate, 1879).
- Iron shot sands (topmost part) and glauconitic limestones (lower part) (Tate & Dennant, 1896).
- Greensands (Adelaide Plains SubBasin) (Glaessner, 1951)
- Polyzoal Limestone, Lower member of Tortachilla Limestone (Reynolds, 1953).
- South Maslin Sands (topmost part) (Reynolds, 1953).
- Tortachilla Glauconitic Limestone (lowermost part) (Reynolds, 1953).
- Blanche Point Limestone (lowermost part) (Crespin, 1954).
- Maslin Sandstone (topmost part) (Crespin, 1954).
- Tortachilla Limestone (Buonaiuto, 1977a).
- Tortachilla Limestone (Cooper, 1977b).

OBSERVATIONS

The name 'Tortachilla Limestone' is inappropriate with respect to its lithological part. Only in parts of the Willunga SubBasin the unit is represented by bryozoal limestone. In the Noarlunga and in the Adelaide Plains SubBasins, it is composed of sands, sandstones or breccias.

In the Noarlunga SubBasin, limestone beds occur in the topmost part of the unit and then only in places. However, since this unit is currently under revision, the traditional name is informally maintained here, for the sake of simplicity.

TYPE LOCALITY AND TYPE-SECTION

The Tortachilla Limestone outcrops on the BARKER 1:250,000 Geological Map and on the Noarlunga Topographic Map 1:50,000, 6627-IV & PT 6527-1 sheet (1:10,000).

The type locality and type section are situated in the southern cliffs of Maslin Bay, between Bennet Creek and Blanche Point (Reynolds, 1953).

OUTCROPS, LOCALITIES AND GENERAL LITHOLOGIES (Fig. 3a,b,c)

Willunga SubBasin (Sections A, B, C and D)

The best outcrops of the units are at the type locality where they consist of pinkish, greenish and brownish red unconsolidated to poorly consolidated clayey sands and micro-conglomerates intercalated with pinkish and pinkish-green mottled limestones. The sand and micro-conglomerates are bioclastic, limonitic, quartzitic, and in places glauconitic (fig. 10).

Noarlunga SubBasin (Sections E, F, G, H and I)

The outcrops at Christies Beach, along the River Road and adjacent to the Noarlunga Oval have been measured. The lithologies are similar to the above, but are generally of finer grain size and contain less micro-conglomerate, and very rare organic remains. These sections display a persistent horizon of intraformational conglomerate of angular sand and

FIG. 7 Lithostratigraphic synopsis and revised nomenclature of the Tertiary formations at Maslin and Aldinga Bays.

REVISED STRATIGRAPHIC RELATIONSHIPS OF THE TERTIARY FORMATIONS OUTCROPPING AT MASLIN AND ALDINGA BAYS (WILLUNGA SUB-BASIN, ST VINCENT BASIN)

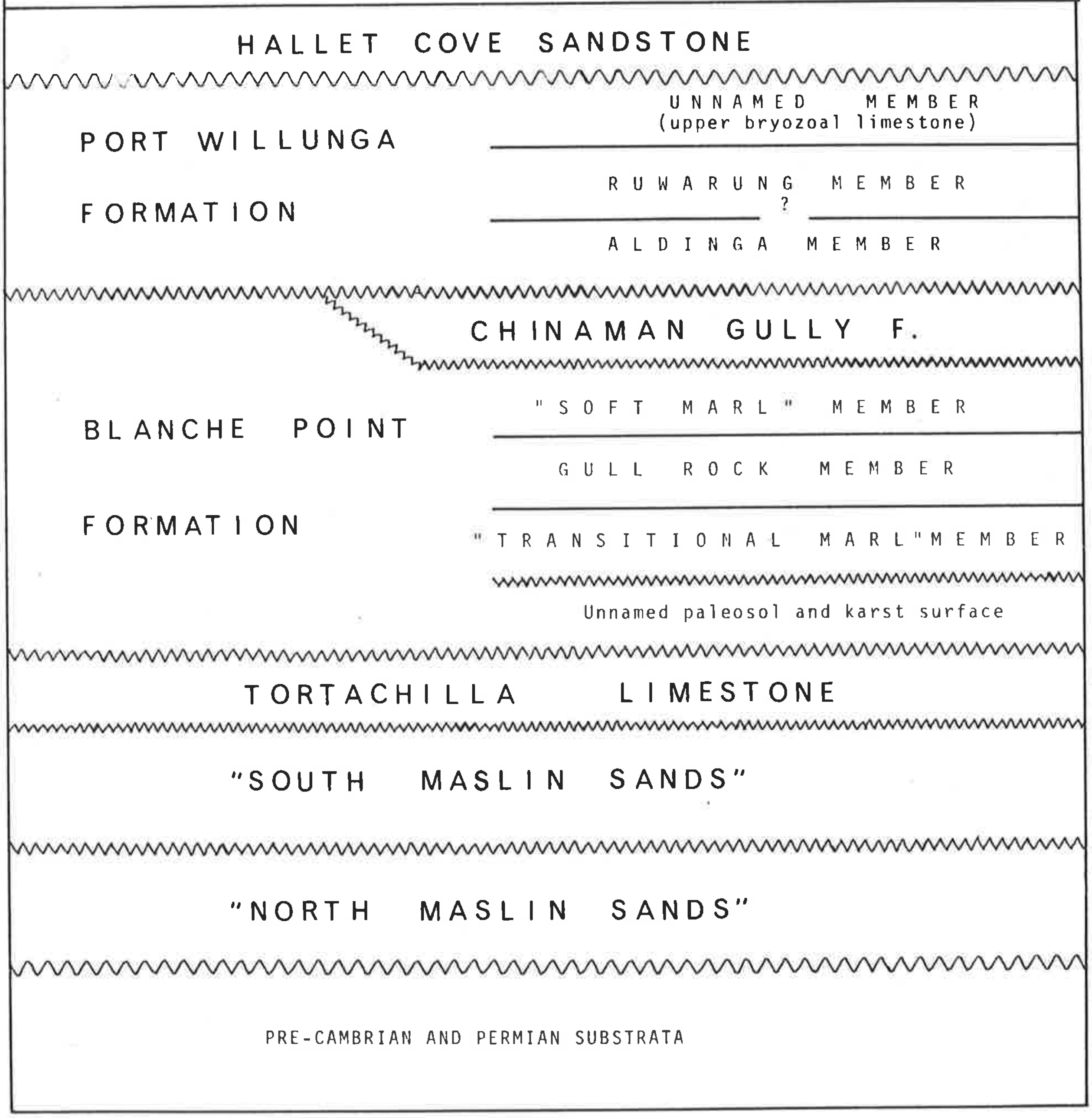
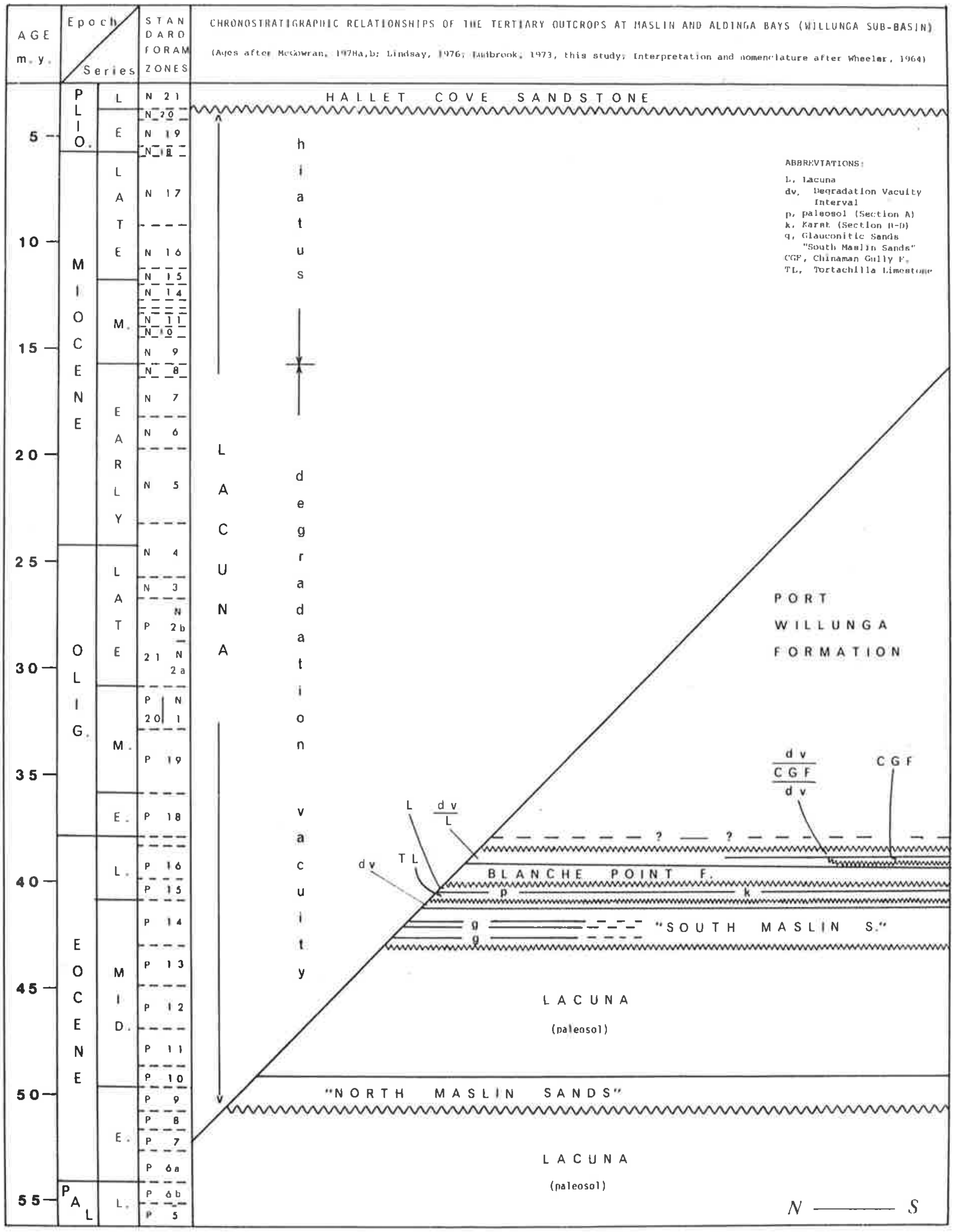


FIG. 8 Chronostratigraphic relationships of the Tertiary deposits at Maslin and Aldinga Bays.



CHRONOSTRATIGRAPHIC RELATIONSHIPS OF THE TERTIARY OUTCROPS AT MASLIN AND ALDINGA BAYS (WILLUNGA SUB-BASIN)

(Ages after McGowran, 1978a,b; Lindsay, 1976; Ludbrook, 1973, this study; Interpretation and nomenclature after Wheeler, 1964)

ABBREVIATIONS:

L, Lacuna
dv, Degradation Vacuity Interval
p, paleosol (Section A)
k, Karst (Section B-D)
g, Glauconitic Sands "South Maslin Sands"
CGF, Chinaman Gully F.
TL, Tortachilla Limestone

clay galls in a stratigraphic position equivalent to the lower bryozoal limestone bed of the Willunga SubBasin (fig. 10, 3b).

At the South Road-Honeypot Road intersection, the unit is represented by about 60 cm of grey coarse compact sands. At the southern end of Moana Beach to the north of Ochre Point, a highly limonitized conglomerate, followed by limonitic clays and sands, is in a stratigraphic position equivalent to the Tortachilla Limestone.

Adelaide Plains Sub-Basin

Only the Longyear Bore has been examined (Fig. 3a, 11). The lithology of the unit is close to that seen in the Noarlunga Sub-Basin. It is represented by a succession of coarse to fine sands which contain sand galls, clayey nodules, occasional pebbles, limonitic and quartz clasts, and glauconitic and limonitic pellets. The cores of the Adelaide Childrens Hospital Bores are now skeletonized, and hence, no lithostratigraphy can be reconstructed satisfactorily.

VERTICAL RELATIONSHIPS

Lower Contact

The Tortachilla Limestone overlies the South Maslin Sands along an erosional unconformity. The topmost part of the South Maslin Sands in Maslin Bay is represented by purplish, unconsolidated, well-sorted, fine limonitic quartzose sands. Above the contact, brownish-red cross-bedded quartzitic limonitic micro-conglomerates with sandy and clayey matrix mark the base of Tortachilla Limestone.

In the Noarlunga Sub-Basin the topmost part of the South Maslin Sands is represented by purplish-red, faintly cross-bedded, quartzitic and limonitic fine sands intercalated with frequent thin layers of finer clayey greenish sands at Christies Beach and by blackish-brown, grey and (at the top) red clays at Noarlunga. Above the contact, brownish-red, unconsolidated, fine, well sorted quartzitic and limonitic clayey sands represent the base of the Tortachilla Limestone.

Although these sands and clays are shown on the Euchunga 1:63,360 Geological Map (Sprigg & Wilson, 1954) as belonging to North Maslin Sands, the occurrence of marine fossils and limonitic pellets indicate that they should be referred to the South Maslin Sands and to the Tortachilla Limestone.

Upper Contact

The Tortachilla Limestone disconformably underlies the 'Transitional Marls' which are the lowest member of the Blanche Point Formation, with a Karst surface developed on the Tortachilla Limestone. Below the contact surface there is generally a pinkish-greenish mottled limestone bed intensely hollowed out with irregular deep, subvertical pits filled with green glauconitic bryozoal sands or, in places, limestone. The infillings of these cavities are referable to the lowest unit of the 'Transitional Marls'(for detailed discussion, see Buonaiuto, 1977a; Appendix F, herein). In places where the contact is an erosional surface truncating nearly all the Tortachilla Limestone an intraformational breccia or conglomerate overlies its different units (section A, G, H).

A trench in front of the South Road-Honeypot Road intersection (Hackham) shows the Tortachilla Limestone to be separated from the greensand unit of the 'Transitional Marls' by a thin, red palaeosol (2-3 cm thick) superimposed on the topmost Tortachilla Limestone. Palaeosols in an analogous stratigraphic position can be observed in the Longyear Bore (Adelaide Plains Sub-Basin) and on the northern slope of Ochre Point (Moana Beach, Noarlunga Sub-Basin). Remnants of highly ferruginized Tortachilla Limestone can be observed in section A (Chaffeys Road, McLaren Vale) and at Maslin Bay, near the top of the knoll, just south of Bennet Creek. Finally, in both the Noarlunga and the Willunga Sub-Basins Tortachilla Limestone is also locally overlain unconformably by the Late Pliocene Hallett Cove Sandstone.

HORIZONTAL AND VERTICAL VARIATIONS

The Tortachilla Limestone displays marked variations in thickness and in lithology in the two sub-basins and even at the same locality, particularly in its middle part. The thickness at Maslin Beach varies between about 3.25 m at 'Uncle Tom's Cabin' (section B) and about 1.95 m at the Reynolds Cave (section C). In the Noarlunga SubBasin it varies from 1.75 m at Christies Beach (section E) to 5.85 m at Noarlunga (section F), and reaches 2.80 m in the Longyear Bore (Adelaide Plains SubBasin).
The Tortachilla Limestone is chiefly characterized by a succession of two alternating sequences (a-b, a-b) where 'a' is a quartz-limonitic sand and/or micro-conglomerate and 'b' is a micro-conglomeratic limestone. Above the lower contact, the lower unit 'a' of the older sequence is generally composed of red-brownish, limonitic and quartzitic, unconsolidated, cross-bedded micro-conglomerates (Maslin Bay) or of limonitic and quartzitic cross-bedded fine sands, which are in places micaceous (Noarlunga SubBasin). The lower unit 'a' of the younger sequence is represented by unconsolidated micro-conglomeratic sands bearing limonitic, quartzitic and skeletal clasts. In places these sands are interbedded with highly porous and poorly consolidated bioclastic intercalations or contain a high content of glauconite (Maslin Bay). The lower unit 'a' is also represented in places by glauconitic sands bearing lenses of micro-conglomerates or sand- and clay-galls (Noarlunga SubBasin). In both basins this unit displays a highly variable thickness. The general occurrence of the two lithified units 'b' is a relatively constant characteristic of the formation. In Maslin Bay, lower and upper units are both represented by a bryozoal biomic-rudite with variable micro-conglomeratic content; it is possible to distinguish the upper from the lower by a higher content of bioclasts and a smaller amount of quartzitic and limonitic clasts. In the Noarlunga SubBasin, the lower unit is represented by an intraformational

conglomerate with large and angular sand and clay galls and microconglomeratic lenses. In both basins the upper limestone is the deeply pitted bio-mic-rudite described above.

Atypical facies of the Tortachilla Limestone have been observed in various localities. In the Longyear Bore, it occurs as coarse to fine, glauconitic-limonitic quartz sands, containing occasional sand galls, pebbles, and almost no fossil content (shell fragments). In the Hackham area, opposite the South Road-Honeypot Road intersection the formation is represented by coarse, compact, grey quartz sands. On the northern slope of Ochre Point (Moana Beach) it occurs as conglomerate with large pebbles up to 20 cm and limonitic cement and it grades upward to limonitic sands and clays, which underlie the 'Transitional Marls'.

The Hackham and Ochre Point outcrops of which the latter is very similar to the continental Baker Gully Sands of Stuart (1969) might represent a marginal facies for the Noarlunga Sub-Basin.

Dissolved tracts of Tortachilla Limestone have been observed in places on the cliffs just north of Blanche Point at Maslin Bay (Reynolds Cave). Here the calcareous content of this formation is completely dissolved except for a few relicts, and only the limonitic and quartzitic content and a few shark's teeth are left. Subsequently, this tract was subjected to compaction phenomena associated with fracturing in the undissolved part of the formation to form collapse breccia (section C). Southward of section D, where the unit is not disturbed by compaction and the dissolution is limited to the upper half of the formation, it is possible to observe undisturbed vertical, glauconitic fillings and horizontal irregular glauconitic lenticules which are included in both the residual sands and preserved limestone. The dissolution front is represented by a very irregular surface truncating the different units of the formation and, in places, it is possible to distinguish South Maslin Sands from the dissolved Tortachilla Limestone just by the different limonitic content.

REVISION OF THE TORTACHILLA LIMESTONE AND ITS CONTACTS

The contacts and the characteristics of the Tortachilla Limestone need further discussion in relation to the interpretations given by the past authors (Fig. 9).

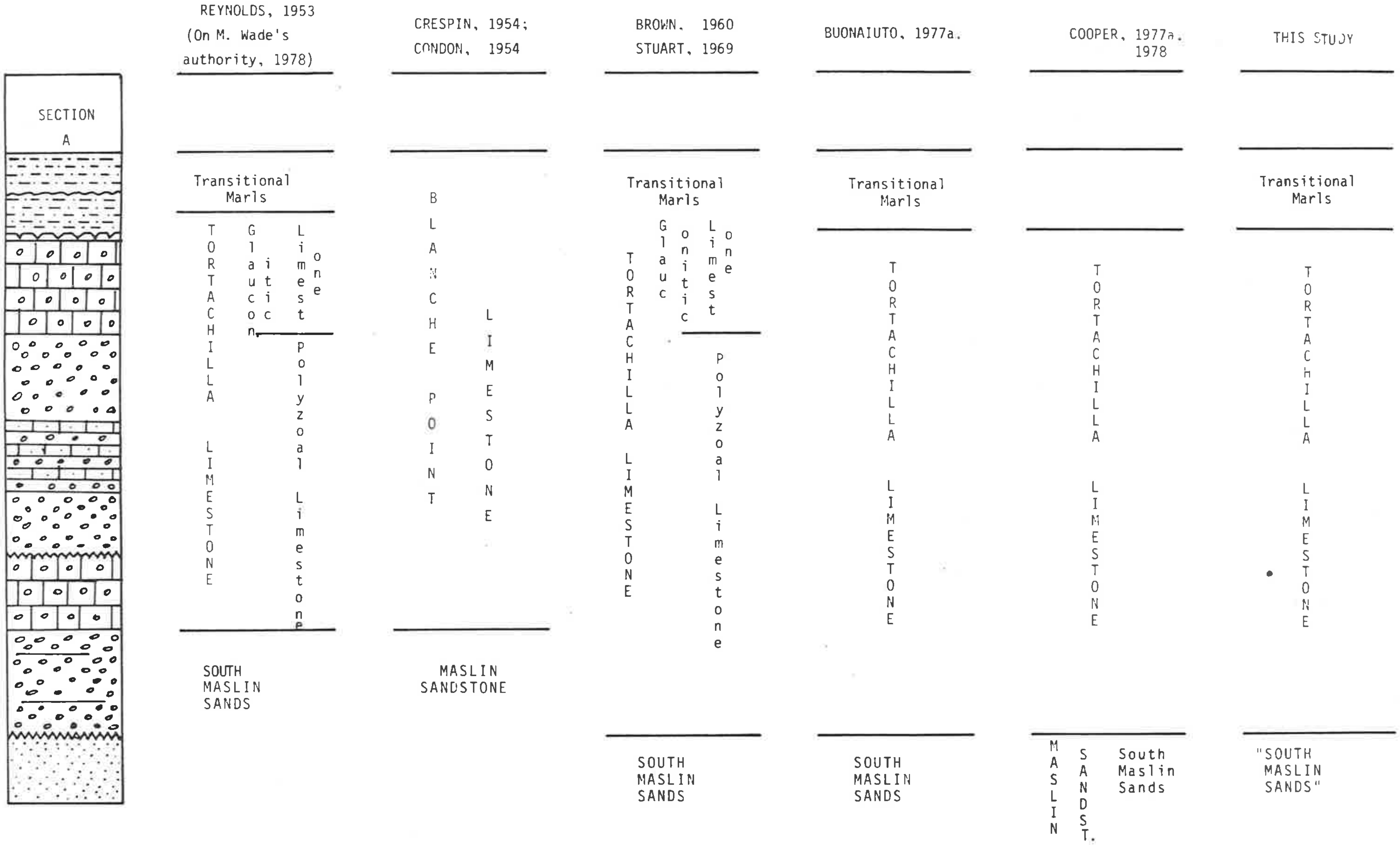
Reynolds (1953, pp. 123-4) divided the Tortachilla Limestone into two members - the lower Polyzoal Limestone and the upper Tortachilla Glauconitic Limestone (corrected nomenclature of Reynolds, Dr. Mary Wade, 1978, pers. comm.). The lower contact of the formation was placed by Reynolds at the bottom surface of the lower limestone bed, which displays in places a broadly undulating surface, simulating an erosional feature. He located the upper contact at the top of the glauconitic unit above the karst surface and included the pit infillings (Tortachilla Glauconitic Limestone).

Crespin's (1954) location of the contact between her Maslin Sandstone and Blanche Point Limestone coincides with Reynolds' contact between South Maslin Sands and Tortachilla Limestone (Condon, in Crespin, 1954, pp. 61-62). Brown (1960, unpubl.) and Stuart (1969, unpubl. pp. 57-65) followed Reynolds for the upper limit, but they more accurately placed the lower limit at the erosional surface at the bottom of the lower micro-conglomeratic bed in the Willunga Sub-Basin and at the base and within the equivalent cross-bedded sandy unit in the Noarlunga Sub-Basin.

In Maslin Bay, the contact between the Tortachilla Limestone and the South Maslin Sands is clearly located at the base of the cross-bedded lower micro-conglomerate. In the Noarlunga Sub-Basin the deposits represent rather different conditions of sedimentation. However, it is possible to recognize an analogous lower sandy unit at the base of the formation on the basis of the following criteria:

A) The quartzitic clasts in the topmost part of South Maslin Sands

FIG. 9 Comparative synopsis of the formations instituted by the authors at Aldinga and Maslin Bays, and their boundaries in relation to Tortachilla Limestone.



COMPARATIVE SYNOPSIS OF THE FORMATIONS AND THEIR BOUNDARIES, INSTITUTED AT " UNCLE TOM'S CABIN, MASLIN BAY, BY THE DIFFERENT AUTHORS IN RELATION TO " TORTACHILLA LIMESTONE ".

are angular or poorly rounded. In the overlaying cross-bedded unit they are spheroidal or very well rounded, well sorted and there is little associated matrix. Clearly, these deposits represent conditions of relatively higher energy.

B) There is a transition from a faint micro-cross-bedding in the top of the South Maslin Sands to the large cross-bedding in the lower sandy unit of Tortachilla Limestone at section E. At section I there is a transition from a clayey episode to a sandy one with very large cross-bedding. The former indicates a rather gradual changing in conditions of energy and depositions; the latter a more abrupt one.

C) The limonitic-geothitic content, which is seen either as organic moulds or as possible terrigenous clastics, increases abruptly at the bottom of the cross-bedded level in all sections.

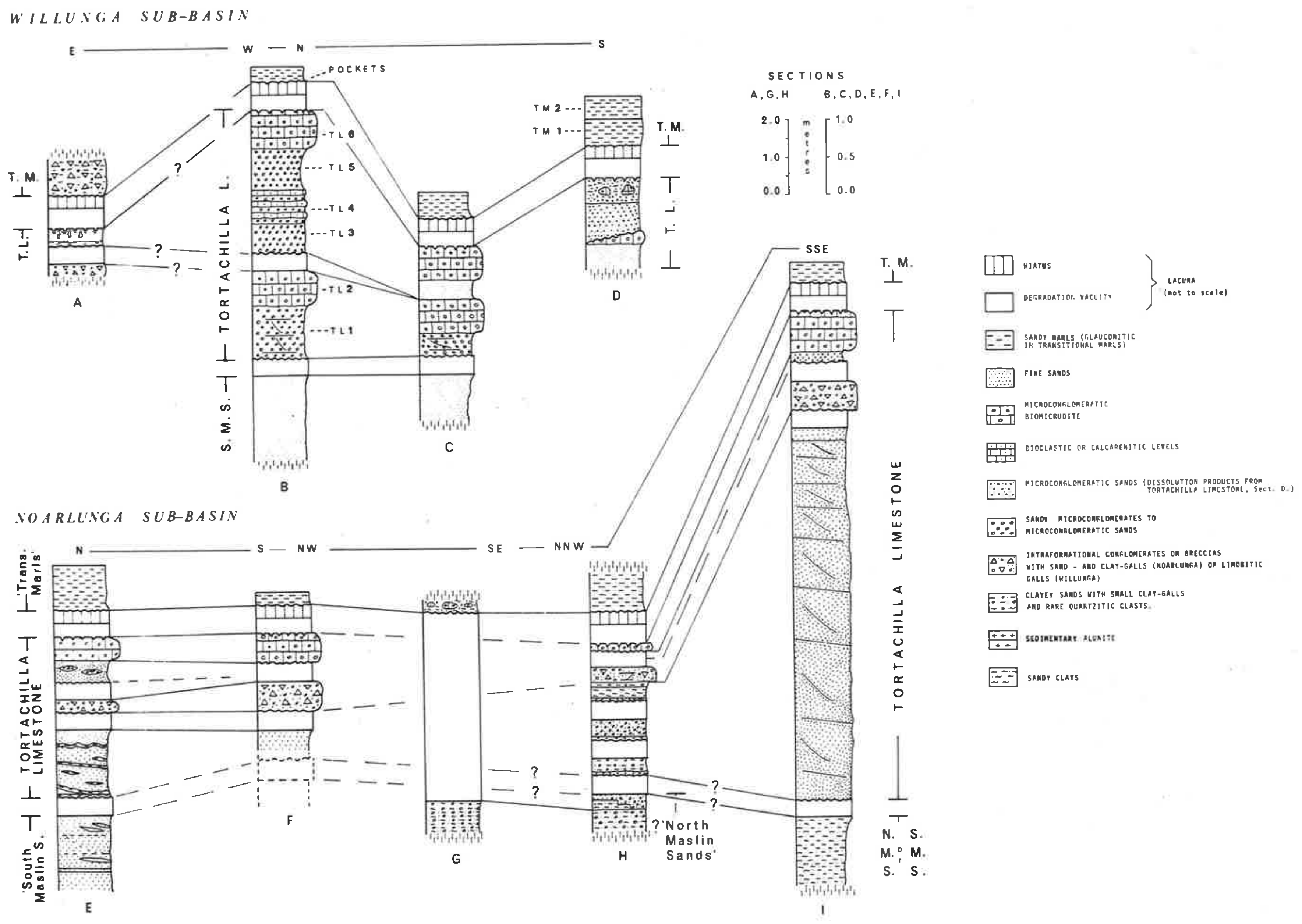
D) There are abundant flattened limonitic clasts in the cross-bedded unit. Such clasts are absent from the South Maslin Sands.

E) A marked increase in limonitized pellets occurs in the cross-bedded unit.

These factors all clearly indicate an abrupt increase of energy during the deposition of Tortachilla Limestone in relation to the underlying South Maslin Sands.

In conclusion, the lower limit of Tortachilla Limestone is maintained at the bottom of the micro-conglomeratic unit in the Willunga SubBasin, following Brown (1960) and Stuart (1969). The upper limit on the other hand is lowered at the karst surface, at the top of the hard bioclastic unit of Reynolds' Tortachilla Glauconitic Limestone, or at the palaeosol on the unit in the Noarlunga and Adelaide Plains SubBasins since it has been proved that the overlying glauconitic member (Reynolds' Tortachilla Glauconitic Limestone, upper part) is separated from the lower member

FIG. 10 Tortachilla Limestone: stratigraphic columns of the main outcrops in the Noarlunga and Willunga SubBasins.

WILLUNGA SUB-BASIN
E — W — N — S
A
B
C
D
T. M.
T.L.
TORTACHILLA L.
S. M. S.
POCKETS
TL 6
TL 5
TL 4
TL 3
TL 2
TL 1
TM 2
TM 1
T. M.
T. L.
?
SECTIONS
A, G, H
B, C, D, E, F, I
2.0
1.0
0.0
metres
1.0
0.5
0.0
NOARLUNGA SUB-BASIN
N — S — NW — SE — NNW — SSE
E
F
G
H
I
'Trans. Marls'
TORTACHILLA LIMESTONE
'South Maslin S.
?'North Maslin Sands'
T. M.
TORTACHILLA LIMESTONE
N. S.
M. or M.
S. S.
HIATUS
DEGRADATION VACUITY
LACURA (not to scale)
SANDY MARLS (GLAUCONITIC IN TRANSITIONAL MARLS)
FINE SANDS
MICROCONGLOMERATIC BIOMICRUDITE
BIOCLASTIC OR CALCARENITIC LEVELS
MICROCONGLOMERATIC SANDS (DISSOLUTION PRODUCTS FROM TORTACHILLA LIMESTONE, Sect. D.)
SANDY MICROCONGLOMERATES TO MICROCONGLOMERATIC SANDS
INTRAFORMATIONAL CONGLOMERATES OR BRECCIAS WITH SAND - AND CLAY-GALLS (NOARLUNGA) OR LIMONITIC GALLS (WILLUNGA)
CLAYEY SANDS WITH SMALL CLAY-GALLS AND RARE QUARTZITIC CLASTS.
SEDIMENTARY ALUNITE
SANDY CLAYS

by a lacuna and that it belongs to a different, successive episode of deposition, i.e. the one of Blanche Point Formation (Buonaiuto, 1977a). B. Daily, Department of Geology, University of Adelaide, offers another interpretation of the Tortachilla Limestone/Blanche Point Formation disconformity at Maslin Bay. He ascribes the origin of the sedimentary break to submarine dissolution and that of the pits to preferential dissolution of bioturbations caused by boring activities of marine organisms (e.g. crabs) (B. Daily, 1978, pers. comm.).

FOSSILS

The Tortachilla Limestone in the Noarlunga SubBasin is practically barren, except for rare shell fragments. The Willunga SubBasin at Maslin Bay is very rich in Mollusca, Echinoida, Bryozoa, Brachiopoda, fish remains (teeth), Crustacea (Decapoda and Cirripedia), Annelida, Foraminifera (most benthonic).

Characteristic Molluscan Assemblages (bottom to top):

Chlamys-Hiatella, *Dimya*, *Dosina-Turritella-Chlamys*.

Molluscan Index-Species: *Chlamys aldingensis* (Tate).

Other Distinguishing Events. Acmes: *Hiatella ?vera* (Deshayes) (lower part); *Dimya sigillata* Tate and *Isolimea alticosta* Tate and Decapoda (middle Part); Cirripedia (throughout). Disappearance of *Chlamys aldingensis* (topmost).

AGE

The Tortachilla Limestone is generally considered as being of early Late Eocene age. Ludbrook (1973) approximated it to the foraminiferal zone P15. Jenkins (1974) suggested a break between Tortachilla Limestone and the Blanche Point Formation. Buonaiuto (1977a, Appendix F) demonstrated that it represented a lacuna spanning an interval as yet undeterminable. Recently McGowran (1978a,b) restricted the Tortachilla Limestone to early P15 and gave the lacuna a middle P15 age.

BLANCHE POINT FORMATION

SYNONYMS

- Lower Aldinga Series (Tate, 1878, 1879) (*pro parte*)
- Middle Aldinga Beds, 'Marine Miocene Strata' (Tate, 1882)
- Lower Aldinga Series (Tate & Dennant, 1896) (*pro parte*)
- Miocene Beds (Howchin, 1923) (*pro parte*)
- Tortachilla Glauconitic Limestone, member of Tortachilla Limestone, (Reynolds, 1953)
- Blanche Point Glauconitic Limestone (Reynolds, 1953) (*nom. err.*, *pro* Tortachilla Glauconitic Limestone)
- Blanche Point Marls (Reynolds, 1953)
- Blanche Point Limestone (Crespin, 1954) (*pro parte*)
- Noarlunga Limestone (Crespin, *loc. cit*) (*nom. err.*, *pro* Blanche Point Limestone)
- Blanche Point Marls (Stuart, 1969, unpubl.)
- Blanche Point Formation (Cooper, 1977b).

TYPE-LOCALITY AND TYPE SECTION

The Blanche Point Formation outcrops in the area covered by the BARKER Geological Map (1:250,000) and the Noarlunga and Yankalilla 1:50,000 topographic map sheets. The type locality and type section (Figs.3c,12) are located on the southern Side of Maslin Bay and on the northern side of Aldinga Bay, in the cliffs between the Tortachilla Trigonometric Point and Chinaman Gully. The area includes the picturesque Blanche Point (Reynolds, 1953, map) (Fig. 3c).

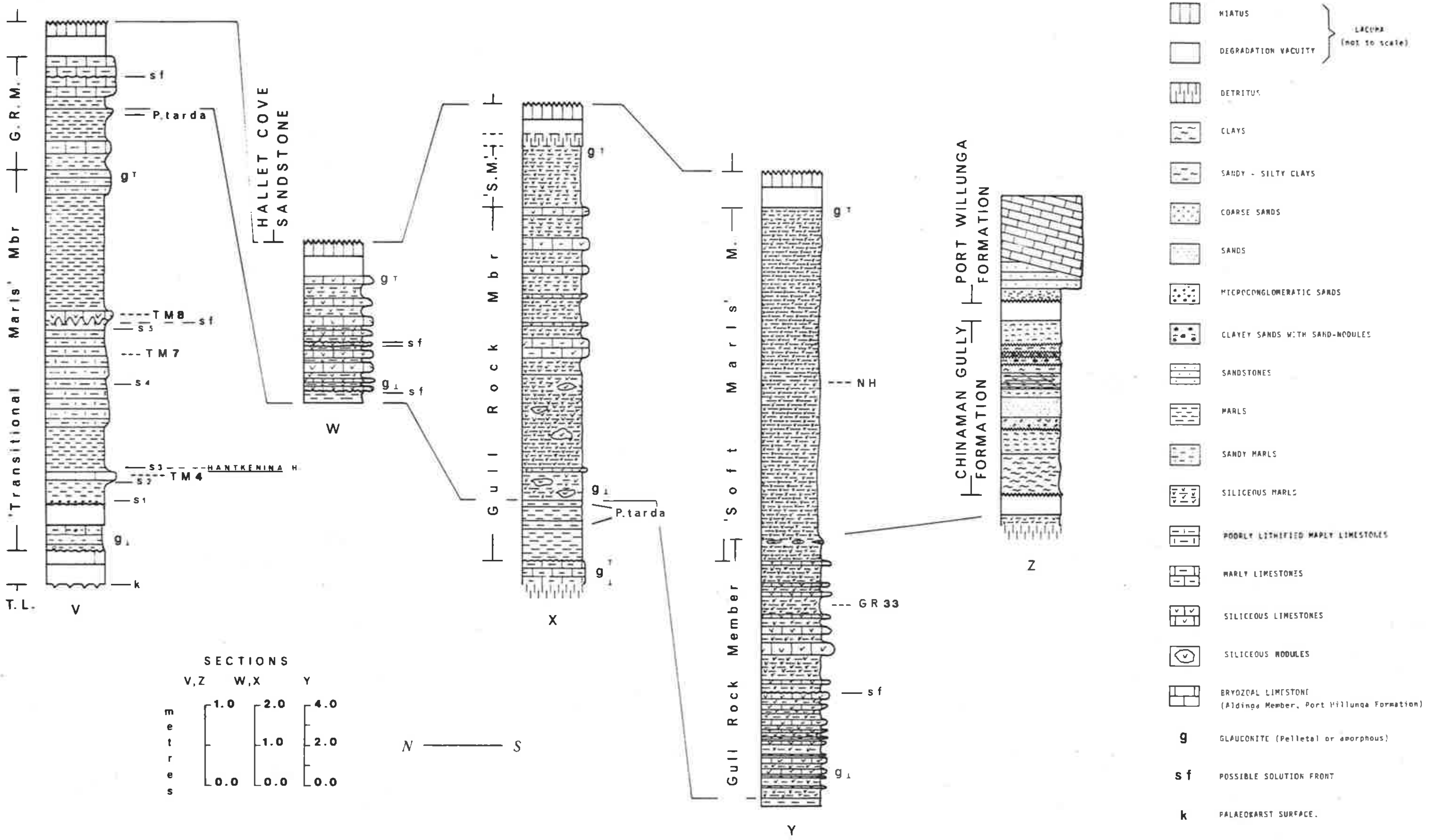
OTHER MAIN OUTCROPS AND LOCALITIES

Willunga Sub-Basin

From Maslin and Aldinga Bays coast to McLaren Flat very poor, small outcrops are scattered throughout the area and are generally exposed in road cuttings (Chaffeys Road, just south west of Coriole

FIG. 12 Blanche Point Formation: stratigraphic columns from the type locality (Maslin and Aldinga Bays).

BLANCHE POINT FORMATION AT MASLIN & ALDINGA BAYS



Winery; Chalk Hill Road (-Stuart, 1969, unpubl. etc.) (Fig. 3c).

Noarlunga Sub-Basin

A coastal outcrop of all the three lithological units of the formation occurs between Witton Bluff (Christie Beach) and Noarlunga Jetty. A series of small outcrops occur along the Onkaparinga River: at Noarlunga, on the south bank opposite the Oval (lower member); west of the Fleming Bridge, on the north bank (middle and upper members; along the River Road (lower member); Onkaparinga River mouth at the footbridge (top of the member) (Lindsay, 1970). In the Hackham area, the formation can be found at the intersection of Honeypot Road with Chilcomb Drive, 200 m east of South Road, and in the trench opposite the Honeypot Road-South Road intersection (lower and middle member) (Fig. 3b).

A series of other small outcrops occur inland at Happy Valley Reservoir and at the southern end of Moana Beach, north of Ochre Point (lower and middle member).

Adelaide Plains Sub-Basin

No surface outcrops occur. However, the formation is well developed in the subsurface and is regularly encountered in bores (Cochrane, 1956; Lindsay, 1968, 1969) (Fig. 3c, 11).

GENERAL LITHOLOGY

The Blanche Point Formation is characterized by a regular succession of three units in all three sub-basins.

A) The 'Transitional Marl' Member, the lower unit, is characterized by a very high content of glauconite and by absence or low content of silica (primary organic and secondary inorganic) and it is also poorly lithified.

B) The Gull Rock Member, the middle unit, is distinguished by: a regular alternance of well and poorly lithified horizons; a very high content of silica (both inorganic and skeletal organic); absence of glauconite in the lower part; and occurrence of pelletal glauconite in the upper part, but in a smaller amount than in the 'Transitional Marls'.

C) 'Soft Marl' Member, the upper unit is characterized by a very high content of sponge spicules and other siliceous micro-organisms and by the presence of glauconitic pellets, somewhat less in amount than in the Gull Rock Member. It is poorly lithified and no bedding plane is visible.

VERTICAL RELATIONSHIPS

Lower Contact: Disconformable or unconformable on the Tortachilla Limestone (see previous discussion.)

Upper Contact: The Blanche Point Formation is in erosional contact with the following three units listed in stratigraphical order.

- The Chinaman Gully Formation (approximately late P16), which represents a non-marine episode of deposition immediately succeeding the Blanche Point Formation as is seen in many bores and outcrops.
- The Aldinga Member of the Port Willunga Formation (latest P16-P17)((Observation Bore WLG 38, Willunga Sub-Basin (Cooper, 1978); Grange Bore 1 and Croydon Bore 2 (Lindsay, 1968), Adelaide Plains Sub-Basin)).
- The Hallett Cove Sandstone (Late Pliocene)which truncates the entire Eocene-Miocene succession in the coastal outcrops of the Willunga and Noarlunga Sub-Basins.

HORIZONTAL RELATIONSHIPS

Stuart (1969) considered the Blanche Point Formation in the Willunga Sub-Basin as heteropic inland with his 'Baker Gully Sands' and in the Adelaide Plains Sub-Basin with his 'Golden Grove Sands'. Both these informal units represent marginal contental episodes (Stuart, 1969). However, the 'Baker Gully Sands' are similar to those underlying the Blanche Point Formation at Ochre Point and to those unconformably overlying the Gull Rock Member in the Hackham area.

OBSERVATIONS

The Tortachilla Limestone/Blanche Point Formation karst surface and palaeosols are here referred to the Blanche Point Formation, because they represent the initial continental episode of the cyclothem, during which this Formation was deposited, and also represent events post-depositional to the Tortachilla Limestone.

'Transitional Marl' Member

(Reynolds, 1953)

SYNONYMS

- Glauconitic marls (Glaessner, 1951)
- Tortachilla Glauconitic Limestone (upper part) (Reynolds, 1953)
- Blanche Point Glauconitic Limestone (Reynolds, 1953) (*nom. err.*, *pro* Tortachilla Glauconitic Limestone)
- Blanche Point Transitional Marls (Reynolds, 1953)
- Greensands of Kent Town (Ludbrook, 1963)
- Blanche Point Transitional Marls (Buonaiuto, 1977a)
- Blanche Point Transitional Marls (Cooper, 1977b).

OBSERVATIONS

The name 'Blanche Point Transitional Marls' is considered informal for the following reasons.

a) The lithological term 'Marls' is too restrictive and does not encompass the other lithologies present in the member, such as: sands, breccias, micro-conglomerates, glauconitic clays, limestone, silicified horizons etc.

b) The adjective 'Transitional' has a doubtful descriptive value in relation to the lithology, and therefore it cannot be considered as part of the lithological term,and hence, as a formal part of the member's name (Australian Code of Stratigraphic Nomenclature, 1973).

c) The geographical name 'Blanche Point' is preoccupied since it is already the name of the Formation. Therefore, its extension to units of the Formation would relegate them to informal nomenclature (International Stratigraphic Guide, 1976; Australian Code of Stratigraphic Nomenclature, 1973).

TYPE-LOCALITY

The cliffs between Tortachilla Trigonometric Point and Blanche Point at the southern side of Maslin Bay.

TYPE-SECTION

First gully southward of the steps ('Uncle Tom's Cabin'); thickness, 4.65 m (Section V, Fig. 12).

GENERAL LITHOLOGY

Green glauconitic sands and clays, micro-conglomerates, and intraformational breccias with glauconitic clay matrix, generally in the lower part and are locally cemented by sparite. Marls and limestones are present in the upper part, with a very high content of glauconitic pellets, and with secondary silica concentrated in irregular horizons or dispersed throughout the member.

THICKNESSES

At Maslin Bay, Reynolds (1953) reports a maximum thickness of 2.3 m, and Crespin (1954) one of 60 cm., maintaining a regular thickness of 4-5 m towards Blanche Point. In the Noarlunga Sub-Basin the Member reaches a thickness of about 3-4 m, but is thinner in the Hackham area due to erosion of its upper part and in the Ochre Point outcrop. In the southern part of the Adelaide Plains Sub-Basin it reaches the maximum recorded thickness of 9.20 m in the Longyear Bore (Longyear Bore 50, Hd Noarlunga Sect. 82, Fig. 11).

Thicknesses indicated by Lindsay (1969) include undifferentiated Tortachilla Limestone and 'Transitional Marls'.

VERTICAL AND HORIZONTAL RELATIONSHIPS

Lower Contact

Unconformable or disconformable with Tortachilla Limestone. See above discussion and Buonaiuto (1977a).

Upper Contact

The boundary between the Gull Rock Member ('Banded Marl' Member) and the 'Transitional Marl' Member has not as yet been clearly described or defined.

Reynolds (1953) placed this contact at the base of the first siliceous hard band, as correctly figured by Jenkins (1974). However, this location appears to fall too low, and well within the 'Transitional Marl' Member. Above this horizon, the typical lithology of the Member still persists and neither is there any evidence of significant faunistic change. Crespin's 1954 description is less definite than Reynolds'. Stuart (1969, unpubl.) and Lindsay (1969) follow Reynolds and give no particular attention to this problem. However, the institution of the new name 'Gull Rock Member' by Cooper (1977) for Reynolds' 'Banded Marl Member' necessitates a revision and a better definition of this contact.

Reynolds' location of the 'Transitional Marls'/'Banded Marls' contact is unsatisfactory for the following reasons:

a) Secondary silica, dispersed in or cementing irregular horizons, does occur in the 'Transitional Marls', particularly in the upper part.

b) The lithological transition between the two members appears to be very gradual in places.

c) The lithological characters of these members vary in the three sub-basins and, as a consequence, the contact may assume a variable

An examination of the best available outcrops and cores (Maslin Bay, Observation Bore WLG 42, Willunga Sub-Basin; Witton Bluff, Noarlunga Sub-Basin; Longyear Bore, Adelaide Plains Sub-Basin) suggested three possible criteria to determine this boundary, which are as follows:

A) The sharp decrease or the disappearance of glauconite, either amorphous or in pellets, in the lower units of Gull Rock Member in contrast to its extreme abundance in the 'Transitional Marls', and its return to a relative abundance in the upper part of the Gull Rock Member itself.

B) The sharp increase to predominance of organic (mainly sponge spicules) and inorganic (secondary) silica in the lower units of the Gull Rock Member in contrast to the very low content of sponge spicules in the upper part of the underlying member.

C) The sharp decrease in fossil remains in the lower unit of the Gull Rock Member. The impoverished oligotypic assemblage of this unit represents a net contrast with the very rich and highly diversified assemblages of the underlying 'Transitional Marls' and Tortachilla Limestone and of the overlying upper part of the Gull Rock Member itself.

On the basis of these three criteria, the boundary should be located as follows:

Willunga Sub-Basin

At Maslin Bay and at Blanche Point the contact should be placed between the last thick glauconitic limestone and the first whitish soft marly horizon, below the Phygraea tarda horizon (Notostrea lubra horizon Auctt.) and well below the first of the regular siliceous hard bands (Fig. 12). This location satisfied two of the three criteria namely the disappearance of glauconite and impoverished fauna.

Inland, in Observation Bore WLG 42 (Fig. 3c) the contact has convincingly been placed by Cooper (1977b) between the mottled glauconitic grey-green silty marls and the hard grey layered siltstones. This contact satisfies all three criteria. It was noted that the interval of whitish marls and limestones, which contains the *Phygraea tarda* horizon, is not present in this bore.

Noarlunga Sub-Basin (Fig. 3b)

At Witton Bluff marls and limestones with high glauconitic content and diffused secondary silica are conformably overlain by a grey to buff soft marl, which is ~ 30-50 cm thick and contains no glauconite but only an impoverished fauna (*Phygraea tarda* horizon). These marls are followed by a glauconitic and highly siliceous upper Gull Rock Member. The Moana Beach (Ochre Point) outcrop is similar, although the members are thinner.

Adelaide Plains Sub-Basin (Fig. 3a)

In Longyear Bore (Fig. 11) the contact appears similar to that in the Willunga Bore WLG 42. Grey marls and limestones, mottled by minute patches and pellets of glauconite, are overlain by grey calcareous marls showing frequent siliceous bands. The contact here satisfies all the above three criteria. The glauconite does not disappear in the Gull Rock Member above the contact, but shows a sharp decrease. Here, the marly-limestone interval containing the *Phygraea tarda* horizon is not represented.

HORIZONTAL AND VERTICAL LITHOLOGICAL VARIATIONS

The 'Transitional Marls' are generally represented by marls and limestones in all the three sub-basins. In many outcrops the lowermost units are sandy and micro-conglomeratic or are represented by intraformational breccias (Chaffeys Road, just south of Coriole Winery). These units are also richer in glauconite, especially the amorphous kind because of secondary concentration. In the Adelaide Plains and Willunga Sub-Basins the upper part of the member is characterized by irregular horizons cemented by secondary silica. In the Noarlunga Sub-Basin the silica is dispersed throughout the member, except in the lowermost glauconitic units. In Maslin Bay, the glauconitic lowermost units of the 'Transitional Marls' may be cemented by calcite (Tortachilla Glauconitic Limestone of Reynolds, upper part).

FOSSILS

Scarce planktonic and very abundant benthonic foraminifera (*Hanktenina primitiva* Zone), Brachiopoda, Echinoidea, solitary corals, Bryozoa, rare Cirripedia, sharks' teeth, fish remains, otoliths, crustacea remains,and rare sponge spicules (in the upper part). The Member is very rich in Mollusca, but all shells are completely dissolved, except the Pterioida (Bivalvia),which leaves only glauconitic or marly moulds. This shell dissolution is generally observed in almost all the outcrops and bores examined. One exceptional record of this fauna is preserved in a silicified horizon running from 'Uncle Tom's Cabin' (the steps) to Blanche Point, at Maslin Bay. Rare Nautiloids have been observed in the field.

Characteristic Molluscan Assemblages

Turritella-Dosina, *Spirocolpus-Dimya*, *Chlamys-Pycnodonte*, *Dimya-Chlamys*, *Spirocolpus-Trophon* (from bottom to top).

Molluscan Index-Species

Vulsella Laevigata Tate, *Pseudomalaxis ludbrookae* sp. nov. (the latter species encompassing the *Hantkenina primitiva* Zone).

Other distinguishing events.

Terminal ranges of *Dimya sigillata* Tate and *Isolimea alticosta* (Tate). Appearance of *Orbitestella margaritata* sp. nov. in the lowermost part. Appearance of fish bones (in the *Hantkenina* zone) and of sponge spicules in the upper part upward.

AGE

McGowran (1977, 1978a,b), Ludbrook (1967, 1973) and Jenkins (1974) consider the 'Transitional Marls' to have been deposited approximately during the late P15-early P16 foraminiferal zones since the lower to middle part of the member is characterized by the occurrence of *Hantkenina primitiva* Zone (P15/16).

Gull Rock Member

(Cooper, 1977)

SYNONYMS

- *Turritella* clays and Marls, (Glaessner, 1951) (*pro parte*).
- Blanche Point Banded Marl Member (Reynolds, 1953)
- Blanche Point Banded Marls (Lindsay, 1969)
- Blanche Point Banded Marls (Stuart, 1969, unpubl.)
- Gull Rock Member (Cooper, 1977b).

TYPE-LOCALITY AND TYPE-SECTION

Cliffs between Tortachilla Trigonometric Point; Maslin Bay; and Aldinga Beach, between Blanche Point and Chinaman Gully. The section measured (this study) is at the two amphitheatres at Blanche Point. (Sect. Y, Fig.12; see also sections W, X)

OUTCROPS AND LOCALITIES

Willunga Sub-Basin (Fig. 3c)

The main outcrop is at the type locality. The member is regularly encountered in the drillings in the sub-basin, except in the very marginal areas (Cooper, 1978). Some very poor outcrops are in road cuts, in the McLaren Vale area.

Noarlunga Sub-Basin (Fig. 3b)

The best outcrop is between Witton Bluff and Port Noarlunga jetty. Another outcrop, tilted and in tectonic contact with the basement, is just west of the Fleming Bridge, on the right river bank. Other outcrops worth mentioning are at Moana Beach, just north of Ochre Point, and at the intersection of Honeypot Road and Chilcomb Drive, 200 m west of South Road.

Adelaide Plains Sub-Basin

No surface outcrops. The member is, however, regularly encountered in drilling (Lindsay, 1969; Stuart, 1969, unpubl.; this study, Fig. 3a,11).

GENERAL LITHOLOGY

Alternating spicular marls or clayey silts and siliceous nodular limestones or siltstones.

THICKNESSES

Willunga Sub-Basin

At the type locality, thicknesses of about 10-12 m are indicated (12 m, Reynolds, 1953; about 11 m, Cooper, 1977; 10 m, this study). The variable value of the thickness is probably due to the different interpretations of the lower and upper boundary. Stuart (1969, unpubl.) indicates a thickening of up to 12-18 m toward the sub-basin axis.

Noarlunga Sub-Basin

At Witton Bluff the member is not thicker than at Blanche Point.

Adelaide Plains Sub-Basin

Stuart (1969) indicates thicknesses of 15-21 m near the axis of the sub-basin. In Longyear Bore, the Gull Rock Member is 6.5 m thick (Fig. 11). Lindsay (1968) gives thicknesses of about 20 m, in Grange Bore and 30 m in Croydon Bore 2.

VERTICAL AND HORIZONTAL RELATIONSHIPS

Lower Contact

Conformable with the 'Transitional Marls' (see previous discussion).

Upper Contact

Conformable with the 'Soft marl' Member by gradual transition. The lithotype of the 'Soft Marl' Member is very similar to the marly intervals of the Gull Rock Member. The boundary is marked by the disappearance of the siliceous hard bands.

The contact is therefore placed as follows:

Willunga Sub-Basin

At Blanche Point, it is placed at the top of the last thick siliceous limestone bed. The thin irregular horizon of siliceous nodules in the lowermost 'Soft Marl' Member may represent either a brief tardive fluctuation to Gull Rock Member sedimentation or the uppermost horizon of concentration of secondary silica.

In Observation Bore WLG 42, there is a sharp contact between the last siliceous siltstone bed and the soft spicular clayey siltstone (Cooper, 1977b).

Noarlunga Sub-Basin

At Witton Bluff the contact is similar to that at Blanche Point. At the intersection of Honeypot Road and Chilcomb Drive, 200 m west of South Road (Hackham),a limonitic quartz conglomerate with loose sand matrix, similar in facies to the Baker Gully Sand of Stuart (1969), overlies an atypical Gull Rock Member with an erosional contact. This conglomerate postdates the Port Willunga Formation, and hence is younger than the Baker Gully Sand (B. Daily, 1978, pers. comm.).

Adelaide Plains Sub-Basin

In the Longyear Bore, the contact occurs between the last hard siliceous limestone and the base of the soft grey marls of the 'Soft Marl' Member.

HORIZONTAL AND VERTICAL VARIATIONS AND OTHER LITHOLOGICAL CHARACTERS

The Gull Rock Member appears to become more silty and sandy toward the proximal parts of the sub-basins and more marly and calcareous off-shore (Stuart,1969, unpubl.; Cooper, 1977b). It may gradually pass to marine sandy and clayey units, shoreward in the Adelaide Plains Sub-Basin (Tate, 1882). The glauconite is present in this member in all the three sub-basins, but is more abundant in the Noarlunga Sub-Basin outcrops.

The silica content of the Gull Rock Member is from two sources:

A) Organic primary (Opal A) in the form of sponge spicules and siliceous micro-organisms (J.B. Jones, 1977, pers. comm.)

B) Inorganic secondary silica (Opal CT) derived from the dissolution of the siliceous skeletal parts (J.B. Jones, 1977, pers. comm.).

The cement of the nodular limestones is composed of this secondary silica. The dissolution of the organic silica and the mobilization of silica-rich solutions in the Gull Rock Member might have occurred in different times by different mechanisms which are listed as follows.

A) Early diagenetic or just after deposition, in which the mobilized silica just dispersed in the surrounding host rocks (J.B. Jones, 1977, pers. comm.). The dispersion of the silica would in this case occur approximately within middle P16 times and would be limited to the Gull Rock Member.

B) In post-diagentic stages, either during:

   (i) the Latest Eocene times (late P16), subsequent to the emergence of Blanche Point Formation (Latest P16); and/or

   (ii) during the Late Miocene-Pliocene times, from the emergence of Port Willunga Formation to before the Late Pliocene transgression (N9 - N20, Ludbrook, 1973).

With respect to the last two possibilities, the silica would have been mobilized and leached downward by solutions seeping from the surface through both the 'Soft Marl' and the Gull Rock Members. This interpretation is supported by the presence in the upper part of the 'Transitional Marls' of silicified horizons and patches or of silica dispersed throughout the entire member, except in its lowermost part.

At Maslin Bay the 'Transitional Marls' are characterized by a silicified horizon running from 'Uncle Tom's Cabin' to Blanche Point. In the former locality, the member is directly in contact with the Late Pliocene Hallett Cove Sandstone. In the latter locality, the member is, on the contrary, normally overlain by both the silica-bearing units.

At Reynolds Cave, the Phygraea tarda horizon, the lowermost unit of the Gull Rock Member, shows a few thin siliceous intercalations present nowhere else. Anywhere else, the silica content of this horizon is generally limited to rare sponge spicules.

Other evidence in support of the second interpretation is as follows.

- The dissolution of almost all molluscan shells in the 'Transitional Marls' in all the three sub-basins and of tracts of the Tortachilla Limestone at Maslin Bay.
- The concentration of amorphous glauconite in the lowermost 'Transitional Marls' and the presence of a glauconitic film on the wall of cavities in the top unit of the Tortachilla Limestone ('Uncle Tom's Cabin').
- The Blanche Point Formation-Tortachilla Limestone-South Maslin Sand succession represents a natural inverted filter system.

The above evidence infers solutions leaching through lithological boundaries and having a probable age not older than Chinaman Gully Formation times.

It is however necessary to point out that the two interpretations do not exclude each other, but that all three cases might have occurred, each superimposed upon the other.

PHYGRAEA TARDA HORIZON

The interval containing the Phygraea tarda horizon (Fig. 12) needs some further discussion. This horizon, although quite distinctive and of particular biostratigraphic interest for the correlation of the Southern Australian Eocene marine deposits on a regional scale, may have limited stratigraphic use on a local scale, because it seems to be represented only in the distal parts of the St. Vincent sub-basins, as it is entirely missing in the Longyear Bore and in the Observation Bore WLG 42. However, its occurrence is very important in defining the boundary between the Gull Rock Member and 'Transitional Marls' because it represents the record of a higher energy environment of deposition different from those of the other two members.

In fact, in the Phygraea tarda horizon,the following has been observed.

- Rare rounded quartz pebbles have been found (ø-1 cm);
- The macroinvertebrate remains are present as minute fragments or skeletal parts, with only rare large size echinoid radioles and very abundant shells of Phygraea tarda (Hutton);
- The scarce benthic foraminifera shells are rather worn;
- The orientation of most shells of P. tarda is non-biological whilst most of their valves are disarticulated, and very few specimens are still articulated;
- The horizon contains an impoverished assemblage composed almost entirely by one species, P. tarda, indicative of a biologically stressed environment.

This is in direct contrast to the very fossiliferous units just below and above this horizon which indicate biologically accommodated environments

- And lastly, there is a sharp reduction or complete absence of glauconite.

The P. tarda horizon is here included in the Gull Rock Member, because it shows a more gradual lithological transition to this member than to the underlying 'Transitional Marl' Member.

FOSSILS

Mollusca, Brachiopoda, rare Echinoidea, sponge spicules, Bryozoa (mainly the lower part), ahermatypic corals, sharks' teeth, otoliths, fish bones, rare Cirripedia and Decapoda, rare Cephalopoda (upper part).

Characteristic Molluscan Assemblages

Barren, *Phygraea*, Barren (Bryozoa only); *Spirocolpus-Dimya-Ledella*.

Molluscan Index-Species

Pseudomalaxis asculpturatus Maxwell.

Other Distinguishing Events

Phygraea tarda (Hutton) acme (lowermost part); Appearances of *Dimya asseretoi* sp. nov., *Jetwoodsia nullarborica* (Chapman & Crespin), *Zeacolpus* sp., *Retusa (Decorifer) crassa* sp. nov., *Notogrammatodon inexpectatus* Maxwell etc.

AGE

From its stratigraphic position in relation to the 'Transitional Marls' the Gull Rock Member may approximate to the early to middle P16 (McGowran, 1977, 1978a,b; Ludbrook, 1967, 1973; Jenkins, 1974; Lindsay, 1969;etc.).

'Soft Marl' Member
(Reynolds, 1953)

SYNONYMS

- *Turritella* Clays and Marls (Glaessner, 1951) (*pro parte*)
- Blanche Point Soft Marls (Reynolds, 1953)
- Blanche Point Soft Marls (Lindsay, 1969)
- Blanche Point Soft Marls (Stuart, unpubl. 1969)
- Blanche Point Soft Marls (Cooper, 1977b)

OBSERVATIONS

The name is informal according to the Australian Code of Stratigraphic Nomenclature (1973) and the adjective 'Soft' should not be maintained, because the use of the adjective indicating rock characters is being neglected by the Code. However, pending a later revision the traditional name is still maintained here.

TYPE-LOCALITY AND TYPE-SECTION

The cliffs between the top of the northern side of Blanche Point (Maslin Bay) and the foot of the cliffs at Chinaman Gully (Aldinga Bay). The section measured (this study) is on the southern cliff of Blanche Point (Aldinga Bay) where this member shows a maximum thickness of 17.3 m (Fig. 12, Section Y).

OUTCROPS AND LOCALITIES

Willunga Sub-Basin

The best outcrop remains the type section. A good section is also exposed on Chalk Hill Road at McLaren Vale (Stuart, 1969 unpubl.). The Member is regularly encountered by drilling in the subsurface, except at the margins of the sub-basin (Fig. 3c).

Noarlunga Sub-Basin

Cliffs between Witton Bluff and the Noarlunga Jetty; Onkaparinga River mouth (top part only) and, inland, on the right bank of the river just off the Fleming Bridge (Fig. 3b).

Adelaide Plains Sub-Basin

No outcrops. The member is regularly encountered in the subsurface by drilling (Lindsay, 1968, 1969; Tate, 1882) (Fig. 3a, 11).

GENERAL LITHOLOGY

Grey, blackish, buff, soft, non-stratified marls, very rich in sponge spicules and glauconitic pellets. Clays, silts and siltstones in the margins of the embayments (Tate, 1882; Cooper, 1977b; this study).

THICKNESSES

Reynolds (1953) reports a thickness of about 19 m in the type section. Stuart (1969, unpubl.) gives a range of 14-17 m in the coastal outcrops and 40-46 m near the structural axes of both Noarlunga and Willunga Sub-Basins. In the Adelaide Plains Sub-Basin, the member reaches a thickness of 31.85 m (this study).

VERTICAL AND HORIZONTAL LITHOLOGICAL VARIATIONS

The marls characterizing this member appear to be rather constant in lithology although they are replaced in places by silts, sands or clays (Cooper, 1977, 1978; Lindsay, 1968, 1969). Elsewhere they display carbonaceous and pyritic content. In the Longyear Bore 50 (Fig. 11) in the topmost part of the member there is a gradual transition from the typical grey marls to dark grey-blackish silts and clays.

Lower Contact

Conformable and gradual with Gull Rock Member (see previous discussion).

Upper Contact

Unconformable. It is generally separated from the overlying Chinaman Gully Formation by a very low angle erosional surface. This unconformity shows a southward dip of about 5^o which is an inclination of 3^o more than the underlying Blanche Point Formation. This erosional contact has been observed in all outcrops and in the Observation Bore WLG and in the Longyear Bore 50. Cooper's current observations in the Willunga Sub-Basin (Cooper, 1978) and Lindsay, 1968, Glaessner (1953) and Stuart (1969 unpubl.) show that the Chinaman Gully Formation is missing in places and the 'Soft Marl' Member is directly in erosional contact with the Port Willunga Formation. Such a contact can be seen at the Onkaparinga River mouth (Stuart, *loc. cit.*, fig. 8).

FOSSILS

Bryozoa (rare), Brachiopoda, ahermatypic corals, sharks teeth, otoliths, Echinoidea, Cirripedia (rare), Decapoda, Mollusca, Cephalopoda (in patches, middle part).

Characteristic Mollusca Assemblages

Ledella-Pectunculina-Zeacolpus.

Molluscan Index-Species

Chrysallida sp. nov., *Miralda.* sp. nov., *Plagioglypta* sp. nov., *Phygraea andreai* sp. nov. (topmost 'Soft Marls').

Other Distinguishing Events

Acmes of *Zeacolpus* sp. and *Pectunculina cancellata* sp. nov. First occurrence of *Styliola* sp.

AGE

From its stratigraphic position in relation to the Gull Rock Member and Chinaman Gully Formation, the 'Soft Marls' may fall approximately within the middle of the foraminiferal Zone P16 (Ludbrook, 1967,1973; Jenkins, 1974; McGowran, 1977,1978a,b; Lindsay, 1969 etc.).

OBSERVATIONS ON SEDIMENTARY CYCLOTHEMS IN THE EOCENE DEPOSITS OF THE ST. VINCENT BASIN AND CORRELATION WITH COEVAL EPISODES IN THE WESTERN AND SOUTHERN AUSTRALIAN PERICRATONIC BASINS

Glaessner (1953 a,b), Glaessner & Wade (1958), Stuart (1969, unpubl; 1970) Ludbrook (1969), Daily, Firman, *et al.*,(1976) offer detailed general descriptions of the Tertiary St. Vincent Basin, and of its tectonics, its development and evolution, and its palaeogeography.

A geotectonic, palaeoenvironmental, and palaeogeographical model of the Southern and Western Australian Margins has been developed through the studies of Deighton, Falvey & Taylor (1976), Quilty (1974, 1977), Ludbrook (1977) and McGowran (1977; 1978 a,b).

The biostratigraphy and intrabasin correlations of the southern and western Australian margins have been outlined by several authors (Abele *et al.* (1976), Ludbrook (1971) and McGowran *et al.* (1971) for the Otway Basin; Lowry (1970) and Quilty (1974; 1977) for the Western Australian basins; Abele *et al.* (1976) and Partridge (1976) for the

Gippsland Basin).

Ludbrook (1963, 1967, 1973, 1977) gives the framework of inter-basin correlations for the southern margin. McGowran (1977, 1978a,b) updates and refines these correlations and (1978b) attempts a correlation of the Australian Paleocene and Eocene with the Indian and SW Pacific regions (see Figs. 14-15 and quoted papers). This study is limited to a more detailed picture of the Middle-Late Eocene sedimentary cyclothems of the St. Vincent Basin and their correlations with analogous coeval or nearly coeval cycles in the other Western and Southern Australian basins and with supraregional events, as outlined by McGowran (1978b).

Middle-Late Eocene Cyclothems In The St. Vincent Basin

The revision of the Late Eocene units in the Eastern St. Vincent Basin allows for the recognition and definition of four distinct cyclothems, which are traceable throughout the basin.

The commencement of each cyclothem is marked by continental deposits or by a lacuna representing a continental episode. The oldest cyclothem is recorded by continental deposits only. Yet, it is correlatable with a coeval marine ingression, hitherto found in adjacent areas outside the basin (Gambier Embayment, Otway Basin).

Cyclothem 1 (?-Palaeocene-Early/early Middle Eocene)

It includes the ?-Palaeocene-Early Eocene palaeosols (Glaessner, 1953b; McGowran, 1978b) and the Early/Middle Eocene continental terrigenous 'North Maslin Sands' (late P8-early P10) and, perhaps, the basal fluvial sediments of the northeastern Yorke Peninsula which are of indeterminate age (Stuart, 1970). The 'North Maslin Sands' mark the initial stage of development of the St. Vincent Basin. No marine sediments correlated with the 'North Maslin Sands' have yet been discovered in the Basin, although arenaceous foraminifera have been observed in the topmost part of this unit by Ludbrook (1978, pers. comm).

This might suggest either that possible marine sediments were deposited in the distal parts of the basin or that such deposits were subsequently obliterated by erosion from the top of the 'North Maslin Sands'. Such a marine episode would correlate with a marine ingression in the Gambier Emayment (Tartwaup Formation, Burrungule Member - Ludbrook, 1971; McGowran, 1978a,b; McGowran et al., 1971)

Cyclothem 2 (Middle to early Late Eocene)

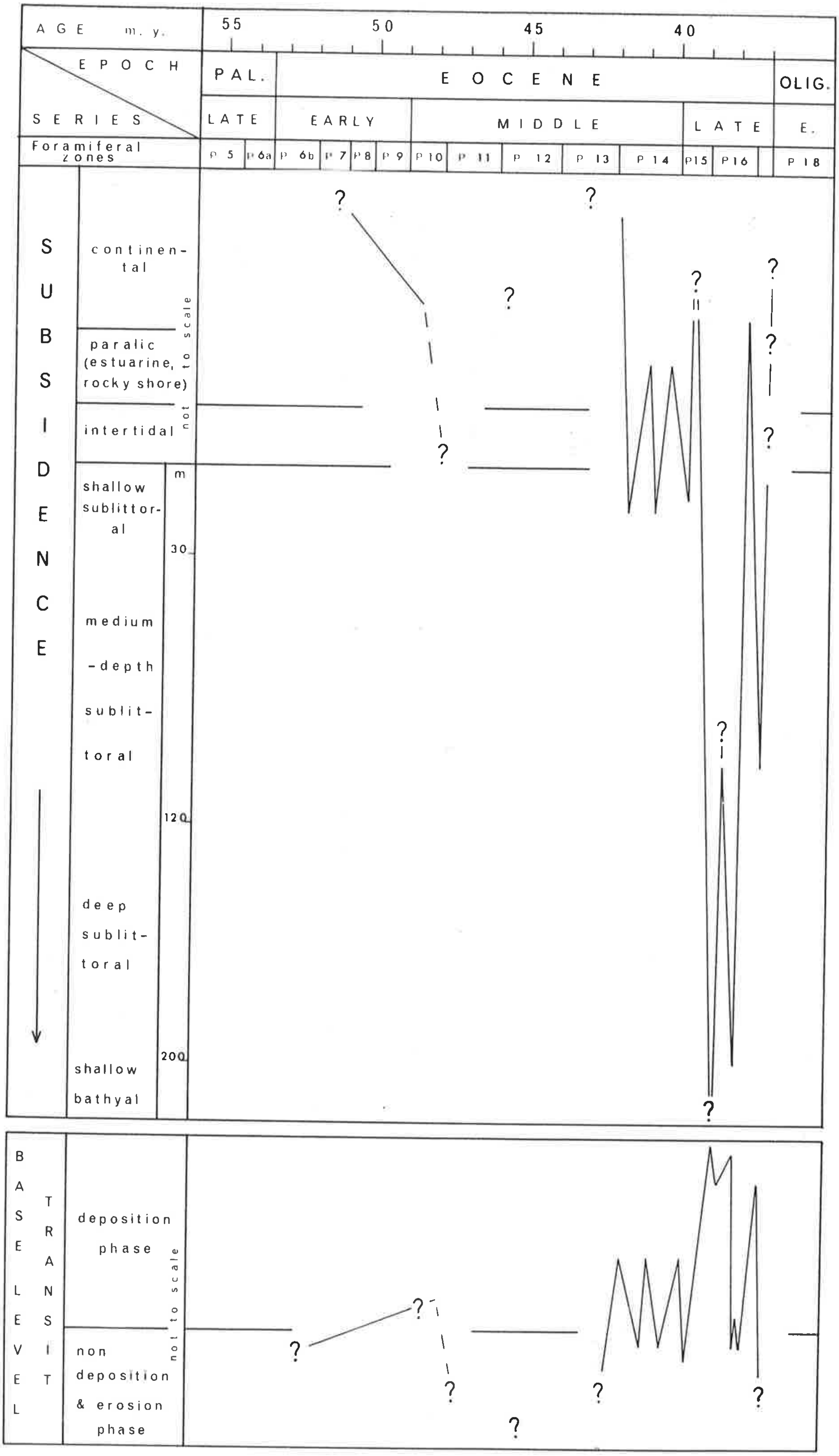
It includes the late P10-P13 palaeosols (Glaessner, 1953; Glaessner & Wade, 1958; Brown, 1960), the paralic to marine terrigenous 'South Maslin Sands' (?P14, McGowran, 1978a,b) and the paralic to marine, terrigenous-bioclastic Tortachilla Limestone (early P15; McGowran, 1978a,b). The basal bryozoal calcarenite at Kingscote (Kangaroo Island), correlatable with the Tortachilla Limestone (Cooper, 1977,pers. comm), the lower Clinton Coal Measures (Inkerman-Balaklava Coalfield) and perhaps, the basal fluvial sediments and the lower Muloowurtie Formation (Yorke Peninsula) (Stuart, 1970) may be referred to this cyclothem.

Brown (1960) indicated that the 'South Maslin Sands' pass laterally into marine glauconitic sediments. This is confirmed by the two brief glauconitic episodes in the lower and middle part of the 'South Maslin Sands' in the Willunga Sub-Basin and the marine carbonaceous glauconitic sands of the Longyear Bore (Adelaide Plains Sub-Basin). The first bioclastic carbonate sedimentation occurred during the final stage of the cyclothem, but was restricted to the southeastern part of the basin (Willunga Sub-Basin, Kingscote, Kangaroo Island).

Cyclothem 3 (Middle Late Eocene)

It is represented by the continental episode indicated by the middle P15 palaeokarst (Buonaiuto, 1977a; McGowran, 1978b) and palaeosols and the marine marly carbonate Blanche Point Formation (late P15-middle P16 McGowran, 1978a,b).

FIG. 13 Eocene subsidence pulsations and baselevel transit migrations at Maslin and Aldinga Bays on the basis of lithological and molluscan evidence. The pattern of positive and negative pulsations emphasizes a general trend of the subsidence and the base-level, and it suggests to be of eustatic origin (See: A.G. Fischer, 1964.And also: McGowran, 1977, 1978a,b,c; Deighton *et al.*, 1976; Partridge, 1976; Steele, 1976). Zone depths from Baldi, 1973.


AGE m.y.
55
50
45
40
EPOCH
SERIES
PAL.
EOCENE
OLIG.
LATE
EARLY
MIDDLE
LATE
E.
Foraminiferal zones
P 5
P 6a
P 6b
P 7
P 8
P 9
P 10
P 11
P 12
P 13
P 14
P15
P16
P 18
SUBSIDENCE
continental
paralic (estuarine, rocky shore)
intertidal
not to scale
shallow sublittoral
m
30
medium-depth sublittoral
120
deep sublittoral
200
shallow bathyal
BASE LEVEL TRANSIT
deposition phase
non deposition & erosion phase
not to scale
?

The Middle and Upper Muloowurtie Formation and the continental upper Clinton Coal Measures, the upper bryozoal calcarenite at Kingscote (Cooper, 1977, pers. comm.) may be referred to this cyclothem.

Cyclothem 4 (Latest Eocene-?Early Middle Miocene)

It comprises the lagoonal estuarine Chinaman Gully Formation and its lateral equivalent lacuna (middle to late P16; McGowran, 1978a,b) and at least the Aldinga Member (late P16-P17) of the marine terrigenous-carbonate Port Willunga Formation (Late P16-N9). The continental Throoka Silt (Yorke Peninsula), the marine Rogue Formation, and probably, the uppermost Clinton Coal Measure (W.K. Harris, in press) may belong to this cyclothem.

The synoptic tables in Figs 14 and 15 show that all the four cyclothems reflect regional and supra-regional events and may be correlated with analogous episodes, traceable throughout the southern and western Australian basins. In particular, the cyclothemic sedimentation in the St. Vincent Basin, and those displayed regionally in the other basins, seem to be dictated by subsidence (Fig. 13; Steele, 1976; Partridge, 1976; McGowran, 1977; 1978a,b) and were probably emphasized by coincident climatic fluctuations (Fig. 15). For more detailed discussion see McGowran, 1977, 1978a,b; Shackleton & Kennett, 1975 .

ADDENDUM

OBSERVATIONS ON THE PORT WILLUNGA FORMATION CYCLOTHEM:

A Speculation

McGowran (1977, 1978a,b) and Carter (1978) indicate a widespread unconformity at the P17/18 boundary (Eocene/Oligocene boundary). McGowran (*loc. cit.*) suggests an eustatic origin and also associates it with the P17-early P18 sharp climatic minimum. Carter (1978) relates this unconformity with the Early Oligocene world-wide regressive episode and considers it as a climatic event. This event has been recorded throughout the Tethys, in the Paratethys, in the Anglo-Parisian Basin, in the Indo-Malayan region, and in western South America (Eames, *et al*, 1962, figs. 4-5; Azzaroli & Cita, 1967, chapters 5-6).

In Australia, it has been recognized throughout the western and most of the southern margins (Abele *et al*, 1976; Quilty, 1976, 1977; Partridge, 1976; McGowran, 1977, 1978a,b). As a result of the present study and that of W.K. Harris (herein) the unconformity in the Murray Basin, between the Buccleuch Beds and the Compton Conglomerate (Ludbrook, 1961, fig. 4) should probably be correlated with this event.

In the St. Vincent Basin a coeval unconformity has not as yet been recognized.

In the type section of the Port Willunga Formation (Willunga Sub-Basin), Lindsay (1969) recorded *Subbotina linaperta* from the basal bed of the Ruwarung Member and assigned a Latest Eocene age. The contact between the underlying Latest Eocene Aldinga Member and the mostly Oligocene Ruwarung Member appears to be conformable. Within the latter Member no unconformity is revealed by a *prima facie* examination in both the Noarlunga and Willunga Sub-Basins. This would therefore indicate an anomalous sedimentation pattern during that time for the St. Vincent Basin.

However, since the P17/18 unconformity seems to reflect a world-wide event also recognized in Australia, and since it is also correlated with the P17/-early P18 climatic minimum, a coeval disconformity in the St. Vincent Basin cannot be excluded *a priori*.

In the Longyear Bore (Adelaide Plains Sub-Basin, Fig. 11) a micro-conglomeratic-sandy horizon (2.7m thick) is interposed between the lithologies of the Aldinga and Ruwarung Members. This horizon also shows evidence of possible erosional surfaces and may thus indicate a possible regressive episode, thus giving support to the possibility that a P17/-early P18 diastemic event also occurred in the St. Vincent Basin.

The confirmation of the existence of a disconformity and a diastema will depend on detailed biostratigraphical and lithostratigraphic scrutiny of the Aldinga/Ruwarung Member contact. J.M. Lindsay of the S.A. Department of Mines & Energy is actively investigating this problem associated with the Eocene/Oligocene boundary in the St. Vincent Basin.

In the revision a number of possibilities can be postulated. At this stage the most apparent would include the following.

A) The Aldinga and the Ruwarung Members have been deposited during the same cycle of deposition. In this case, there is no disconformity nor diastema; the horizon in the Longyear Bore would then record some local condition.

B) The Aldinga and the Ruwarung Member are separated by a disconformity. In this case, the disconformity might be located either at the lithological boundary, or just above the lowermost unit of the Ruwarung Member.

In the latter case the lowermost siliceous unit of the Ruwarung Member might in reality belong to the Aldinga Member and therefore it might represent the remnants of an episode of deposition in Ruwarung facies, or it might have been silicified subsequently by downward mobilization of silica, from the overlying units.

C) By extension of the previous case the disconformity might occur within the Ruwarung Member.

In the case B) and C), the clastic horizon of the Longyear Bore may reflect a regressive event and may correlate with the disconformity in the other two sub-basins.

CHAPTER 2

BIOSTRATIGRAPHY

The stratigraphic framework of the Australian Cainozoic Mollusca is still very sketchily known. The ranges of the species are recorded at epoch or stage level only, and are still largely based on the locality check-lists of Tate & Dennant (1893-96), Hall & Pritchard (1895, 1897, 1902) and on the synopsis by Dennant & Kitson (1903). The stratigraphy and the systematics were recently revised and updated by Darragh (1970) and Ludbrook (1973).

On a more refined scale, Singleton (1967) and Singleton & Darragh (1970) recognized about 20 molluscan assemblages in the Tertiary of south-eastern Australia, four being in the Late Eocene of Victoria (Browns Creek, Aire District). Singleton & Darragh's 1970 paper was an abstract and the details were never published. Singleton (1967) correlates the second oldest assemblage of the Browns Creek Formation with the Tortachilla Limestone faunas; the third (*Phygraea tarda* assemlage) and the molluscan faunas above it were correlated with the Blanche Point assemblages. The first two assemblages, however, occur within the *Hantkenina* zone (Singleton, 1967; McGowran, 1978a) and field observations on their faunistic composition would indicate a correlation with the 'Transitional Marls' assemblages. The *Phygraea* assemblage correlates with the similar assemblage at the basal Gull Rock Member, although the St. Vincent one is slightly younger (see further discussion). Field observations suggest that the assemblages above the Browns Creek *Phygraea tarda* horizon may correlate with those of the upper Blanche Point Formation. The fourth assemblage distinguished by Singleton is of Latest Eocene age, and it may then correspond to the Aldinga and Buccleuch assemblages in the St. Vincent and Murray Basin respectively. It is clear that a re-elaboration upon the existing information beyond the above discussion would be of very little utility in the restricted time span dealt with in this study.

The following discussion represents the first attempt to establish a detailed biostratigraphic succession based on Australian Cainozoic molluscan index species.

Materials and Methods

About 17,000 specimens were examined from the section at Maslin and Aldinga Bays, and several hundreds from the subsurface of the Willunga and Adelaide Plains Sub-Basins and of the Padthaway Ridge (Murray Basin). The material from the last locality forms the topic of a current project carried out on behalf of the S.A. Department of Mines & Energy.

For the Maslin-Aldinga Bays section the percentage distribution of the species has been noted against the lithostratigraphic succession. The distribution of the species from subsurface material has not been plotted either because of the randomness of the samples studied, or because they were represented by randomly picked specimens (S.A. Department of Mines Collections). These specimens do not represent the full assemblages statistically. However, species from subsurface samples have been found either to be restricted to distinctive horizons or to form stratigraphically significant series or lineages. Therefore, the information from these species has been integrated with the results from the outcrop material in order to produce a more refined framework and to overcome gaps in information from parts of the Tortachilla Limestone, 'Transitional Marls' and 'Soft Marls', where dissolution has partially or completely deleted the molluscan record.

The examination of such a large number of specimens has also permitted the selection of a number of taxa of potential biostratigraphical value within the Late Eocene. The choice of these taxa has been based on presence/absence criteria controlled in two or more localities (usually the Willunga Sub-Basin, in contrast to the Adelaide Plains Sub-Basin) or in horizons of similar facies (i.e. lower and upper *Spirocolpus aldingae* horizons of the Blanche Point Formation contrasted with each other and with the *Spirocolpus aldingae* horizons of the Buccleuch Beds (A) and (B)). This approach, which reduces or eliminates possible environmental biases, has been a particularly useful criterion in the selection of species with ranges and first occurrences which might be of actual biostratigraphic value (confront the vertical distribution of the assemblages with the ranges of the significant species, Fig. 16). Among these forms, a further screening was undertaken in the selection of the species. Only those were chosen which were well-identified, at least at subgeneric level, and at the same time present in sufficient abundance to be easily found during routine sample examinations.

Finally, the Late Eocene ranges of these individual species have been matched with the vertical distribution of the molluscan assemblages of Tortachilla Limestone and Blanche Point Formation, and both against the standard foraminiferal zonation (Fig. 16). Such a zonation is used here for the sake of simplicity and according to the correlation between tropical and extratropical events, as suggested by Ludbrook (1973) and McGowran (1978a,b).

The Buccleuch assemblages, although roughly homotaxial in places with the Blanche Point ones, have not been defined here because they are from very small and therefore inadequate samples. Also, they indicate the coexistence of different facies, for example: *Spirocolpus* in contrast to Caecidae assemblages. Although they are still under investigation, the information already yielded by them is incorporated here, because it is vital for the definition of the Late Eocene Molluscan events and for a better correlation of the Late Eocene deposits of the southern Australian basins.

Further information from non-molluscan taxa (acmes, first appearances, etc.) from the Maslin and Aldinga Bays Section is also included in the Fig. 16 (see also Appendix C).

BIOSTRATIGRAPHIC SIGNIFICANCE OF THE TORTACHILLA AND BLANCHE POINT FAUNAS

The vertical distribution of the species and assemblages of these two formations are summarized in Fig. 16 and Appendix C. The assemblages are described in detail in the chapter on palaeoecology.

TORTACHILLA LIMESTONE

The basal unit of the formation is barren but the higher parts of the formation are characterized in succession by the following assemblages: *Chlamys Hiatella*, *Dimya*, *Dosina-Turritella-Chlamys*.

The only stratigraphic event possibly meaningful at species level is the disappearance of *Chlamys aldingensis* (Tate) in the *Dosina-Chlamys-Turritella* assemblage, and even its disappearance could have been obscured by preservation. Some specimens of *Chlamys* sp. might still be referable to this species. However, *C. aldingensis* was not found anywhere in the Blanche Point Formation or in the Buccleuch Beds. In particular, it was not found in the lower 'Transitional Marls' which have an assemblage similar to the *Dosina-Chlamys-Turritella*. The disappearance may also have been caused by competition among the three species of *Chlamys*. A decrease of *C.aldingensis* in the Tortachilla Limestone corresponds to an increase of *C.peroni* (Tate) while *C.flindersi* (Tate) maintains a subordinate position.

Other possibly meaningful events are represented by acmes: *Hiatella* in the lower Tortachilla Limestone reaches an abundance found nowhere else. *Dimya* and *Isolimea* have an analogous acme in the middle Tortachilla Limestone. The upper part of the Tortachilla Limestone is characterized by the first acmes of *Dosina* and *Turritella*. The last acme of

Dosina only re-occurs in the basal 'Transitional Marls' (Fig. 16).

Other distinctive events among non-molluscan taxa in the Tortachilla Limestone can be found in the Decapoda and Cirripedia acmes which are not repeated in the Blanche Point Formation, and in the first Bryozoa acme which is distinguishable from the second by its detrital nature.

BLANCHE POINT FORMATION

The sampling in this formation has yielded much richer samples than in the previous unit. However, dissolution phenomena have meant that the 'Transitional Marls' and the upper 'Soft Marls' have yielded an incomplete record of the fossil assemblages. Fortunately, the existence of a silicified horizon in the upper'Transitional Marls' in Maslin Bay still bears evidence of the rich fauna which occurred in this unit.

'Transitional Marl' Member

The upward succession here is: Barren (continental to supralittoral), Turritella-Dosina, Spirocolpus-Dimya, Chlamys-Pycnodonte, Dimya-Chlamys, Spirocolpus-Trophon.

The member thus appears to be characterized by two Spirocolpus acmes - one in its lower part and one in its upper part. Turritella sp. is very probably Spirocolpus aldingae (Tate), but because its type series is composite with Late Eocene, generically different forms which would produce similar moulds, it is better to leave the species undetermined.

The middle part of the 'Transitional Marls' seems to be characterized by the only Pycnodonte acme in the entire section, and by a return in dominance of the Bivalvia Dimya and Chlamys. However, to stress this dominance could very well be misleading because of the dissolution of most of the Mollusca.

At the species level, information can, however, be derived from the 'Transitional Marls' of the Adelaide Plains Sub-Basin and integrated with the scanty record at Maslin Bay, and hence, extrapolated to form a significant picture. The 'Transitional Marls' are thus characterized by the following events: the first appearance of *Orbitestella margaritata* sp. nov. (Adelaide Plains) in the lowermost part, a brief incursion of *Pseudomalaxis ludbrookae* sp. nov. embracing the *Hantkenina* Zone in the middle part (Adelaide Plains - J.M. Lindsay, *in* Buonaiuto, 1975), a brief appearance of *Pinctada* sp. nov. in the upper part (Maslin Bay) (1 specimen recorded), the terminal range of *Dimya sigillata* Tate and *Isolimea alticosta* (Tate) in the upper part (Maslin Bay) and an occurrence of *Vulsella laevigata* Tate throughout, but restricted within the 'Transitional Marls' (Maslin Bay, Willunga Sub-Basin; Christies Beach, Noarlunga Sub-Basin).

In regard to the non-molluscan taxa, the middle part of this Member, from the *Hantkenina* Zone upward, is characterized in Maslin Bay by the presence of fish bones and the upper part from the silicified horizon upward, by the appearance of sponge spicules.

Gull Rock Member

This member contains a basal barren interval (marine, discontinuous) and three assemblages, one of which is non-molluscan: *Phygraea*; *Bryozoa*; *Spirocolpus-Dimya-Ledella*.

The barren interval is clearly observable in Maslin Bay, just below the *Phygraea tarda* horizon, and may be included in it.

In this member, there are discrete significant events: the *Phygraea* acme, discussed below; the second Bryozoa acme, differing from the first one particularly in lithology and in preservation (marly in contrast to bioclastic, non-detrital in contrast to detrital) and the fourth *Spirocolpus* acme, which is characterized by a series of new occurrences.

The *Spirocolpus* acme coincides with the first record of *Cyclopecten* sp. nov., *Dimya asseretoi* sp. nov., *Retusa (Decorifer) crassa* sp. nov., *Kaurnacteon elevatus* gen. & sp. nov., *Tenuiacteon acicularis*, *Acteocina* scalarum sp. nov., Zeacolpus sp. (Figs. 176-179, 181-182), Cadulus sp. (Figs. 22-24), Jetwoodsia nullarborica (Chapman & Crespin), etc. Two other species deserve particular mention: Pseudomalaxis asculpturatus Maxwell, which makes a brief appearance here, and Notogrammatodon inexpectatus Maxwell. Both these species are believed to be immigrants from New Zealand, where they are already present in Kaiatan times (late Middle-early Late Eocene). However, they are not yet recorded in Australia earlier than in the Gull Rock Member.

'Soft Marl' Member

The Ledella-Pectunculina-Zeacolpus assemblage characterizes this member. The species are very similar to those of the Gull Rock Member. However, a few new appearances can be recognized, such as Chrysallida sp. nov, Miralda sp. nov., and Plagioglypta sp. nov. (Figs. 18-21). Though represented by only one specimen, the first occurrence and record of the pteropod Styliola sp. nov. is worthy of mention.

Because of dissolution in its upper part the 'Soft Marls' have hitherto yielded only one species of possible stratigraphic value, Phygraea andreai sp. nov. (1 specimen), a specialized descendant of P. tarda (Hutton).

STRATIGRAPHIC SIGNIFICANCE OF THE PHYGRAEA TARDA HORIZON IN INTERBASIN CORRELATIONS

This discussion is speculative and preliminary; it is presented to stimulate studies on a distinctive molluscan biofacies in the St. Vincent, Eucla, and Otway Basins.

In southern Australia very distinctive thin horizons, extremely rich in Phygraea tarda (Hutton) (Notostrea lubra Finlay), have been noted in the greensands of the Browns Creek Clays (Otway Basin, Aire District) (Jenkins, 1974; Abele *et al.*, 1976), in the gypsiferous calcarenite of the Wilson Bluff Limestone (Eucla Basin) (Tate, 1879a; Ludbrook, *in*

Lowry, 1970), and in marls of the lowermost Gull Rock Member, Blanche Point Formation (St. Vincent Basin).

In the Otway Basin, the *P. tarda* horizon falls within the *Hantkenina* Zone (Abele *et al.*, 1976; McGowran, 1978a). In the St. Vincent Basin, it occurs above the *Hantkenina* datum within zone P16.

The age of the *P. tarda* horizon in the Eucla Basin, on the other hand, is still to be defined precisely. Hitherto, it was considered of Late Eocene age, *sensu lato* (Ludbrook, *in* Lowry, 1970). Just recently, however, J.M. Lindsay, S.A. Department of Mines & Energy, discovered a new *Hantkenina* form during the examination of a sample from this horizon. Lindsay (1978, pers. comm., Appendix F) considers this form to be either an extreme morphotype of the P15/16 *Hantkenina primitiva*, or an intermediate form between *H. Primitiva* and the Middle Eocene *H. australis*.

It thus appears clear that the *P. tarda* horizon in the three basins might represent an important biofacies marker in interbasin correlations, reflecting similar stages of basinal subsidence or transgression. Thus, the age difference of the horizon among these basins might be used to determine the rate of the penultimate Eocene transgression onto the southern Australian margin.

Assuming that the *Hantkenina* sp. of Lindsay is conspecific with *H. primitiva*, then the horizon in the Eucla Basin is coeval with the one in the Otway Basin. This would therefore indicate that the transgression was a very rapid event throughout most of the southern margin, and that it would have been subjected to some delay, only in reaching the intra-cratonic St. Vincent Basin.

Assuming, on the other hand, that the *Hantkenina* sp. is an older species than *H. primitiva*, then the Eucla Basin horizon would be older than the Otway Basin one, and therefore, the transgression rate would have been slower, having reached initially the Eucla, then the Otway, and finally, the St. Vincent Basin. The morphological differences of *Hantkenina* sp. distinctive from *H. primitiva* might rather support this hypothesis.

In conclusion, there is a strong indication that the P. tarda horizon might be a powerful biofacies indicator and that, once the age of the Eucla Basin horizon has been more precisely determined it may ascertain and time the diachronism and give further proof of the polarity of the penultimate transgression in the Eocene.

THE AGE OF THE TOPMOST KNIGHT GROUP AND OF THE BUCCLEUCH BEDS (Padthaway Ridge, Murray Basin).

The integration of the results of this study with those of an ongoing project on the Late Eocene Mollusca from the Padthaway Ridge (Fig. 4) (Buonaiuto, 1978, in preparation) led to a reconsideration of the age of the topmost Knight Group and Buccleuch Beds. Hitherto, the topmost Knight Group was correlated with the South Maslin Sands, Tortachilla Limestone, and possibly with the lowermost Transitional Marl Member (Zones P14-P15). The Buccleuch Beds were correlated with the Blanche Point, Chinaman Gully, and lower Port Willunga Formations (Zones P15-P17) (Ludbrook, 1957,1961,1969,1971; Lindsay & Bonnett, 1973; McGowran, 1978a,b) on the basis of faunistic similarities in benthonic foraminifera and in macromollusca.

Analyses of the marine dinoflagellate assemblages recently indicated that the Buccleuch Beds are of Latest Eocene or Early Oligocene age, i.e., they are correlatable with the P17-P18 zones and therefore younger than what Ludbrook (1961,1973) shows (W.K. Harris, 1978, pers. comm.).

The Late Eocene micromollusca of the Padthaway Ridge bring further evidence in support of this conclusion.

Although generally reflecting a paralic-euxinic environment, the Knight Group displays a marine interval in its topmost part, represented by a Spirocolpus aldingae assemblage in the Kiki Town Bore at 129-117 m (Ludbrook, 1969) and in the Conalpyn E & W Bore 2 at 123-121 m (Ludbrook, 1961). The only meaningful species found in this assemblage is *Jetwoodsia nullarborica* (Chapman & Crespin), otherwise known only from the upper Gull Rock Member and the Soft Marl Member of the Blanche Point Formation and from the Plantagenet group in the South Coast Norseman Embayment (early Late Eocene; Quilty, 1974).

The Buccleuch Beds, including the depth intervals 116-110 m of B.Q. Butler Bore 4, 116-104 m of Kiki Town Bore (Ludbrook, 1969) and 119-116 m of Coonalpyn E. & W. Bore 2, referred by Ludbrook (1961) to the topmost Knight Group, are characterized by *Orbitestella rugosa* sp. nov., *Vitrinella* s. *B*. sp. nov. *B*, *Scissurella lamellularum* sp. nov., *Strebloceras darraghi* sp. nov., *Brookula* sp. nov. *B*, ?*Elachorbis pentagonalis* sp. nov., and the subgenus *Australiotia*. These taxa have been found only in the lower Aldinga Member of the Port Willunga Formation. Furthermore, a group of forms from the Buccleuch Beds have ancestral species in the Blanche Point Formation in the Adelaide City Area (South Parkland Bore CH-1a; West End Brewery Bore CH-2) and in the Willunga Basin, i.e., *Vitrinella* sp. nov. *B*; *Limacina* sp. nov. *B*, *Praehyalocylis* sp. nov. aff. *annulata* (Tate), *Pseudomalaxis* sp. nov. aff. *asculpturatus* Maxwell, (Figs. 372-375), *Brookula* sp. nov. *B*, *Circulus* sp. nov.*B*, and, above all, *Orbitestella rugosa* sp. nov. (Appendix D-1).

The presence of these species indicates that the Buccleuch Beds are in stratigraphic position correlatable with the lower Port Willunga rather than with the Blanche Point Formation. The presence of *Orbitestella rugosa* and the absence of *O. spinosa* sp. nov. give further support to a restricted Latest Eocene age (about P17) which thus relates the entire Buccleuch Beds to the last Eocene marine transgression. The presence of *Jetwoodsia nullarborica*, together with the stratigraphic position and age of the overlying Buccleuch Beds as indicated above, seems to indicate that the topmost Knight Group is not younger than middle Late Eocene (about middle P16).

TOWARD A MOLLUSCAN ZONATION FOR THE LATE EOCENE:

a tentative outline.

From Fig. 16 and the above discussion, it appears possible to distinguish 4 molluscan zones in the Late Eocene. They are characterized by the following index species listed in succession: *Chlamys aldingensis* (Tate), *Orbitestella margaritata* sp. nov., *Orbitestella spinosa* sp. nov. and *Orbitestella rugosa* sp. nov. A further series of well defined events could be used to refine these zones.

CHLAMYS ALDINGENSIS ZONE

C. aldingensis (Tate) appears to be restricted to the Tortachilla Limestone and has already disappeared in the topmost part, perhaps because of successful competition from *C. peroni* (Tate). It is not found higher in the section or in the Buccleuch Beds, even in horizons where *Chlamys* is abundant.

The species is also recorded in the Late Eocene part of the Wilson Bluff Limestone (Eucla Basin) together with *Phygraea tarda* (Hutton) and *Dimya sigillata* Tate (Ludbrook, *in* Lowry, 1970), but its distribution and the horizons of provenance are not known in comparable detail. Therefore, it is plausible to conclude that the record of *C. aldingensis* does not extend above the early part of foraminiferal zone P15, at least in the St. Vincent and Murray Basins.

In the Willunga Sub-Basin the other significant events within this zone are the acmes of: *Hiatella vera* (Deshayes) in its lower part; *Dimya sigillata* Tate, *Isolimea alticosta* Tate, and crabs' remains in the middle part; and Bryozoa and Cirripedia for the entire span.

ORBITESTELLA MARGARITATA ZONE

In the Adelaide Plains Sub-Basin (City area) the index species has been commonly found throughout the entire Blanche Point Formation (J.M. Lindsay, pers. comm., 1978). It is not yet recorded from the Willunga

Sub-Basin, but dissolution, bad preservation, facies factors, or just its very small size, might have impeded its discovery. However the range of *Orbitestella margaritata* sp. nov. seems to be restricted to the Blanche Point Formation. This species seems to have been replaced by *O. spinosa* sp. nov. in the Port Willunga Formation, lowermost Aldinga Member. The *O. margaritata* zone can be further subdivided into three subzones on the basis of the following species: *Vulsella laevigata* Tate, *Phygraea tarda* (Hutton) and *Dimya asseretoi* sp. nov.

Vulsella laevigata subzone

This species is restricted to the 'Transitional Marl' Member in both the Willunga and Noarlunga Sub-Basins. No specimens were found in the Gull Rock and 'Soft Marl' Members or in the Buccleuch Beds. Therefore, its range appears at least in the St. Vincent Basin, to be restricted to approximately late P15-early P16. Its brief appearance was probably controlled by climatic factors (see Palaeoecology, below).

In the lower part of this subzone, no significant event can be recognized, except a possible acme of *Pycnodonte tatei* (Suter). On the contrary, the middle part is marked by the first brief incursion of *Pseudomalaxis* Fischer, with *P. ludbrookae* sp. nov., the range of which just embraces the *H. primitiva* datum. The upper part is characterized by the brief incursion of *Kosugeia costatosulcata* gen & sp. nov. and by the top of the ranges of *Dimya sigillata* Tate and *Isolimea alticosta* Tate. In this part, one specimen of *Pinctada* sp. nov., which represents the only record of the genus in the Australian Eocene, was found.

Phygraea tarda acme-subzone

Phygraea tarda (Hutton) is a species ranging from the Palaeocene to the Eocene. Recorded from the Palaeocene in New Zealand, it seems to have been present in southern Australia only late in the Eocene. The *P. tarda* acme-subzone in the St. Vincent Basin falls entirely within zone P16.

In the distal parts of the St. Vincent Basin, the species is very rare below the acme-horizon already discussed, with the oldest individuals at the level of the *H. primitiva* zone. The possibility of its range extending to the topmost Gull Rock Member cannot be excluded *a priori*. Although it has not been found in the upper part of this member, rare valves do occur at an equivalent horizon above the acme at Browns Creek. However, the top of its range in the St. Vincent Basin is probably controlled by the appearance of the specialized *P. andreai* sp. nov. in the topmost 'Soft Marl' Member. The stratigraphic value of *P. tarda* therefore resides in its acme-horizon, which in the St. Vincent Basin is located in the lowermost part of the Gull Rock Member. However, the *P. tarda* acme, as already discussed, is an event of significance in several basins.

Dimya asseretoi subzone

This species seems to replace the older *D. sigillata* Tate, and it first appears in the *Spirocolpus aldingae* horizon of the upper Gull Rock Member. It occurs throughout the 'Soft Marl' Member, but at present there is no record of this species in either the Lower Port Willunga Formation or in the Buccleuch Beds. Therefore its range appears to be limited to within Zone P16.

The lower part of this subzone, encompassing the upper Gull Rock Member, is characterized by the second *Pseudomalaxis* incursion with the New Zealand immigrant *P. asculpturatus* Maxwell, and by a plethora of first occurrences of new taxa, among which are: *Dimya asseretoi* itself, *Aclis (Graphis) costata* sp. nov., *Jetwoodsia nullarborica* (Chapman & Crespin), *Retusa (Decorifer) crassa* sp. nov., *Kaurnacteon elevatus* gen & sp. nov., *Acteocina scalarum* sp. nov., *Zeacolpus* sp. (Fig. 176-179, 181-182), *Laevidentalium* sp. nov. (Fig. 16-17), *Siphonodentalium* sp. nov. (Fig. 13-15), *Cadulus* sp. nov. A (Fig. 22-24), *Cyclopecten* sp. nov. etc. *J. nullarborica* is already present in the Plantagenet Group in the early Late Eocene (Quilty, 1974).

The upper Dimya asseretoi subzone can be distinguished not only by the acme of Zeacolpus sp. and of Gadilina tatei Pilsbry & Sharp, but also by a new series of first occurrences such as Plagioglypta sp. nov. (Figs. 18-21), Miralda sp. nov., Chrysallida sp. nov., and the pteropod Styliola sp. nov. The replacement of Praehyalocylis annulata (Tate) by a new but related species in the Buccleuch Beds suggests a further possible refinement of the top of this subzone.

ORBITESTELLA SPINOSA ZONE

At present, this zone is based only on the very restricted range of O. spinosa sp. nov. found in the lowermost Aldinga Member (late P16, B.J. Cooper, 1976, writt. comm.). At the same locality (Willunga Bore WLG40, Willunga Sub-Basin) this species seems to have been replaced by O. rugosa sp. nov. from about the P16/17 boundary onward.
Supporting the possible validity of this restricted range is the discovery of a less specialized form of O. rugosa with characteristics transitional to O. spinosa in the lowermost Buccleuch 'A' Beds of the Kiki Town Bore (103.63-116.13 m) (Padthaway Ridge, Murray Basin). No other meaningful event is yet known in this zone except the coeval first appearance of Strebloceras darraghi sp. nov.

Studies on the molluscan fauna of the lowermost Aldinga Member have yet to be undertaken and are badly needed for a better definition and refinement of this zone.

ORBITESTELLA RUGOSA ZONE

This zone is better defined and known than the previous one, with a series of first appearances common to both the Willunga Sub-Basin (St. Vincent Basin) and the Padthaway Ridge (Murray Basin). The most meaningful event is the appearance of the index species O. rugosa sp. nov. approximately coeval with the P16/17 boundary, as mentioned above.

The O. rugosa event seems to be linked in both the Willunga Sub-Basin and on the Padthaway Ridge with a further series of first appearances such as those of the taxa ?Elachorbis and Australiotia and of species with ancestors in Blanche Point Formation such as Limacina sp. nov. B, Vitrinella s.l. sp. nov. B, Brookula sp. nov. B, Circulus sp. nov. B, Scissurella lamellularum sp. nov. and Praehyalocylis sp. nov. aff. annulata (Tate).

However, the lower ranges of these species, with the exception of O. rugosa, are still to be determined and they may or may not extend into the O. spinosa zone. Therefore, further studies are needed to define properly the events characterizing the O. rugosa zone.

The only other event of apparent significance in this zone, which should be mentioned, is the third incursion of Pseudomalaxis with P. sp. nov. aff. asculpturatus Maxwell (Fig. 372-375) in the upper Buccleuch 'B' Beds (Tintinara Area School Bore 12, 81.50-78.00 m). This species might be a good marker to distinguish the upper O. rugosa zone.

CHAPTER 3
PALAEOECOLOGY

Although many forms have been described from other localities and formations, this discussion will be limited to the molluscan assemblages of the Tortachilla Limestone and Blanche Point Formation from the sections at Maslin and Aldinga Bays (Willunga Sub-Basin). This restriction has been adopted because the sampling method was consistent throughout the section and has yielded a very large number of specimens which allows quantitative interpretations.

Furthermore, the Late Eocene species from the Adelaide Plains Sub-Basin (City area) and from the Murray Basin suggest differences in environmental conditions and assemblage composition which are yet to be studied and determined.

TERMS ADOPTED

In describing the molluscan assemblages the terms here adopted to characterize the dominance relationships of the species are those of Baldi (1973). Departures from Baldi's terminology are due to the quantitative approach of this study, in contrast to Baldi's semi-quantitative one. The former allows a better definition of the abundance relationships among the species composing the assemblages.

The terms adopted are the following:

Major dominant species: the most abundant or the dominant element(s) in the assemblage. The term is equivalent to Baldi's 'typical species' pro parte. Here, they correspond to the elements naming an assemblage.

Minor dominant species: the lesser abundant element(s) in the assemblage. Frequently, some of these elements are major dominants in other assemblages. The term is equivalent to Baldi's 'typical species' pro parte and 'frequent companions'. It indicates elements constantly present in percentages greater than 1%.

Other species: assemblage components present in percentages less than 1%.

The general term 'assemblage' is used here in the arbitrary meaning of thanatocoenosis. The more exact terms 'palaeoecoenosis' or fossil community cannot properly be applied to these faunas because of the difficulty in distinguishing the autochthonous from the allochthonous elements, particularly in the case of Tortachilla Limestone assemblages.

In this regard, all the articulated Bivalvia and those species absolutely predominant in the assemblages - Spirocolpus aldingae, Dimya sigillata and D. asseretoi, etc. - might represent autochthonous elements, although for the bivalved specimens and the micromollusca immediate post-mortem transport by bottom currents cannot be dismissed entirely.

The quantitative approach of this study also contributes further information through the analysis of the variations in diversity and of the disarticulation indexes in Bivalvia.

DIVERSITY

The concept of diversity in time and space has been discussed by several authors and a number of formulae have been produced in the attempt to qualify and give a measure of diversity (Spight, 1977; Rosenberg 1975; and for detailed information, Sanders, 1968).

In this study, Simpson's formula (Simpson, 1959, in Reyment, 1971, p. 164) has been adopted for its simplicity (see Pokorný, 1971).

$$D = 1 - \sum_{J=1}^{s} \frac{N_J (N_J - 1)}{N (N - 1)}$$

where s is the total number of species in the sample, N is the total number of specimens in the sample and N_J is the number of specimens belonging to the j-th species.

According to Sanders (1968) this formula expresses a dominance diversity since it is influenced by the possible presence of species with a very large number of individuals. This observation especially applies to the Spirocolpus, Dimya, and in particular to the Phygraea (D_s=0) acmes. To overcome this possible handicap, Simpson's formula has been extended to the genera, (D_g) where the total number of species replaces the total number of specimens and so on. Thus, expressed genera diversity shows a minimum only where it was expected, at the monotypic Phygraea tarda assemblage (D_g=0). As a result, a trend can be distinguished in both the Tortachilla Limestone and the Blanche Point Formation. The Tortachilla Limestone shows a marked minimum which coincides with the greatest dominance of Dimya. This corresponds to a weak maximum in generic diversity. In the Blanche Point Formation, the two curves show similar fluctuations, but in the D_g curve the fluctuation is much weaker, except at the Phygraea assemblage where both coincide (D_s=D_g=0).

In conclusion, from the D_s and D_g curves (see Fig. 17) there is the suggestion that relatively stressed environments existed at the beginning and at the end of the deposition of the Tortachilla Limestone and during the early deposition of the 'Transitional Marls' and that a very biologically stressed environment occurred at the beginning of the Gull Rock Member as indicated by the monotypic Phygraea assemblage. Fairly stable and biologically accommodated conditions seem to have occurred in the middle Tortachilla Limestone, the upper 'Transitional Marls', the upper Gull Rock Member and, especially, in the middle of the 'Soft Marls' (Fig. 17).

DISARTICULATION INDEXES

Three indexes were calculated here for both infaunal and epifaunal bivalves on the basis of the data from the distribution and the frequency of the valves (LV, RV, BV, vv).

Articulation Ratio

This ratio expresses the degree of variation from the environmental conditions allowing the post-mortem preservation of articulated specimens

(Eagar, 1960; Ager, 1963).

Differential Transport Index

This index is based on the discussion by Schäfer (1972, p. 159-166) which states that disarticulated valves from the same individual are usually subjected to different rates of post-mortem transport.

Uncertainty Index

This index expresses the possible percentage error in the computation of the disarticulated valves. The error represents that percentage of the valves which cannot be distinguished as being right or left (vv) due to incomplete preservation, fragmentation and breakage due to the disaggregation procedure of the samples. The possible bias of this error is generally very high.

To calculate these indexes the following formula was applied:

$$\sum_{j=1}^{s=v} = \frac{Vj(Vj-1)}{V(V-1)}$$

In the *articulation index*, *s* is the total number of the disarticulated specimens, *Vj* is the number of articulated specimens of the j-th species, and *V* is the total number of the disarticulated specimens. In the *differential transport index*, Vj is the number of the LV's in the j-th species. In the *uncertainty index*, Vj is the number of undeterminable valves (vv) of the j-th species. These indexes, at present, offer only a relative measure of possible energy conditions in palaeoenvironments. A discussion of the indexes will be integrated in the description of the assemblages. Their vertical variation is shown in Fig. 17.

MOLLUSCAN ASSEMBLAGES

As shown in Fig. 16, the molluscan faunas of the Tortachilla Limestone and Blanche Point Formation are represented by a succession of assemblages generally characterized by the same taxa but recurring in variable percentages (e.g. Chlamys, Dimya, Spirocolpus, Dosina, Hiatella, Ledella, Poroleda, etc.). However, the faunas of these two units are quite distinctive: the Tortachilla Limestone assemblages are dominated by Bivalvia (89.03%) whereas those of the Blanche Point Formation are prevalently represented by Gastropoda (67%).

It must also be pointed out that the major part of the material from the Tortachilla Limestone and the 'Transitional Marls' is represented by moulds which are mostly of doubtful determination and therefore the interpretation of the assemblages from these units should be considered tentative and subject to future revision. Only the most important or meaningful species will be mentioned in describing the assemblages, and therefore, the reader is referred for further details to the Tables Ia,b and the sample check-list of Appendix C.

TORTACHILLA LIMESTONE ASSEMBLAGES

The faunistic succession in this unit is from bottom to top: a barren interval, Chlamys-Hiatella, Dimya and Dosina-Turritella-Chlamys assemblages.

Barren Interval. This encompasses the basal unit of the Tortachilla Limestone. The only fossil content is represented by isolated, rare, extremely decalcified shells of Mollusca and echinoids, none of which are determinable, and frequent shark teeth. No microfauna has been found. This, and the abundance of pellets, seem to indicate probable supralittoral conditions similar to those of the immediately underlying South Maslin sands.

CHLAMYS-HIATELLA Assemblage

Major dominant species: Chlamys aldingensis (Tate) (16.3%), Hiatella ?vera (Deshayes) (12.5%).

Minor dominant species: *Chlamys peroni* (Tate) (10.5%), *C. flindersi* (Tate) (11.8%), *Pycnodonte tatei* (Suter) (10.24%), *Limatula margaritata* Buonaiuto (2%), *?Nemocardium* sp. (3.7%), *Dosina* sp. (4.72%), *Spondylus tortachillensis* sp. nov. (1.8%), *Dimya sigillata* Tate (1.8%), *?Gari sp.* (3.15%), *Glycymeris kaurna* sp. nov. (1.8%), *?Periglypta* sp. (1.8%), *Cucullaea* cf. *adelaidensis* (Tate) (3.4%), *Lima maslinensis* Buonaiuto (1%) *Glans* sp. *B* (1.3%), *Macra* sp. (1.3%), *Cirsotrema mariae* (Tate) (1.8%).

The infaunal *Clavagella lirata* (Tate), *Jouannetia (Pholadopsis) cuneata* Tate, *Corbula* sp., *Dosina* sp., and the epifaunal *Hiatella?vera* (Deshayes), *Chlamys aldingensis* (Tate), and among the non-molluscan groups, Cirripedia (short form) might represent authochthonous elements because of the presence of articulated specimens and the vertical distribution of their genera (Table Ia). In particular *H?vera*, although only present in disarticulated valves, might be included among the autochthonous components because of its abundance and by analogy with the depth distribution of the extant *H. arctica* (Linnaeus), which is generally reported as being frequent in intertidal and subtidal waters (Hunter, 1959; Cotton & Godfrey, 1938). The true abundance of *H.?vera* is much greater than it appears, since a large number of specimens were unavoidably destroyed during mechanical disaggregation of the samples.

The assemblage is highly diversified (D = .9170). The Bivalvia are predominantly epifaunal (77.5%). The genera are today restricted to or abundant in shallow waters (e.g.: *Chlamys*, *Katelysia*, *Mactra*, *Spondylus*, Arcacea, Pholadidae, *Glycymeris*, Turritellidae, etc., see Table Ia) but some deeper water forms are also present such as *Pycnodonte* and *Nuculana*. The Bivalvia show a low articulation index (infaunal, .0004; epifaunal 0.0) and a low differential transport index (aggregate 0.0252) which indicate a high energy environment.

No analogous extant community has hitherto been described.

DIMYA assemblage

This encompasses the middle part of the Tortachilla Limestone. On the basis of the relative distribution of the minor dominants, three sub-assemblages can be recognized from bottom to top:

Dimya-Chlamys sub-assemblage

Major dominant species: *Dimya sigillata* (Tate) (50.10%), *Chlamys peroni* (Tate) (8.04%).

Minor dominant species: *Chlamys flindersi* (Tate) (1.81%), *C. aldingensis* (Tate) (1.74%), *Limatula margaritata* Buonaiuto (4.13%), *Spondylus tortachillensis* sp. nov. (2.30%), *Glycymeris* cf. *kaurna* sp. nov. (1.88%), *Pycnodonte tatei* (Suter) (2.75%), *Hiatella ?vera* (Deshayes) 2.46%), *Limea (Isolimea) alticosta* Tate (1.01%), *Gari* sp. (2.03%), *Dosina* sp. (1.59%) *Nemocardium* sp. (3.04%), *Glans* sp. B (1.09%), *Siliquaria* sp. (1.01%), *Cirsotrema mariae* (Tate) (1.23%), *Trochus* sp. (1.38%).

Dimya-Isolimea sub-assemblage

Major dominant species: *D. sigillata* (Tate) (43.57%), *Limea (Isolimea) alticosta* Tate (15.16%).

Minor dominant species: *Pycnodonte tatei* (Suter) (4.35%), *Chlamys peroni* (Tate) (3.58%), *C. aldingensis* (Tate) (1.15%), *Parvamussium* sp. (3.85%), *Hiatella?vera* (Deshayes) (1.47%), *Tellina* sp. (1.79%), *Cypraea* sp. (1.02%).

Dimya-Isolimea-Nemocardium sub-assemblage

Major dominant species: *D. sigillata* (Tate) (29.94%), *Isolimea alticosta* Tate (9.8%), *Nemocardium* sp. (8.64%).

Minor dominant species: *Limatula margaritata* Buonaiuto (3.8%), *Pycnodonte tatei* (Suter) (2.88%), *Chlamys aldingensis* (Tate) (3.1%), *Clavagella lirata* (Tate) (2.1%), *Propeamussium* sp. (1.0%), *Mactra* sp. (1.55%), *Gari* sp. (1.33%), *Hiatella?vera* (Deshayes)(2.53%), *Cucullaea adelaidensis* Tate (2.38%), *Dosina* sp. (1.11%), *Glycymeris* sp. (1.26%), *Barbatia* cf. *limatella* Tate (1.18%), *Cirsotrema mariae* (Tate) (1.33%), Turbo sp. (2.07%), Trochus sp. (1.11%), Dentalium sp. (2.22%).

Autochthonous species seem to include D. sigillata, C. lirata and P. tatei, since some specimens were found still articulated. H.?vera, I. alticosta, Dosina sp., and Nemocardium sp. might also be included in the above because of their abundance, although all their specimens are disarticulated.

The extant species of Dimya, the dominant element of the assemblage, are constantly recorded at a depth range of 20-790 m (Table Ia). However, D. sigillata differs from them and from the younger Late Eocene D. asseretoi sp. nov. in having a thicker and larger shell and in its left valve being flatter and internally ribbed. The morphological differences suggest a possible adaptation of D. sigillata to higher energy conditions than the younger forms. This, in the context of the other species and the non molluscan taxa present in the sample (Cirripedia) might indicate a depth range for D. sigillata shallower than for the extant Dimya species.

Isolimea, one of the characteristic forms of this assemblage, is today recorded at a relatively deep range of 91-255 m (Table Ia). Its occurrence in a seemingly shallow water fossil assemblage may have two possible explanations. A) I. alticosta, due to its minute size, may be an allochthonous element transported for long distances from deep waters. This hypothesis would be supported by the worn shell conditions, but it is rendered doubtful by the rarity of this species in the deeper water 'Transitional Marls' assemblages. B) Alternatively, and more convincingly, Isolimea might have migrated in more recent times to deeper waters, either due to a possible selectivity for cooler waters, or because of a possible successful competition of the Pliocene-Holocene Gemellima Iredale, the other southern Australian subgenus of Limea. This latter form lives today in a shallower habitat than Isolimea (14.6-366 m, with acme at 36.6 m - Buonaiuto, 1977a).

The decrease of Hiatella?vera and the appearance of other deep water forms, such as Propeamussium, Pronucula and Limopsis, suggest a deeper environment than that of the Hiatella-Chlamys assemblage.

No extant analogue of the Dimya assemblage has yet been described.

DOSINA-TURRITELLA-CHLAMYS assemblage

This assemblage encompasses the top unit of the Tortachilla Limestone.

Major dominant species: Dosina sp. (12.82%), Chlamys flindersi (Tate) (5.13%), Turritella sp. (8.55%).

Minor dominant species: Chlamys peroni (Tate) (1.7%), Chlamys sp. (27.35%), Limatula margaritata Buonaiuto (3.42%), Lima maslinensis Buonaiuto (1.7%), Corbula sp. (1.7%), Gari sp. (1.7%), Isolimea alticosta Tate (2.56%), Ostrea sp. (1.7%), Cucullaea cf. adelaidensis Tate (1.7%), Natica sp. (1.7%), Dimya sigillata Tate (1.7%).

The autochthonous species are similar to those of the preceding assemblage. Among the gastropods, Turritella should probably be included because of its abundance. This assemblage shows some analogy with the Maoricolpus-Dosina (=Dosinula) community from New Zealand, as described by Powell (1937). As dominant elements the two have in common Dosina and a turritellid although in the extant community the gastropod is more abundant.

In regard to the other significant forms in the assemblage and in the community, the following comparison may be made. Of the other four dominants in the community, Trochus,Paphirus and Cominella are not represented or replaced by an allied genus in the fossil assemblage; Notocorbula is substituted by Caryocorbula, which however, is in a subordinate position. Chlamys, dominant in the assemblage, is a secondary component in the live community. In regard to non-molluscan taxa, crabs are present in both assemblages as secondary forms; Bryozoa are dominant in the fossil assemblage. Finally, the overall number of taxa is much less in the assemblage than in the community.

In conclusion, the *Dosina-Turritella-Chlamys* assemblage might represent an impoverished analogue of the *Maoricolpus-Dosina* community, differing from it in composition and in the abundance of the correlative forms other than the two key ones. The differences between the community and the assemblage might have been augmented by natural causes, such as environmental, evolutionary, or biogeographical factors, which might also account for the presence of different forms altogether, besides the simple variations in relative abundance. These differences could have been emphasized by other causes such as preservation, or total post-mortem removal by transport of species, etc. It is noteworthy that with the onset of this assemblage, *Chlamys aldingensis* (Tate) disappears.

Powell (1937) considered the *Maoricolpus-Dosina* assemblage as a connecting community between the deeper '*Maoricolpus* association' (analogous to the fossil *Spirocolpus* assemblage here) and the shallower intertidal-shallow subtidal communities. He further indicated that the sub-stratum of the *Maoricolpus-Dosina* assemblage is represented by coarse shell debris dragged from higher levels by tidal currents, and by silt and fine sediments.

Very high energy conditions for the fossil assemblages are suggested by the following:

A) that the lithological composition of the host rock shows a large component of skeletal and inorganic clasts and a fine detrital fraction produced by shell abrasion.

B) that the values of the articulation index (0.0000) and of the differential transport index for both infaunal and epifaunal Bivalvia (0.0318) are very low.

C) that the indeterminable valves, fragmented by post-mortem processes are present in a very large number.

Shell transport from deeper waters by currents cannot be excluded. Johansen (1901, fide Sorgenfrei, 1958) "found that wave action forms a belt of movement parallel to the coast, down to a depth of 15 m along open coasts. Shells are moved up or down this belt. An upward movement prevails on gently dipping shores, while on steep rocky shores the shells mostly move in deeper waters".

Therefore, if the fossil assemblage lived in a subtidal environment similar to that of the living community (Powell, 1937) upward shell transport cannot be excluded, since the Tortachilla Limestone angle of deposition could have been negligible, as suggested by the superimposed Karst surface.

BLANCHE POINT FORMATION ASSEMBLAGES

The upward assemblage succession in this formation is the following: 'Transitional Marl': Barren; Turritella-Dosina; Spirocolpus-Dimya; Chlamys-Pycnodonte; Dimya-Chlamys; Spirocolpus-Trophon. Gull Rock Member: Barren; Phygraea; Barren (Bryozoa); Spirocolpus-Dimya-Ledella. 'Soft Marls': Ledella-Pectunculina-Zeacolpus.

'Transitional Marl' Member

BARREN INTERVAL

This gap is due to the suggested continental-supralittoral episode interposed between the Tortachilla Limestone and the Blanche Point Formation (see also Buonaiuto, 1977a, Appendix F).

TURRITELLA-DOSINA Assemblage

Major dominant species: Dosina sp. (13.19%), Turritella (=?Spirocolpus) sp. (19.78%).

Minor dominant species: Chlamys peroni (Tate) (7.69%), C. flindersi (Tate) (3.3%), Chlamys sp. (15.38%), Dimya sigillata (Tate) (7.69%), Arca s.l. sp. (3.3%), Cucullaea cf. adelaidensis Tate (4.4%), Limatula margaritata Buonaiuto (4.4%), Isolimea alticosta Tate (3.3%).

This assemblage, collected from a karst pit filling, appears to be similar to the Dosina-Chlamys-Turritella assemblage of the uppermost Tortachilla Limestone. However, in this assemblage Turritella is more abundant than Dosina. Chlamys peroni should in reality be included among the major dominants since its abundance is probably decreased by bad preservation, and since some of the specimens included in Chlamys sp. should be referred to either C. peroni or C. flindersi. The impoverished aspect of this assemblage is probably due to two factors other than environmental: sampling and preservation.

SPIROCOLPUS-DIMYA assemblage

This assemblage occurs in the lower part of the 'Transitional Marls'. It is very doubtful that this and the next two assemblages fairly reflect their palaeocommunities, because intensive dissolution selectively favoured an over-representation of Pterioida against all other Mollusca.

In this assemblage, two sub-assemblages can be recognized.

Spirocolpus-Dimya-Chlamys sub-assemblage

Major dominant species: Spirocolpus aldingae (Tate) (4.87%), Dimya sigillata Tate (7.14%), Chlamys flindersi (Tate) (3.35%), C. peroni (3.12%).

Minor dominant species: Turbo sp. (1.79%), Lima maslinensis Buonaiuto (1.12%), Vulsella laevigata Tate (1.12%), Spondylus tortachillensis sp. nov. (1.34%), Dosina cf. multilamellata (Tate (2.01%).

Spirocolpus-Dimya-Pycnodonte sub-assemblage

Major dominant species: S. aldingae (21.75%), D. sigillata (24.73%), Pycnodonte tatei (Suter) (14.50%).

Minor dominant species: Dosina cf. multilamellata (5.33%), Turbo sp. nov. (5.12%), Chlamys peroni (5.33%), C. flindersi (6.61%), Spondylus tortachillensis (1.07%).

These two sub-assemblages are very similar to each other, although the latter is more impoverished. Both assemblages seem to be close to the previous Dosina-Turritella-Chlamys assemblage, since they contain the same dominants, although in different percentage abundance.

The concurrence of dominant Spirocolpus and of the shallow water species of the previous assemblages and the appearance of new taxa such as Lentipecten, Vulsella, Phygraea, Trophon, Modiolus, and Paraglans latissima (Tate) suggest a somewhat deeper water environment. Still relatively shallow waters are suggested for the Spirocolpus-Dimya assemblage. Probably this represented a transitional environment to the deeper Spirocolpus-Trophon assemblage.

The predominance of epifaunal Bivalvia, the higher articulation index (infaunal, 0.0969; epifaunal, 0.0014), together with the relative differential transport indexes (0.0256; 0.0000) still suggests high energy conditions, but less than in the previous assemblages. The Spirocolpus-Dimya-Pycnodonte sub-assemblage indicates an upward increase of energy, not only from the indexes, but also from the increase in abundance of Dimya and Pycnodonte.

PYCNODONTE-CHLAMYS assemblage

This assemblage is from a thin hard bryozoal lens enclosed in the glauconitic marls, just below the Hantkenina horizon.

Major dominant species: Pycnodonte tatei (Suter) (48.20%), Chlamys flindersi (45.90%).

Minor dominant and other species: Chlamys peroni (2.62%), Dimya sigillata (1.3%), Spondylus tortachillensis sp. nov. (.98%), Cirsotrema mariae (Tate) (.33%).

The fauna is very poorly diversified and is represented almost entirely by epifaunal Bivalvia (99.67%), of which P. tatei and C. flindersi are autochthonous. These forms, together with the low articulation (0.0001) and differential transport (.0918) indexes suggest very high energy conditions. The lens probably represents local tidal channel deposits partly formed by transported shells and shell debris.

DIMYA-CHLAMYS assemblage

This assemblage characterizes the upper 'Transitional Marls' and is from a silicified horizon which preserves the only record of the rich fauna of this unit.

Major dominant species: *Spirocolpus aldingae* (7.61%), *Trophon (Trophonopsis) hypsellus* (Tate) (2.84%).

Minor dominant species: *Acteon subscalatus* Tate & Cossmann (1.50%), *Tanea falsa* sp. nov. (1.02%), *Dimya sigillata* (1.38%).

This assemblage, although very diversified (92 species, 76 genera), is absolutely dominated by *Spirocolpus aldingae*. It still contains elements of the older assemblages, such as *C. peroni*, *C. flindersi*, *Lima maslinensis*, *Dosina multilamellata*, etc., but only as secondary species ($<$ 1%). The infaunal Bivalvia (46.91%) become predominant in relation to the epifaunal ones (43.83%). Articulation and differential transport indexes still indicate high energy conditions, but less than in the previous assemblages.

Living *Turritella* communities have been described by Powell (1937), Thorson (1957) (=*Amphiura* communities), Vatova (1949), Buchanan (1958) and Parker (1964). Fossil *Turritella* assemblages have been discussed by Hekker (1962, 1963) and by Baldi (1973).

Baldi (1973), summarizing the results of the other authors, indicates that assemblages with dominant turritellids have a depth range of about 3-100 m. According to Baldi (1973), the substratum - i.e. the host rock in fossil assemblages - gives further palaeobathymetric information: a coarse substratum indicates a shallow sublittoral environment (0.30 m ca) and a fine, muddy bottom indicates a sublittoral one of medium depth (30 to $\geq$ 60 m).

The glauconitic marls, host rock of the *Spirocolpus-Trophon* assemblage, would therefore suggest that this assemblage inhabited waters deeper than 30 m.

From the palaeobathymetric viewpoint, the assemblage is characterized by wide depth range, and shallow and deep water forms. Among the shallow forms are: *Distorsio*, *Latirus*, *Waimatea*, *Argobuccinum*, *Arcopsis*, *Septifer*, *Pinctada*, *Dosina*, *Lima* (shallow water form) etc. Among the deep water forms are: *Poroleda*, *Ledella*, *Pectunculina*, *Actaeon*, *Comitas*.

The co-occurrence of these two groups seems to suggest a depth range with the upper limit of 40 m, as indicated by the abundance of *Acteon*, and a lower limit of about 100 m, as inferred by the abundance of *Spirocolpus* and the presence of *Cerithiopsis* and *Melanella*. The presence of shallow water forms can be explained in two ways: either that those species living below 15 m depth might have been transported to deeper waters (Sorgenfrei, 1958, II, p. 409); or the record of their maximum depth range is incomplete, which is the more likely possibility. Therefore, all these indications suggest a probable depth of about 100 m.

Gull Rock Member

BARREN INTERVAL

This is located at the base of this Member and contains shell debris and worn foraminifera such as in the *Phygraea* horizon.

PHYGRAEA assemblage

This assemblage is from the lowermost Gull Rock Member.

Dominant species: *Phygraea tarda* (Hutton) (100%).

This monotypical assemblage is entirely composed by this deep water grypheid oyster. *Phygraea* Vyalov is a subgenus which becomes extinct by the Miocene (Stenzel, 1971). The only pycnodontid extant ally with grypheid morphology is *Neopycnodonte* Stenzel.

Neopycnodonte lives in distal deep waters (45-184-2000 m) and in cold to warm temperate belts (Stenzel, 1971),at and beyond the shelf margins (Robba, 1968). According to Stenzel and other authors (*loc. cit.*) all grypheid oysters, as they are found associated with clays, marls, chalk, limestones and glauconitic marls, were selective for unconsolidated water logged oozes, with shell debris and faecal pellets, for substrates swept by gentle currents, and for oceanic euhaline conditions.

The host rock of the Phygraea assemblage is a soft calcareous marl with very fine bioclasts, and is consistent with the above observations. From the climatic viewpoint, Phygraea seems to have existed in warm temperate to tropical waters since it was quite common in the Eocene-Oligocene Tethys as P. brongniarti (Bronn) and in Patagonia as the Cretaceous-Palaeocene P. burckhardti (Boehm) and in Australasia, as the Palaeocene-Eocene P. tarda (Hutton). Consistent with the above record Dormann (1968, 1969) gives an oxygen-isotope temperature of 16.5^{o}C as measured on specimens of P. tarda from Browns Creek. (see footnote p. 72).

From the above, this assemblage suggests a deep sublittoral to possibly shallow bathyal environment and seems to mark the deepest episode of the Blanche Point transgression.

BARREN INTERVAL

This interval encompasses marls very rich in Bryozoa; however in places it can be completely barren of macrofauna (Noarlunga Sub-Basin). From Strauss (1928, fide Baldi, 1973, pp. 121-122) and Ryland (1970), the optimal depth range in which Bryozoa reach greatest diversity and maximum abundance is 20-80 m with an acme at 40 m. This horizon therefore may indicate a return to shallower conditions, i.e. medium depth sublittoral (Baldi, 1973).

SPIROCOLPUS-DIMYA-LEDELLA assemblage

The upper Gull Rock Member is characterized by this assemblage:

Major dominant species: Spirocolpus aldingae (54.61%), Dimya asseretoi sp. nov. (5.77%), Ledella leptorhyncha (Tate) 5.07%).

Minor dominant species: Marginella sp. nov. (1.33%), Kleinacteon dubius sp. nov. (1.37%), Retusa (Decorifer) crassa sp. nov. (1.69%), Zeacolpus sp. nov. (1.76%), Trophon (Trophonopsis) hypsellus (Tate) (1.50%), Lunatia aldingensis (Tate) (1.03%), Siphonodentalium sp. (2.85%), Cadulus sp. (2.56%), Pectunculina cancellata sp. nov. (3.99%).

This assemblage is similar to the previous Spirocolpus-Trophon one. It differs in an increased abundance of deep water forms, such as Pectunculina, Limopsis, Parvamussium, Cyclopecten, Poroleda, Ledella, the deep water form of Dimya, Retusa, Aclis, Austrosassia, Siphonodentalium and Cadulus. All these taxa indicate a deeper habitat than that of Spirocolpus-Trophon. However, the presence of a few specimens of shallow water genera, such as Acteocina, Dosina, Marginella, Lunatia, Melanella, still suggests relatively shallow conditions. The presence of Austrosassia, Poroleda and Ledella indicates a minimum depth of 72-114 m. Cadulus is given as common between 9 and 24 m depths and abundant between 24 and 91 m depths (Parker, 1956). Bandy (1948) indicates two acmes of Cadulus, each represented by a different species; the shallower between 15 and 73 m reaches a maximum abundance 5-6% of the entire assemblage; the deeper between 219 and 913 m reaches as a maximum 20% of the entire assemblage. Bandy (1958) also observed a general percentage increase of the Scaphopoda in the assemblages directly related to the depth. Parker (1956) reports Cyclopecten as being abundant in deep shelf waters (24-91 m depth). The dominance of Spirocolpus suggests a depth of about 100 m.

It is noted that another Turritellid, Zeacolpus also occurs among the minor dominants. This genus seems also able to thrive in waters deeper than 100 m (Marwick, 1957a).

The Bivalvia are dominated by infaunal forms (62.09%). The higher articulation and differential transport indexes indicate the presence of currents, although weaker than those in the 'Transitional Marls'.

'Soft Marl' Member

In this member only the assemblage from the middle part has been described. As already mentioned, the upper part has been subjected to dissolution. Check samples from the lower part have shown gradual transition between the previous assemblage and that from the middle 'Soft Marl'.

LEDELLA-PECTUNCULINA-ZEACOLPUS Assemblage

Major dominant species: *Ledella leptorhyncha* (Tate) (10.61%), *Pectunculina cancellata* sp. nov. (7.76%), *Zeacolpus* sp. (6.69%).

Minor dominant species: *Spirocolpus aldingae* (4.83%), *Polinices nothos* sp. nov. (1.50%), *Retusa (Decorifer) crassa* sp. nov. (1.23%), *Margarites (Periaulax) rhysus* sp. nov. (1.66%), *Mesoginella (Plicaginella) aldingae* (Tate) (1.03%), *Limacina* sp. nov. *A* (1.66%), *Trophon (Trophonopsis) hypsellus* (Tate) (1.58%), *Knefastia* sp. nov. *B* (1.58%), *Kleinacteon dubius* sp. nov. (1.35%), *Siphonodentalium* sp. (2.61%), *Gadilina tatei* Pilsbry & Sharp (5.46%), *Salaputium lamellatum* (Tate) (1.90%), *Condylocardia radiata* (Tate) (1.50%), *Parvamussium* sp. (5.85%), *Dimya asseretoi* sp. nov. (5.66%), *Salaputium aldingensis* (Finlay) (1.35%), *Nuculana (Saccella) chapmani* Finlay (1.82%), *Cardium* sp. (2.53%), *Nemocardium* sp. (3.88%).

This assemblage is gradational from that of *Spirocolpus-Dimya-Ledella*. It is characterized by the disappearance of *S. aldingae* among the major dominant forms and by a marked increase in the number of major and minor dominant species. The forms here best represented, both as dominant and secondary species, are deep water micromollusca.

The sharp decrease in turritellids and the increased abundance of the deeper *Zeacolpus* in constrast to *Spirocolpus*, the diversification and the abundance of the Pteropoda, the dominance of micromollusca characteristi in the muddy substrata of the 200-500 m depth range ("minute shells facies") (Robba, 1968), the dominance of the Bivalvia over the Gastropoda, and the abundance of Scaphopoda (Bandy, 1958) suggest a habitat much deeper than

100 m which is consistent with Robba's above observations. However, the persistence of shallow water forms such as Lunatia, Melanella, Latirus, Acteocina, Dosina, and Arcidae still suggests only moderate depths.

The presence of Baryspira, Retusa, Narona and Ataxocerithium tends to restrict the lower limit of depth range to less than 200 m. Thus, the Ledella-Pectunculina-Zeacolpus assemblage might have some analogies with the Turritella profunda zoocenose (Vatova, 1949, fide Baldi, 1973) recorded in the Adriatic Sea between 59 and 140 m depth. However, the only common element would be represented by the subordinate position of the turritellid in the assemblage and the zoocoenose.

Among the Bivalvia, the infaunal forms in this assemblage are absolutely dominant (72.95%). Higher articulation and differential transport indexes indicate a decrease of water energy, but do not rule out the probable presence of current action.

PALAEOCLIMATOLOGICAL SIGNIFICANCE OF THE LATE EOCENE MOLLUSCA

This discussion has been based upon the information by Palmer (1974), Robba (1971), Fleming (1944, 1975), Beu (1966), Beu & Maxwell (1968), Hall (1964), Wenz (1938-44), Zilch (1959), R. Moore (1960, 1969, 1971), Strauch (1968, 1969), Parker (1964), Cernohorsky (1970) etc. and based on extant forms (see Tables Ia, Ib).

In the Tortachilla Limestone the most indicative taxa from the palaeoclimatological viewpoint are: Cucullaea, Dimya, Clavagella, Spondylus Turritella, Pholadopsis, Calliostoma, and Hiatella. Dimya today lives in a recorded temperature range of 8.6-17.6^{0}C. Pholadopsis, Calliostoma, Cucullaea, and Spondylus are warm temperate to tropical genera, Turritella is subtropical to tropical, and Clavagella a very warm form. The size of the specimens of Hiatella (see further discussion) suggests temperatures oscillating between a possible minimum of 6^{0} to a possible maximum of 23^{0} which is consistent with the temperature range of Dimya.

The Blanche Point Formation also contains the same species and a plethora of other warm water taxa (Tables Ia,Ib) with a few colder, deeper water forms such as *Crenella*, *Limopsis*, and *Cuspidaria*.

The 'Transitional Marl' Member is characterized by genera such as *Salaputium*, *Septifer*, *Pseudomalaxis*, *Vulsella* and *Pinctada*, which indicate possible subtropical conditions. Similarly, the Gull Rock and the 'Soft Marl' Members have yielded, for example, *Phygraea*, *Pseudomalaxis*, *Sigmesalia*, *Styliola*, *Arcopsis*, *Praehyalocylis*, *Limacina*, which suggest warm temperate to tropical conditions. However, the absence of *Vulsella*, notwithstanding the favourable presence of siliceous sponges, indicates that the two members accumulated in conditions somewhat cooler than those for the 'Transitional Marls'.

The climatic indications given by Gastropoda, Bivalvia and Scaphopoda receive further support by the Late Eocene nautiloid record in the St. Vincent Basin.

Cimomia felix (Chapman) and *Aturia clarkei* Teichert are commonly found in both Tortachilla Limestone and Blanche Point Formation, and they probably represent the remnants of populations autochthonous to the southern Australian waters in the Late Eocene (Appendix D-2).

The present distribution of *Nautilus* Linné (Stenzel, 1964), the palaeogeographic distribution of *Cimomia* Conrad and *Aturia* Bronn in the Tertiary (Appendix D-2), and the diversity gradient of the Australian Eocene nautiloid assemblages (*loc. cit.*) infer that *C. felix* and *A. clarkei* at least lived in warm temperate to subtropical waters.

On a more refined scale, in the Blanche Point Formation, the acme in the 'Transitional Marls' (Appendix D-2) may indicate an initial warm peak followed by a gradual climatic deterioration, which might have been the cause of disappearance of *A. clarkei* in the 'Soft Marls'.

In the Tortachilla Limestone, the presence of both the species indicate a climate similar to that of the Blanche Point Formation.

However, since the shells 'stranded' in the high energy environment of the Tortachilla Limestone would have had lesser chances of preservation than those that sank during the deposition of the Blanche Point Formation, no relative climatic comparison is possible between these two formations.

Among the non molluscan taxa, two other groups significantly contribute to the paleoclimatic reconstruction of the southern Australian Late Eocene. Consistent with the molluscan evidence, the following foraminifera suggest three warm peaks during that time (Lindsay, 1976; McGowran, 1978c):

1) This first peak occurred during early P15 (McGowran, 1978a,b) with an incursion of the large shallow water benthonic Halkyardia and Linderina (Tortachilla Limestone, eastern St. Vincent Basin - Lindsay, 1976).
2) The second peak occurred at the P15/16 boundary with the brief appearance of the planktonic Hantkenina primitiva ('Transitional Marls', St. Vincent Basin; Lacepede Formation, Gambier Embayment; lower Browns Creek Formation, Otway Basin - Lindsay, 1976).
3) The third peak occurred during Late P16-P17 with a second incursion of Halkyardia and Linderina (Port Willunga Formation, St. Vincent Basin; Buccheluch Beds, Murray Basin - Lindsay, 1976; Ludbrook, 1961).

The other group is represented by penguins, whose remains are found in the basal 'Transitional Marls' below the H. primitiva horizon and in the middle Gull Rock Member (Jenkins, 1974).

Three possible interpretations of the significance of penguin remnants have been proposed:

A) The penguins were adapted to cooler climates (Jenkins, 1974). The presence of penguins in these two horizons would then indicate at least two cold fluctuations in the Blanche Point Formation with surface water temperatures of about 12-16°C (Jenkins, 1974). These fluctuations would probably have been long enough to allow short migrations of penguins to the St. Vincent Basin from the circum-antarctic regions.

B) The penguins were at that time adapted to warmer climates than they are today (Stonehouse, 1969). This would also be suggested by the survival of penguin populations along the southern Australian coasts today.

C) Single individuals or flocks of penguins were stranded occasionally from off shore cooler waters. The rarity of the findings would support this hypothesis.

In the first case, the localized stratigraphic position of the penguin remnants and their occurrence on bed surfaces (Jenkins, 1979, pers. comm.) may favour the possibility of minor cold fluctuations. This possibility cannot be excluded because the older occurrence follows and the younger precedes the two cold peaks of middle P15 and middle/late P16 (Shackleton & Kennett, 1975; McGowran, 1978a,b,c) respectively. Such minor fluctuations are, in any case, very difficult to prove or disprove, since they are well beyond biostratigraphical resolution and/or might have been associated with diastematic episodes.

The second case is supported by the co-occurrence of Cucullaea, Siliquaria, Spirocolpus, Vulsella, etc. with the penguins in the lower 'Transitional Marls' and of Spirocolpus and the pleurotomariid Mikadotrochus in the middle Gull Rock Member, and by the occurrence throughout the lower and middle Blanche Point Formation of the planktonic gastropoda Limacina and Praehyalocylis (Table Ia,b), and of the nectonic Aturia and Cimomia. These forms suggest temperature ranges for the entire water column higher than the range given by Jenkins (1974) for the penguins.

The third case, the possibility of stranding, receives some support from the rarity of the penguin findings. It is also supported by the fact that they probably represent the remnants of adult individuals only (Jenkins,

1974) and not of several individuals at different stages of growth, which is a sure sign of the presence of a population. The optimal conditions of preservation displayed by the other groups, especially in the Gull Rock Member, might have enhanced the chances of fossilization for the occasional penguin skeleton.

At the present stage, none of these three cases can be dismissed. The evidence supporting the first and the second interpretation is not mutually exclusive, because the penguin record may represent distinct cool episodes interposed between warm events. The third case, just intermediate between the first two, allows for co-occurrence of cooler climate penguins and warm molluscan assemblages.

In conclusion, the molluscan and other faunas suggest that the Tortachilla Limestone and Blanche Point Formation were deposited during periods of warm temperate to subtropical climate (early P15 and late P15-middle P16). There are also indications in the 'Transitional Marl' faunas of a climatic optimum (late P15 to early P16) which is consistent with the oxygen isotope curves by Dorman (1968, 1969) which were linked by Jenkins (1974) with the Blanche Point Formation and with those by Dorman & Gill (1959), Devereaux (1967), Shackleton & Kennett (1975) and Boersma & Shackleton (1977). The indications from silicoflagellates (Mandra, 1971, 1973) give further support to this conclusion.

The only discrete cold fluctuations seem to coincide with regressive episodes: the Tortachilla Limestone/Blanche Point Formation supralittoral to continental lacuna (middle P15) and with the continental Chinaman Gully Formation (middle/late P16) as suggested by the correlation of McGowran (1978a,b,c) of Shackleton & Kennett's 1975 curves with the Late Eocene sedimentary events in Southern Australia.[1]

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[1] N.B. Hudson (1977) showed that the oxygen isotope data do not represent a direct measure of palaeotemperatures, since the different isotopic composition (lower O^{18}/O^{16} ratio) in waters of glacial origins biases the results.

Observations on Hiatella as a possible palaeotemperature indicator

Strauch (1968,1969) found that for living and fossil populations of *Hiatella arctica* (Linné) from the Northern hemisphere: -

- 'The adult shell size attained by *Hiatella* increases gradually by falling temperatures, at first gradually but at winter temperature of 2°-3°C sharply';
- the adult shell size depends on the minimum winter temperature;
- the range in adult shell size is smaller between tropical and boreal zones (8-20mm) than between boreal and arctic (20-45mm);
- such a behaviour is not only limited to the present but can be traced far back to the Middle Eocene (Strauch, 1968, pp. 223-26).

For the above reasons *Hiatella* can be used as a palaeotemperature indicator. Consistent with the methodology of Strauch, the lengths of the largest moulds of *Hiatella* from the Tortachilla Limestone and the largest specimen from the Adelaide Bore were measured. The maximum value obtained is 16 mm; the average 12-13 mm. The palaeotemperature for the Tortachilla Limestone can be interpolated from Strauch's graph (his fig. 4, p. 225). The maximum length gives a palaeorange of roughly 6-18°C and the average length one of roughly 8-23°C. Both these rough estimates agree well with the oxygen isotope temperature curves of Dormann (1968, 1969), Dormann & Gill (1969), Devereaux (1967) etc. Mandra (1971, 1973) obtained from the analysis of silicoflagellate assemblages similar temperatures for the early Late Eocene. Mandra (*loc.cit.*) and Jenkins (1974) also give indications a cooler phase before the climatic optimum at the *Hantkenina primitiva* zone. *Hiatella*?*vera* shell size seems to support these cooler conditions. The wide temperature range indicated by *Hiatella*?*vera* could find an explanation in the intertidal-very shallow plaaeoenvironment of the Tortachilla Limestone where seasonal temperature fluctuations probably provide the major control of water temperature.

TABLE Ia

SELECTED TAXA	Depth ranges(m)	Temperature range (°C)	Authors
Siphonodentalium	23-33-405-662	11-22	Cotton & Godfrey, 1940; Parker, 1964.
Cadulus	9.14-548.6 max. 3547	11-24, min. 1.6	as above
Laevidentalium	11-420	10-22	Parker, 1964
Fautor	0-9.14-365.76	-	Cotton, 1959.
Niso	5-137	13-18	Emerson, 1965; Parker, 1964.
Eulima	7-18.3-110.6	warm temperate max. 24	Parker, 1964; Cotton, 1959; Van Winkle Palmer, 1974.
Graphis	10.97-260	temperate	Powell, 1940; Sorgenfrei, 1958.
Polinices	0-549	11-30	Parker, 1964; Marinkovich, 1977.
Tanea	0-45.72-604	?tropical	Powell, 1940; Marinkovich, 1977; Dell, 1956.
Lunatia	shallow waters	cold to warm	Marinkovich, 1977; Baldi, 1973; Sorgenfrei, 1958.
Austrosassia	91.14-127.60	warm	Iredale & McMichael, 1962; Van Winkle Palmer, 1974.
Argobuccinum	21.87-29.16	-	Cotton, 1959.
Cirsotrema	10.94-238-366	12	Powell, 1937,1940; Parker, 1964.
Distorsio	13-88	11-30	Parker, 1964; Van Winkle Palmer, 1974.
Fusinus	0-26-229	12-26	Parker, 1964; Cotton, 1959; Iredale & McMichael, 1962.
Pterynotus	0-18-366	10.2-21	Parker, 1964.
Latirus	13-61	15-24	Parker, 1964.
Baryspyra	3.2-200.51	warm to tropical	Powell, 1937,1940; Cotton, 1959.
Notopeplum	12-200		Wilson, 1972.
Austromitra	shallow-458	warm temperate	Cernohorsky, 1970.
Waimatea	0-36	-1 - +12, max. 20	as above
Marginellidae	shallow waters		Robba, 1968.
Narona	18-187	11-30	Parker, 1964.
Acteocina	4-31	15-22	Parker, 1964.
Acteon	41.92-342		Powell, 1937,1940,1951.
Retusa	21.87-182.28		Powell, 1940.

Limacina		25.7-28	Herman & Rosenberg, 1969.
Styliola		17-26	Robba, 1971.
Turritella	0-549	10.30	Parker, 1964.
Zeacolpus	0-400		Marwick, 1957.
Ataxocerithium	0-8 - 201.3		Cotton, 1959; Powell, 1951; Dell, 1956.
Trophon	0-342		Powell, 1951.
Cerithiopsis	0-102		B.A. Marshall, 1978.
Seila	LTM-88-805		B.A. Marshall, 1978.
Pronucula	10.94-546.84		Cotton & Godfrey, 1938; Dell, 1956.
Sarepta	82.03-546.84-604		Cotton & Godfrey, 1938; Dell, 1956; Iredale & McMichael, 1962.
Ledella	107.97-1731.66		as above
Poroleda	72.91-604		as above
Saccella	0-420-604	10-30	Parker, 1964; Dell, 1956.
Arca	0-604	warm	Dell, 1956.
Arcopsis	0-6	20-24	Parker, 1964.
Pectunculina	36.71-1281		Iredale & McMichael, 1962; Dell, 1956.
Vulsella	shallow water-218.74	warm to tropical	Cotton & Godfrey, 1938; E.A. Smith, 1911.
Exosiperna	27.34-364.56		Cotton & Godfrey, 1938; Iredale, & McMichael, 1962.
Septifer	9-13-64	21-22	Parker, 1964; Iredale & McMichael, 1962.
Pinctada	6-9	pantropical	Dall *et al.*, 1938; Moore, 1969;
Pinna	LTM-182.3	warm temperate-to tropical	Cotton & Godfrey, 1938.
Chlamys	0-364.56	12-21	Parker, 1964; Cotton & Godfrey, 1938
Parvamussium	114.83-604		Iredale & McMichael, 1962; Cotton & Godfrey, 1938; Dell, 1956; Robba, 1971.
Cyclopecten	33-662	11-21	Parker, 1964;Dell, 1956.
Spondylus	0-5-64	21-30	Parker, 1964.
Neopycnodonte	45-184-2000		Stenzel, 1971; Lamy, 1930; Robba, 1968.

Dimya	20-790	8.6-17.6	Dall *et al.*, 1938; Bartsch, 1913; Habe, 1970; Parker, 1964; Dell, 1956.
Caryocorbula	0-7-549	10-30	Parker, 1964.
Pholas	0-6	20	Cotton & Godfrey, 1938; Parker, 1964.
Clavagella	0-200.51	very warm	B.J. Smith, 1971, Cotton & Godfrey, 1938.
Glycymeris	2-662	12-30	Parker, 1964; Dell, 1956.
Hiatella	0-2000, optimal intertidal		Strauch, 1968; Hunter, 1949; Dell, 1956.
Salaputium	29.2-273.4	subtropical-tropical	Iredale & McMichael, 1962; Cotton & Godfrey, 1938.
Dosinia	0-9-113		as above
Tellina	0-42-320	warm	Parker, 1964; Cotton & Godfrey, 1938.
Dosina	4.56-14.58		Powell, 1937.
Isolimea	91.14-255.19		Cotton & Godfrey; 1938.
Cuna	36.46-604		Cotton & Godfrey, 1938; Iredale & McMichael, 1962; Dell, 1956.
Limatula	0-549		Cotton & Godfrey, 1938; Dell, 1956.
Lima	0-27.34-549		Cotton & Godfrey, 1938; Dell, 1956.
Mactra	LTM		Cotton & Godfrey, 1938.

TABLE Ib

Taxa	Qualitative temperature range	Taxa	Temperature range
Sigmesalia	pantropical	*Limopsis*	boreal
Caecidae	warm	*Crenella*	boreal to warm
Crossea	tropical	*Barbatia*	warm temperate
Hyalocylis	warm to tropical	*Cucullaea*	warm to tropical
Calyptraea	warm	*Phygraea*	warm to tropical
Pseudomalaxis	warm to tropical	*Cuspidaria*	cool to temperate
Turbonilla	warm	*Pholadopsis*	temperate to tropical
Chemnitzia	warm	*Ctenoides*	warm
Emarginula	warm	*Pteria*	warm
Siliquaria	warm to tropical	*Amaurellina*	warm to tropical
Sinum	warm	*Siratus*	warm
		Pterochelus	warm

(see text for references)

CONCLUSIONS

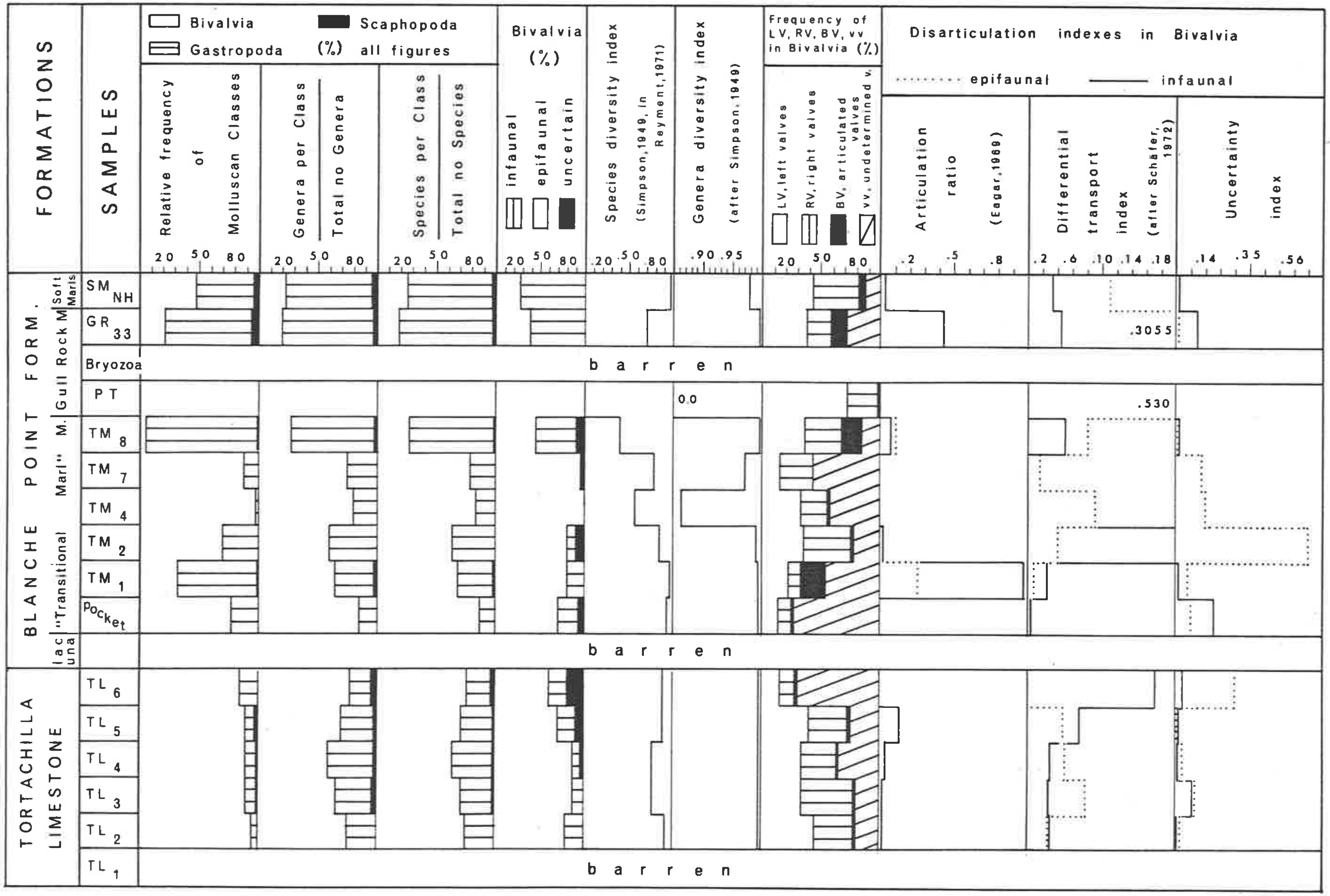
The quantitative analysis of the Molluscan faunas of the Tortachilla Limestone and the Blanche Point Formation revealed a number of distinct assemblages, as previously described.

The succession of these assemblages suggests a supralittoral to subtidal environment of deposition for the Tortachilla Limestone. In the Blanche Point Formation, the assemblages indicate a gradual transition from subtidal to shallow-medium sublittoral conditions in the 'Transitional Marl' Member; a medium depth to possibly deep sublittoral-shallow bathyal environment for the lower Gull Rock Member; a return to shallow medium depth sublittoral in the upper Gull Rock Member; and again, a reversal to deeper conditions in the 'Soft Marl' Member. Two continental to supralittoral episodes are recognized here: the older represented by the lacuna between Tortachilla Limestone and Blanche Point Formation; the younger by the Chinaman Gully Formation (Fig. 13).

The high diversity indexes of the assemblages suggest that biologically accommodated conditions for Mollusca persisted almost continuously throughout both Tortachilla Limestone and Blanche Point Formation, with the exception of the _Phygraea_ _tarda_ assemblage and the overlying Bryozoa assemblage, which indicate biologically stressed conditions (Fig. 17).

The molluscan faunas indicate warm temperate to subtropical climatic conditions persisting throughout the Late Eocene, with a climatic optimum in the middle 'Transitional Marl' (roughly late zone P15-early P16), and less warm conditions in the Gull Rock and 'Soft Marl' Members. Climatic minima seem to coincide with regressive events at the Tortachilla Limestone/Blanche Point Formation boundary (roughly middle zone P15) and at the Chinaman Gully Formation continental episode (roughly middle zone P16).

FIG. 17 Resumptive synopsis. Vertical distribution of: relative frequencies of Molluscan classes, genera and species; species and genera diversity indexes; epifaunal/infaunal Bivalvia ratios; frequency of Bivalvia valves; disarticulation ratios in Bivalvia.


FORMATIONS
SAMPLES
Bivalvia
Gastropoda
Scaphopoda
(%) all figures
Relative frequency of Molluscan Classes
Genera per Class / Total no Genera
Species per Class / Total no Species
Bivalvia (%)
infaunal
epifaunal
uncertain
Species diversity index (Simpson, 1949, in Reyment, 1971)
Genera diversity index (after Simpson, 1949)
Frequency of LV, RV, BV, vv in Bivalvia (%)
LV, left valves
RV, right valves
BV, articulated valves
vv, undetermined v.
Disarticulation indexes in Bivalvia
epifaunal
infaunal
Articulation ratio (Eagar, 1968)
Differential transport index (after Schäfer, 1972)
Uncertainty index
20 50 80
.20 .50 .80
.90 .95
.2 .5 .8
.2 .6 .10 .14 .18
.14 .35 .56
BLANCHE POINT FORM.
Soft Marls
Gull Rock M.
"Transitional Marl" M.
lacuna
TORTACHILLA LIMESTONE
SM NH
GR 33
Bryozoa
PT
TM 8
TM 7
TM 4
TM 2
TM 1
Pocket
TL 6
TL 5
TL 4
TL 3
TL 2
TL 1
barren
.3055
0.0
.530
barren
barren

CHAPTER 4

PALAEOBIOGEOGRAPHY OF THE AUSTRALIAN LATE EOCENE MOLLUSCA

Biogeographical studies are currently subjected to a two-fold revolution which is profoundly modifying once widely accepted theories on dispersal mechanisms and routes and on faunal relationships. The initial advance was induced by the general acceptance of the theory of plate tectonics. The second advance resulted from increased studies and information on the biology of the marine invertebrate larvae and their role in dispersal (Thorson, 1946-1971; Scheltema 1967-1977; Mileikowsky, 1966-1968a,b; Ockelmann, 1965; Thiede, 1974-1975; Radwin & Chamberlain, 1973), and from the possible application of these studies to palaeobiogeography (Scheltema, 1977,in press). Since the approach to the present discussion is heavily based on the latter series of studies, a brief synthesis of the most significant facets of larval biology and dispersal in marine mollusca seems necessary.

LARVAL BIOLOGY IN MOLLUSCA

As are most marine invertebrates, molluscs are characterized by both pelagic and non-pelagic larval development (Thorson, 1946, 1950; Scheltema, 1971,etc; Radwin and Chamberlain, 1973). Thus the Archaeogastropoda display both kinds of larval development in equal measure, whereas the former mode prevails in the Mesogastropoda and Toxoglossa, and the latter in the Stenoglossa (Radwin & Chamberlain, 1973).

As a general rule, either larval mode does not appear to characterize particular genera or families. Thus the Muricidae display genera with both non-pelagic and pelagic larvae (Radwin & Chamberlain, 1973; Scheltema, 1971a,b) and Polinices Montfort has species with one or the other larval mode (Thorson, 1950, p.33).

The two types of development may even occur in different populations of the same species (hitherto only three cases are known; see Thorson, 1950, p.10). Finally, the occasional formation of twin embryos in eggs of normally non-pelagic larvae may cause the development of pelagic larvae within the same species (Thorson, 1950).

On the other hand ,the Opisthobranchia and Bivalvia seem to be more selective and are characterized by one or other of the two larval types, but not both together (Thorson, 1950).

The larval mode is genetically controlled by the kind of larval development and is strictly related to the nature of the eggs produced by marine invertebrates (Thorson, 1950). Large sized eggs with large yolks produce large, clumsy larvae, unfit for active locomotion. These larvae, which are called lecithotrophic, are often carried almost passively by the currents and feed exclusively on their own egg yolk. Their planktonic life can be either very short (non-pelagic) or very long (pelagic) (Thorson, 1950). Small sized eggs with very poor yolk produce larvae which usually have a long pelagic life, and are able to swim actively in order to feed on phytoplankton (planktotrophic larvae).

The lecithotrophic larvae, which have a long life-span,can be spread by the action of currents over great distances. Because of their independence from plankton as a source of food, they have a better chance of reaching the stage of metamorphosis than planktotrophic larvae. However, because of their large size they are disadvantaged by the much smaller number of eggs produced per individual and by the consequent inability of the rather small stock of larvae to increase their species populations during periods of bountiful food. These factors reduce the chances of success in long distance dispersal. In contrast, ephemeral lecithotrophic larvae tend to remain in established optimal environments where they are protected by a large food supply and parental brooding (Radwin & Chamberlain, 1973).

The planktotrophic larvae have some advantages with respect to dispersal in comparison to lecithotrophic larvae. An enormous number of eggs is produced per individual (more than 500,000 in some species);

phototropy and active swimming increase their chances of capture by shoreline drifts and oceanic currents. The disadvantages are their higher food requirements, dependence on food availability in the plankton, lack of protection against predators, and high larval mortality rates during periods of food scarcity. The duration of their pelagic life is positively related to water temperature.

DURATION OF LARVAL LIFE IN MOLLUSCA

Pelagic larvae, either lecithotrophic or planktotrophic, have a variable life span from the time of spawning to settlement. Opisthobranchia and Bivalvia, for instance, settle within 1 to 5 weeks, although cases of up to 13 weeks are known (Thorson, 1961; Scheltema, 1971a,b). On the other hand, Prosobranchia generally show longer larval stages and many of their families are characterized by larvae with a life-span of 7 to 26 weeks, with a recorded maximum of 46 weeks for Cymatium partenopeum (Von Salis) (Scheltema, 1972). However, in the absence of a suitable habitat where postlarval survival is possible, their normal lifespan can be further prolonged and their settlement delayed (Scheltema, 1968). The duration of this 'delay period' varies with the time of discovery of favourable conditions and the resistance of the species. The maximum 'delay period' recorded is 138 days (ca. 20 weeks) for C. partenopeum, (Scheltema, 1967, 1971b). Although this is one of the few records available, and may very well represent an extreme case, data from pelagic groups other than Mollusca indicate that very long-lived larvae are moderately frequent among marine invertebrates, in which 'delays' of 8, 12 and over 52 weeks have been recorded (Scheltema, 1971b).

Therefore, there are strong indications that the 'delay' factor cannot be excluded in estimating the ability or probability of dispersal in Mollusca. (For the causes thought to control the 'delay period', the reader is referred to: Thorson, 1966; Scheltema, 1967, 1971b, 1974;

Doyle, 1975.)

CORRELATION OF LARVAL DISPERSAL, CURRENTS AND GEOGRAPHICAL DISTRIBUTION

Scheltema (1968a,b, 1972, 1975a,b) showed that in the North and Equatorial Atlantic Ocean, pelagic larvae of marine invertebrates are normally dispersed by both shoreline and oceanic currents. In particular, he indicated the following.

A) Long-lived and far-wandering larvae may successfully colonize both sides of the Atlantic shelves.

B) On the basis of a study of 5 gastropod species, a remarkably direct correspondence has been shown between the estimated frequency of larval dispersal and the degree of morphological similarity of Eastern and Western Atlantic populations. Adults of species estimated to have a high frequency of larval dispersal show little or no differences between the eastern and western Atlantic populations. Conversely, species having a restricted larval dispersal usually are represented by different subspecies on either side of the Atlantic.

C) There is a positive correlation between larval dispersal by current and the geographical distribution of marine invertebrates.

The frequency of long distance dispersal across oceanic basins chiefly depends upon:

A) the'drift coefficient', which is the probability that larvae will be carried off-shore into the major ocean surface currents rather than retained in the coastal waters of the parent populations;

B) the size of the area of origin of the larvae and its expansion by shore-line drift dispersal;

C) size of the parent population of the larvae;

D) the density of populations of the same species in the area of origin;

E) the fecundity of the parent population (also Thorson, 1950);

F) the larval mortality rate;

G) the maximum duration of pelagic larval life as represented by the sum of the 'development' and 'delay periods';

H) and the larval tolerance to temperature ranges where eurythermality is a positive and stenothermality a negative factor for long range dispersal.

PALAEOBIOGEOGRAPHIC RELATIONSHIPS OF THE AUSTRALIAN LATE EOCENE MOLLUSCA

As the Australian Cainozoic Mollusca are poorly known, their biogeographical relationships and their origin are still uncertain.

Although scarcely studied non-marine Mollusca biogeography is perhaps best known through the works of Climo (1974), Iredale and McMichael (1959), McMichael (1967) and Solem (1959). Buonaiuto (in prep.) will shortly present a further contribution on their Cainozoic palaeobiogeography as linked with the plate tectonic history of Australia.

Marine molluscan biogeography has been directly dealt with only in the papers of Ludbrook (1954, 1969, 1971a) and to a lesser extent, in those of Darragh (1973) and Vokes (1974). Ludbrook (1954) remains the major reference.

However, indirect information pertinent to Australian molluscan palaeobiogeography can be gathered from the South American (Ihering, 1907; Ortmann, 1902) and from the New Zealand literature (Fleming, 1944, 1952, 1953, 1963, 1967, 1975, 1978; Beu, 1966). On the living forms, Knox (1960, 1963), Powell (1951), Dell (1958) and Iredale & Allen (1940) supply additional scanty information. Among these papers, Fleming's works are distinguished for their thoroughness and for the introduction of the concepts of marine molluscan immigations and their link with climatic optima.

Approach and limitations of the present discussion

On the basis of Ludbrook's 1954 observations on Pliocene Mollusca and the author's previous work on the Oligocene Tethyan Mollusca (Buonaiuto, 1971) and comparative observations carried out on the rather large collection of Palaeogene Anglo-Paris Basin Mollusca kept in the Geology Department of Adelaide University, it was often noted that a strong affinity existed between the Australian Late Eocene Mollusca and the Eocene faunas of the Anglo-Paris Basin. Further comparison with illustrations and less frequently with specimens revealed a remarkable relationship between numerous species from South America, North America and New Zealand. On the basis of these preliminary observations and the ideas of Fleming, Thorson and Scheltema, an attempt has been made to determine possible palaeodispersal routes from the main centres of origin of immigrant faunas and also to ascertain the degree of endemism amongst the local Late Eocene Molluscan faunas. This discussion is restricted to the taxa recorded in the southern Australian Late Eocene. They embrace those described in this study and those listed in Ludbrook (1973). The aim is to individuate possible trends such as endemism, dispersal patterns and mechanisms operating at that time which might have been obscured by possible overlapping of younger faunistic events.

An attempt has also been made to note the generic distribution and the oldest records of the species referable to the taxa occurring in the Late Australian Eocene, in the Boreal, Tethyan, Patagonian, Nigerian Coastal, and New Zealand Basins. To this end, the following works and check-lists were analyzed:

Boreal Basins: Glibert (1973), Glibert & Van der Poel (1973), Van Winkle Palmer (1937), Van Winkle Palmer & Brann (1965-66), (Palaeocene-Eocene);

Central & Western Tethyan Basins: Bellardi & Sacco (1772-1904) (Eocene -Oligocene-Neogene);

Paratethys: Baldi (1973) (Oligocene);

Eastern Tethys: Eames (1951, 1952), Cossmann & Pissarro (1908-1927); Vredenburg (1938), Douvillé (1928, 1929); Cox (1930) (Palaeocene-Eocene); Western Pacific: Oyama, Mizuno & Sakamoto (1960) (Palaeocene-Oligocene); Nigerian Coastal Basin: Adegoke (1972,1977), Eames (1957) (Palaeocene-Eocene);

Peruvian basins: Olsson (1928, 1930, 1929) (Eocene);

Patagonian basins: Ihering (1907), Feruglio (1949), Ortman (1902), (?Palaeocene-Miocene-stratigraphy not precisely defined);

New Zealand basins: Fleming (1966, 1967), Maxwell (1969).

The data from these lists are integrated with the information from the general works by Wenz (1938-44); Zilch (1959); Glibert (1960-63), Glibert & Van der Poel (1965-70); Ludbrook (1960); Brookes, Knight, Cox, Keen *et al.*, (*in* Moore, 1960); Cox, Newell *et al.* (*in* Moore, 1969); Stenzel (1971), Cossmann (1896-1925, *cum granu salis*); Schilder & Schilder (1971); and Eames & Savage (1975). Notwithstanding the numerous works consulted, it is here acknowledged that the following limitations might bias the present discussion. Knowledge of the Palaeogene mollusca of the linking zones of Patagonia, Indonesia, and Papua New Guinea is very scanty. K. Martin's 1914 work on the Java fossil Mollusca mainly describes Oligocene forms with strong 'Tongrian' affinities and therefore it can be considered of doubtful value to this discussion. As for the Australian Palaeogene faunas, the Palaeocene to Middle Eocene assemblages are practically undescribed. The Palaeocene ones are currently under study by T.A. Darragh, National Museum of Victoria. About half of the Australian Late Eocene Mollusca remain largely unknown, the estimated minimum number of species still to be studied probably ranging from 100 to 200.

COMPOSITION OF THE SOUTHERN AUSTRALIAN LATE EOCENE MOLLUSCA ACCORDING TO THEIR SUPRASPECIFIC AFFINITIES

The 169 Molluscan taxa, genera, subgenera and discrete species-groups recorded in the Australian Late Eocene have been divided into 7

Proto-Atlantic Dispersal	Eastern Tethys Indomalayan Dispersal	Cosmopolitan	Australia (Endemic)	Australasian (New Zealand & Australia)	Amphinotic Dispersal	Doubtful Origin	Possible Dispersal
Saccella striata Group.	*Vulsella* s.str.	*Arca* s.str.	*Pronucula*	*Poroleda*	*Limopsis campa* Group.	*Ledella*	Atlantic
Pectunculina	*Dimya*	*Barbatia* s.str.	*Ludbrookella*	*Notogrammatodon*	*Phygraea tarda* Group.	? *Cardita*	?Tethyan-Indomalayan
Limarca	*Clavagella*	*Arcopsis* s.str.	*Allasinazella*	*Hedecardium*			
Pteria		*Crenella*	*Cosa*				
Lentipecten		*Ryenella*	*Trichomusculus*				
Ctenoides		*Glycymeris*	*Pinctada*				
Cuna		*Pinna*	*Monia*				
Caryocorbula		*Parvamussium*	*Isolimea*				
Cucullaea s.str.		*Chlamys*	*Divarilima*				
		Spondylus	*Eotrigonia*				
		Lima	*Salaputium*				
		Limatula	*Semelangulus*				
		Phygraea	*Dosina*				
		Pycnodonte	*Fossacallista*				
		Glans	*Myadora*				
		Hiatella					
		Cuspidaria					
		Pholadopsis					

TABLE IIB

ORIGINS AND AFFINITIES OF THE MOLLUSCAN TAXA RECORDED IN THE LATE EOCENE OF SOUTHERN AUSTRALIA

ProtoAtlantic Dispersal	Eastern Tethys Indomalayan	Cosmopolitan	Endemic	Australasian New Zealand & Australia	Amphinotic Dispersal	Doubtful Origin	Possible Dispersal
Periaulax	*Olivia*	*Acteon s. str.*	*Gadilina*	*Perotrochus*		*Scissurella s. str.*	*Atlantic*
Vexinia	*Praehyalocylis*	*Tornatellaea*	*Mikadotrochus*	*Spirocolpus*			"
Leucorhynchia		*Chemnitzia*	*Fautor*	*Tanea*		*Punctiscala*	"
?Elachorbis plicatella group		*Cirsotrema*	*Austroliotia*	*Semitriton*		*Ataxocerithium*	"
		Emarginula s.str.	*Cycloliotia*	*Austrosassia*		*Margineulima*	*Eastern Tethys*
Orbitestella		*Pseudomalaxis s. str.*	*Crosseola*	*Gracilispira*		*Cantharus*	*Indomalayan*
Sigmesalia			*Nobolira*	*Waimatea*		*Pachysyrnola*	*Atlantic*
Acrocoelum		*Polinices*	*Haurakia*	*Anapepta*			
Siliquaria striata group		*Cypraedia*	*Merelina*	*Rugobela*			
		Lunatia	*Pedumicra*	*Cylichnania*			
Anguillospira		*Amaurellina*	*Stephopoma*	*Triploca*			
Ogivia		*Fusinus*	*Jetwoodsia*				
Cerithioderma		*Antalis*	*Kosugeia*				
Atlanta			*Inella*				
Niso			*Isotriphora*				
Columbarium			*Viriola*				
Trophonopsis			*Granulotriforis*				
Laevityphis			*Sirius*				
Pterynotus			*Clypeola*				
Ptenochelus			*Calyptropsis*				
Murexul			*Nototrivia*				
Personella			*Willungia*				
Mitraria			*Ectosinum*				
Knefastia			*Cymatiella*				
Borsonia			*Ratifusus*				
Conorbis			*Trophon*				
Kleinacteon			*Gemistyxus*				
Tenuiacteon			*Siratus*				
Acteocina			*Enantimene*				
Cylichna			*Brocchitas*				
Bovicornu			*Tectifusus*				
Limacina			*Microcolus*				
Auristomia			*Austromitra*				
Turbonilla			*Austrolithes*				
Cossmannica			*Vexithara*				
Graphis			*Notopeplum*				
			Notovoluta				
			Ternivoluta				
			Inglisella				
			Cottonella				
			Alaginella				
			Conuginella				
			Marginella s.l.				
			Carinaginella				
			Plicaginella				
			Kaurnaginella				
			Comitas				
			Oamauria				
			Kaurnacteon				
			Decorifer				
			Siliquaria kaurna group				

TABLE III

AFFINITY	Bivalvia		Gastropoda		Scaphopoda		Total	
	No.	%	No.	%	No.	%	No.	%
ProtoAtlantic	9	17.3	34	29.6	-	-	43	25.4
Eastern Tethyan	3	5.8	2	1.7	-	-	5	3.0
Cosmopolitan	18	34.6	11	9.6	1	50	30	17.8
Australian	15	28.8	51	44.3	1	50	67	39.6
Australasian	3	5.8	11	9.6	-	-	14	8.3
Amphinotic	2	3.8	-	-	-	-	2	1.2
Doubtful origin	2	3.6	6	5.2	-	-	8	4.7
	52	99.7 (Δ = 0.3)	115	100	2	100	169	100.0

groups according to the occurrence of the oldest recorded species of the taxon. These groups are: Atlantic Boreal, which includes North American, Danish, and Anglo-Parisian Basins; Eastern Tethyan; Australasian, i.e. species common to Australian and New Zealand; Amphinotic, i.e. species restricted to Australia, New Zealand and Patagonia (Meier-Brook & B.S. Smith, 1976); Cosmopolitan; Australian (endemic) and a group of doubtful origin (Tables II, III). The percentage composition is synthesized in Table IV.

The Bivalvia are mainly represented by cosmopolitan elements (34.6%), endemic stocks (28.8%) and by a strong Atlantic Boreal component (17.3%). The Australasian (3%), amphinotic (2%) and Eastern Tethyan (2%) forms are relatively minor. On the other hand, the Gastropoda show a stronger endemic (44.3%) and an Atlantic Boreal (29.6%) component. The cosmopolitan groups (9.6%) are relatively less numerous than in the Bivalvia; The Eastern Tethyan elements are in minor presence (1.7%). Scaphopoda are represented by one cosmopolitan genus (Antalis) and one endemic genus (Gadilina).

The affinities of the endemic cerithiid Jetwoodsia Ludbrook deserve particular mention. This genus appears to belong to a group with homogeneous shell morphology and is represented by the North African Maastrichtian Libycerithium Checchia-Rispoli, the Nigerian Palaeocene Nigerithium Andegoke, the American Eocene Texmelanatria Palmer and the Peruvian Eocene Lagunitus Olsson. The callus and ornament suggest that the placement of Jetwoodsia is much closer to Lagunitus. Therefore, Jetwoodsia might represent the only known Australasian Late Eocene derivative of the old Cretaceous-Palaeocene Tethyan faunas, which might have migrated from the Peruvian region (see further discussion, pp. 87-88).

POSSIBLE EARLY PALAEOGENE MOLLUSCAN DISPERSAL ROUTES

According to the study of current palaeogeographic reconstructions of seas and oceans (Berggren & Hollister, 1974, 1977; Azzaroli & Cita, 1967; Edwards, 1975) the following dispersal routes may have been open to marine

FIG. 18 Approximate world distribution of marine Tertiary sediments (from C.G. Adams, 1973, after Papp, 1959).

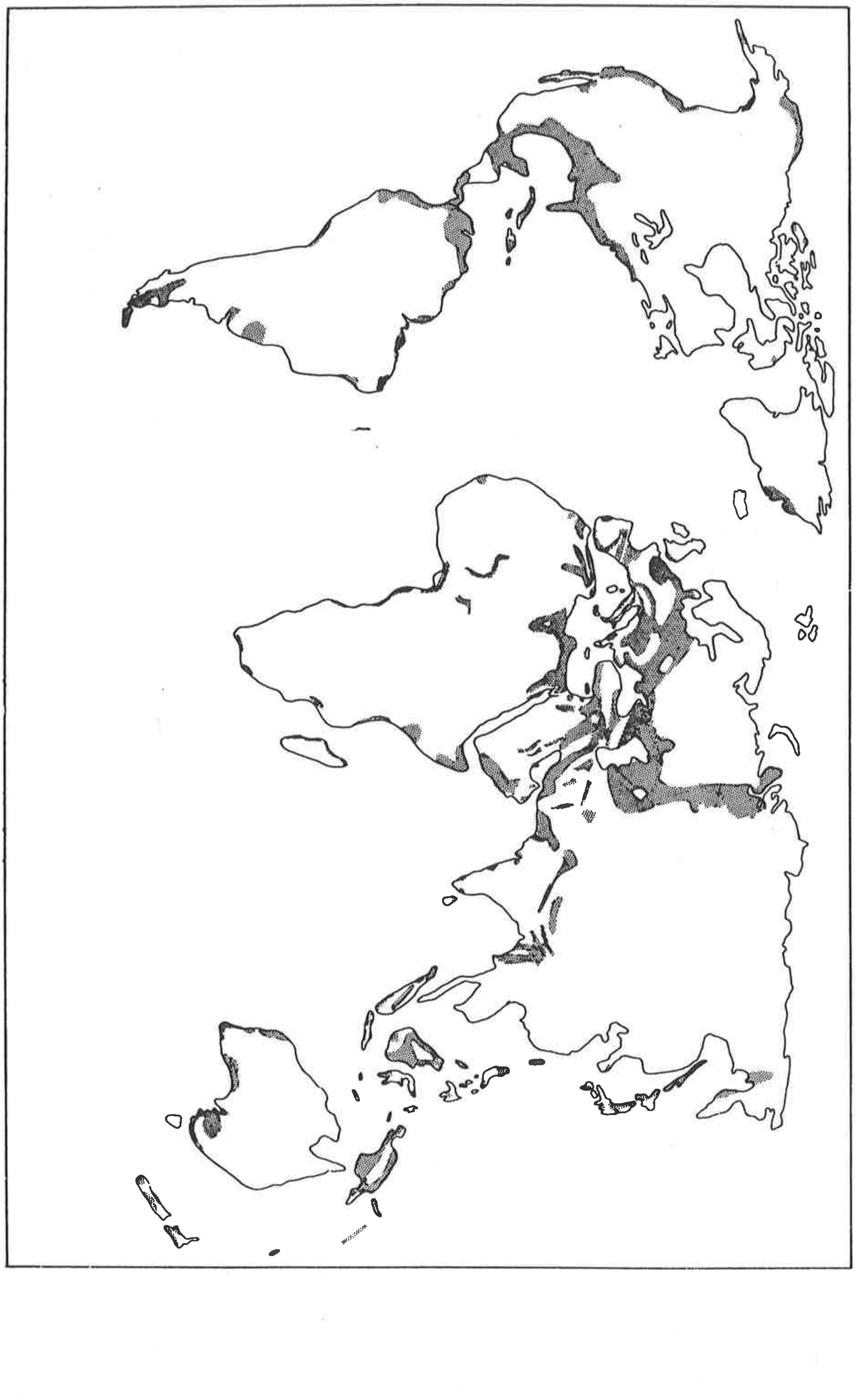


FIG. 19 Plate tectonic reconstruction and main surface circulation in the Late Eocene (after Newell, 1972; Kimura, 1974; Stoneley, 1974; Berggren & Hollister, 1974,1977; Davies & Kidd, 1975; Moberly, 1972; Barker, Dalziel, et al., 1976; Craddock & Hollister, 1976; Edwards, 1975; Deighton et al., 1976; McGowran, 1977, 1978a,b,c; Sclater & Fisher, 1974; McKenzie & Sclater, 1971; Sigal, 1974, etc.)

FIG. 20 Late Eocene Molluscan dispersals.

BARRIERS

// Bidirectional

E, Ekman Barrier

D, Drake Passage (intermittent ?, shallow water connections?)

S, Scotia Islands (intermittent ?, shallow water connections?)

T, South Tasman Rise (intermittent, shallow water connection)

W, Marine analogue of the Wallace Line

// // Undirectional (E---W)

P, Panama

G, Gibraltar

⋮ C, Climatic barriers, temperate/subtropical convergence? (after Tedford, 1974).

DISPERSALS

——→ Main Routes

T, Tethyan

AB, Atlantic Boreal (Eastern Pacific leg after Hickman, 1976)

AN, Amphinotic

AS, Australasian

NP, North Pacific (after Hickman, 1976).

- - - - - Occasional Routes

ET, East Tethyan

IM, IndoMalayan

J, probable route of the Jetwoodsia stock.


60
?
30
P
0
G
?
?
?
?
?
60
30
0
30
?
30
?
60
D
S
T
60


NP
60
?
30
AB
AB
AB
AB
G
T
?
?
?
T
?
ET ?
P
0
T
T
E
?
?
?
IM
?
W
E
0
60
NP
?
30
AB
?
30
?
?
?
J
60
D
S
J
C
AB, AN
?
C
T
AS
60

Mollusca during the Early Palaeogene: ProtoAtlantic-ProtoSouthern Ocean; ProtoAtlantic-Central and Eastern Tethys-IndoMalayan ProtoArchipelagoes; ProtoNorth Atlantic-ProtoPacific (Figs. 18-20).

ProtoAtlantic-Central-Eastern Tethys-IndoMalayan Route

Although it should have been quite practical for shallow water organisms to follow this route, its utilization in the Early Paleogene for migration to the Australasian region seems to have been open to only a very few forms, such as the tropical Vulsella and Dimya and the eurythermal Olivia, Praehyalocylis, and Clavagella. The Late Eocene Australian fauna seems to bear very little resemblance to the Early Palaeogene forms of the Eastern Tethys. Several factors might have contributed to this lack of affinity:

A) Stenothermality of the precinctive Tethyan fauna, due to the long-time stability of the Tethyan Ocean in the tropical belt (Kauffman, 1973; Berggren & Hollister, 1974) as is also indicated by the distribution of its faunas (Cox, 1930; Andegoke, 1977);

B) a western barrier represented by the Proto-Gibraltar Strait, which allowed only an East-West flow of surface currents from the Central Tethys and deflected any deep current back to the Atlantic (Berggren & Hollister, 1974);

C) the possible existence from the Jurassic to the Late Oligocene of a north tropical to south temperate climatic boundary between the Eastern Tethys and the Southern Pacific (Kauffman, 1973) and therefore the restriction of climate-controlled migration;

D) the possible Jurassic to Late Oligocene isolation of the Australian and Eastern Tethyan regions by oceanic barriers (Kauffman, 1973), such as the extension of the Equatorial Counter and South Equatorial Currents into th Proto-Indian Ocean, as suggested by Edwards (1975) and Kennett et al.(197

E) and the existence of an Early Palaeogene East-West faunal dispersal trend which is inidcated by the appearance of few Eastern Tethyan Palaeocene genera during the Early and Middle Eocene in the Anglo-Paris Basin (Cox, 1930).

The latter is probably due to the East-West flow of the main Tethyan current (Berggren & Hollister, 1974, 1977) and the Pacific Equatorial Counter and South Equatorial currents. The combination of current patterns and a climatic barrier might thus have inhibited faunistic exchanges between the Eastern Tethys and the Australian region. However, as indicated by the arrivals of warm Tethyan genera (e.g. Siliquaria obtusa Group, Conidae) in the Late Oligocene, this barrier seems to have ceased only then to operate when the barrier raised by the collision between the Australian and the Asian plates might have broken the Equatorial Counter and the Southern Equatorial Currents into the present Indian and Pacific ones (Edwards, 1975; Audley-Charles & Carter, 1972; Moberley, 1972; Carter, et al., 1976; Davies & Kidd, 1977; Kennett et al., 1974). In addition, the arrival of the Australian continent in the tropical-subtropical belt may have forced a southward migration of the tropical temperate climatic boundary (today's Subtropical -Temperate convergence?).

North ProtoAtlantic-Pacific Route

An East-West dispersal by this route appears to have been inhibited at least throughout the Cainozoic by the 'East Pacific Barrier' (Ekman, 1953; Emerson, 1967). This barrier is constituted by a 4,800 km stretch of deep waters in the tropical belt of the Pacific Ocean, which is unsuitable for settlement of shallow water marine invertebrates. This barrier would, however, be effective only for the dispersal of stenothermal and/or short lived larvae, but not for eurythermal long lived ones. The other contributing mechanism to the effectiveness of this barrier might have been the counter-clockwise circulation system in the Pacific, but only if it were to have remained constant throughout the Cainozoic. This system results in a West-East dispersal in both the southern and the northern gyres (Kay, 1967).

On the other hand, the relationships of Jetwoodsia Ludbrook with the

Peruvian Lagunitus Olsson suggest the possibility of occasional faunistic exchanges through the Magellan Strait region during periods of optimal climatic and transgressive events, as is inferred by Foster (1974) and Berggren & Hollister (1974,1977). Shoreline drift and gradual southward colonization might have played a major role in the South American leg of this dispersal, the South Pacific gyre being an obstacle to any North-South dispersal on a large scale. A subtropical temperate climatic barrier may have acted as a further possible inhibiting mechanism as is inferred by Tedford (1974).

North-South ProtoAtlantic-ProtoSouthern Ocean Route

This route seems to have been most probable for the dispersal of the boreal and subtropical Atlantic Mollusca. From Berggren & Hollister's 1974 and 1977 palaeogeographic reconstructions, the main currents in the Atlantic seem to have remained basically similar in pattern throughout the Cainozoic, aside from the Late Neogene-Quaternary periodical breakup of the Tethyan Current into a Pacific and an Atlantic gyre. Hence, it is plausible to assume that the present larval distribution and dispersal in the Atlantic (Scheltema, 1971a,b) may be similar to those of the Cainozoic. Therefore, it may be supposed that the northern gyre probably allowed a trans-oceanic faunal exchange between the eastern and the western, North and Central Atlantic, which was much more intensive than today, because of the better climatic conditions and the shorter distances larvae had to cover. This is suggested by the amphi-atlantic distribution of many molluscan genera in the Palaeogene (Van Winkle Palmer, 1963,1967; Adegoke, 1977; Berggren & Hollister, 1974). The Equatorial Counter Current and the southern gyre may have been responsible for the faunistic exchange in the South Atlantic, which may have, for instance, provoked the replacement of the old Tethyan Palaeocene forms with faunas closely related to the North Atlantic ones (compare Adegoke, 1977 with Eames, 1957). The southern gyre, and in particular, the Proto-Brazil current may have been the principal carriers of larvae into the ProtoSouthern Ocean. The final leg of this route may have been represented by the Atlantic-Indian branch of a warmer Proto-Westwind Drift, or at least by a warmer northern branch of it.

The likelihood of this route is also supported by the Central American affinities of the Eocene New Zealand Corals (Squires, 1956) by the Atlantic Boreal and Central American relationships of the Australian and New Zealand Palaeocene-Eocene Decapod Crustacea (Glaessner, 1960; Jenkins, 1972) and by the Central American affinities of the Middle and Late Eocene New Zealand foraminifera (Hornibrook, 1953). Affinities between the Anglo-Parisian Basin dinoflagellates and those from southern Australia (W.K. Harris, 1978, pers. comm.) also tend to support this dispersal route,as well as the massive temperate to subtropical North Atlantic component in the Late Eocene Australian and Middle-Late Eocene New Zealand Mollusca (this study; Ludbrook, 1954; Fleming, 1953; Maxwell, 1968).

Should the present situation reflect that of the past,it does appear that during the Cainozoic there was no significant barrier between the North and South Atlantic gyre, except perhaps a climatic one for stenothermal forms (see Van Winkle Palmer, 1974, 1967). On the other hand, it seems that a climate-controlled temperate-subtropical barrier was operating between South America and Atlantic Antarctica as suggested by Tedford (1974) and by Berggren & Hollister (1974).

The route under discussion seems to have been reactivated successively during the Late Oligocene-Early Miocene and Middle Miocene climatic optima (Ludbrook, 1969; Vokes, 1974). During climatic cold fluctuations only the southern leg, South America to Antarctica, seems to have remained open and only for 'cold guests' i.e. organisms with some pre-adaptation for cold seas (e.g. marsupiate echinoids, Philip & Foster, 1971; penguins, Jenkins, 1974; living trochids and other gastropods, see Powell, 1951).

Cretaceous-Palaeocene	Middle Eocene	Middle-Late Eocene (late P14 - P15)	Late Eocene (P16)	Early Oligocene	Middle Oligocene	Late Oligocene	Early Miocene	Middle Miocene	Late Miocene	Early Pliocene	Late Pliocene to Holocene	Never recorded	Never recorded	Never recorded
Cucullaea*	*Limopsis zitteli group*$^{\#}$	*Notogrammatodon*^{o}	*Olivia**	*Pinna*		*Dosina s. str.*	*Ledella*	*Promucula*		*Cosa*		*Ludbrookella*	*Inella*	*Carinaginealla*
Pectunculina^{o}	*Poroleda*^{o}	*Arcopsis*^{o}		*Monia*		*Salaputium*	*Arca s. str.*	*Stephopoma*		*Ctenoides*		*Allasinazella*	*Isotriphora*	*Kaurnaginella*
Chlamys^{o}	*Saccella*^{o}	*Glycymeris**		*Lima*		*Fossacallista*	*Barbatia s. str.*			*Trophon*		*Limarca*	*Viriola*	*Knefastia*
Phygraea^{o}	*Cirsotrema*^{o}	*Parvamussium**		*Cuspidaria*		*Myadora*	*Pteria*					*Crenella*	*Ogivia*	*Conorbis*
Hedecardium^{o}	*Niso*^{o}	*Lentipecten**				*Nobolira*	*Spondylus*				*Ryenella*	*Trichomusculus*	*Punctiscala*	*Kleinacteon*
Caryocorbula^{o}	*Semitriton*^{o}	*Dimya**				*?Elachorbis plicatella gp.*	*Cuna*				*Divarilima*	*Pinctada*	*Sirius*	*Kaurnacteon*
Polinices^{o}	*Austrosassia*^{o}	*Limatula**				*Cerithioderma*	*Cardita*				*Granulotriforis*	*Vulsella*	*Calyptropsis*	*Triploca*
Lunatia^{o}	*Waimatea*^{o}	*Spirocolpus**				*Atazocerithium*	*Hiatella*				*Clypeola*	*Isolimea*	*Nototrivia*	*Tenuiacteon*
Gracilispira^{o}	*Anapepta*^{o}	*Pseudomalaxis*^{o}				*Willungia*	*Scissurella*				*Cominella s.str.*	*Pycnodonte*	*Cypraedia*	*Acteocina*
Rugobela^{o}	*Borsonia*^{o}	*Tanea*^{o}				*Cymatiella*	*Emarginula*					*Eotrigonia*	*Marginulima*	*Cylichna*
Acteon^{o} *s.str.*	*Turbonilla*^{o}	*Fusinus*^{o}				*Pterochelus*	*Fautor*					*?Paraglans*	*Amaurellina*	*Decorifer*
Tornatellaea^{o}		*Persoonella*^{o}				*Verithara*	*Crosseola*					*?Glans*	*Ratifusus*	*Bovicornu*
Cylichnania^{o}		*Praehyalocylis*				*Inglisella*	*Haurakia*					*Semelangulus*	*Columbarium*	*Pachysyrnola*
		Triploca^{o}				*Alaginella*	*Merelina*					*Pholadopsis*	*Gemistyrus*	*Auristomia*
						Comitas	*Sigmesalia*					*Clavagella*	*Enantimene*	*Cossmannica*
						Oamaruia	*Archierato*					*?Antalis*	*Trophonopsis*	*?Contrainea*
						Limacina	*Ectosinum*					*Gadilina*	*Laevityphis*	
						Chemnitzia	*Pterynotus*					*Mikadotrochus*	*Brocchitas*	
							Murexul					*Periaulax*	*Tectifus*	
							Austromitra					*Basilissa*	*Cantharus*	
							Graphis					*Austroliotia*	*Microcolus*	
												Cycloliotia	*Notopeplum*	
												Vexinia	*Carinaginella*	
												Leucorhynchia	*Notovoluta*	
												Pedumicra	*Ternivoluta*	
												Acrocoelum	*Mitraria*	
												?Siliquaria striata group	*Cottonella*	
												Anguillospira	*Conuginella*	
												Jetwoodsia		
												Kosugeia		

Cretaceous - Late Eocene records in comparison with Australia -

^{o} earlier
* coeval
$^{\#}$ later

TABLE IV

FIRST RECORD IN NEWZEALAND OF THE TAXA PRESENT IN THE AUSTRALIAN LATE EOCENE

TABLE V

New Zealand Earliest Record	Bivalvia		Gastropoda		Scaphopoda		Mollusca	
	No. taxa	%	No. taxa	%	No. taxa	%	No. taxa	%
Cretaceous-Palaeocene	6	11.5	7	6.1			13	7.7
Middle Eocene	3	5.8	8	7.0			11	6.5
Middle/Late Eocene	7	13.5	6	5.2			13	7.7
Late Eocene (P16-17)	-	-	1	.9			1	0.6
E. Oligocene	4	7.7	-	-			4	2.4
Middle Eocene	-	-	-	-			-	-
Late Oligocene	4	7.7	14	12.71			18	10.7
Early Miocene	8	15.4	14	12.71			22	13.0
Middle Miocene	1	1.9	1	.9			2	1.2
Late Miocene	-	-	-	-			-	-
Early Pliocene	2	3.8	1	.9			3	1.8
Late Pliocene/Holocene	2	3.8	3	2.6			5	3.0
Never recorded	15	28.8	60	52.17	2	100	77	45.6
	52	99.9	115	101.2	2	100	169	100.2

Frequency of first arrivals in New Zealand of the taxa present in the Australian Late Eocene.

RELATIONSHIPS BETWEEN AUSTRALIAN AND NEW ZEALAND MOLLUSCA, AS SUGGESTED BY THE AUSTRALIAN LATE EOCENE MOLLUSCA

Tables V and VI offer indications suggestive of the relationships between Australian and New Zealand faunas. Because of the proximity of these two bioprovinces the existence of a two-way dispersal route is not surprising. However, the opening and closing of this route and its polarity in the Palaeogene seems to have been controlled by different factors before and after the opening of the Southern Ocean and the beginning of the Circum-Antarctic Current. Notwithstanding the present lack of information on the Palaeocene to Middle Eocene Australian Mollusca, there are some indications of faunal exchange between the two provinces during this time. With respect to the Australasian precinctive groups, it appears that in the Early Palaeogene there was a marked immigration of New Zealand elements to Australia. The following forms present in the Southern Australian Late Eocene have earlier records in New Zealand: *Phygraea*, *Hedecardium*, *Gracilispira*, *Rugobela*, *Cylichnania* (Palaeocene); *Poroleda*, *Semitriton*, *Austrosassia*, *Waimatea*, *Anapepta* (Middle Eocene); *Notogrammatodon*, *Spirocolpus*, *Tanea*, *Triploca* (Kaiatan Middle Late Eocene Zones P14-15, McGowran, 1978a). To this group can be added *Pseudomalaxis asculpturatus* Maxwell, which is initially recorded in New Zealand during foraminiferal Zones P14-15, and appeared in southern Australia not earlier than middle P16.

The dispersal route probably passed south of Tasmania, where a shallow marine connection was established between the South West Pacific and the South East Indian Ocean across the South Tasman rise during the Late Eocene (Kennett *et al.*, 1974).

The assumption of an opening of this marine connection during the Late Eocene finds support in the widespread shallow bathyal episodes in the Eucla, St. Vincent and Otway Basins, as is suggested by the acmes of *Phygraea tarda* (Hutton) and by the subsequent appearance in the St.

Vincent Basin of Middle/Late Eocene immigrants such as P. asculpturatus and Notogrammatodon inexpectatus. From the time distribution of Eocene and post-Eocene first arrivals in New Zealand, the activation of the dispersal route was probably connected with the coincidence of periods of maximum regional transgression and of climatic optima (McGowran 1978a,b; this study). After the establishment of the Circum-Antarctic current from the Late Oligocene to Early Miocene onward (Kennett et al., 1974) the re-opening of the route probably depended on climatic factors only. In particular, climatic fluctuations and the establishment of the circum-Antarctic Current probably initiated the subtropical temperate and/or temperate subantarctic convergences near New Zealand (Edwards, 1975, figs. 5-6). These probably acted as barriers fluctuating with climate. Thus, during the general climatic optimum of the Late Oligocene to Early Miocene, New Zealand was north of the subtropical convergence (Edwards, 1975), and this event is linked with the highest rate of first arrivals from Australia (Tab. 5,7), Eastern Tethys, and the Indo-pacific (Fleming, 1952, 1957, 1967 and 1975).

LATE EOCENE MOLLUSCA AND POST-EOCENE DISPERSAL PATTERNS

The term 'endemic' is used here to encompass all the taxa hitherto only known or recorded in Australia until the Late Eocene. From Table IV it appears that in the Late Eocene the Molluscan faunas were characterized by a very high endemic component (36.6% of the total Molluscan taxa; 28.8% of the Bivalvia; 44.3% of the Gastropoda; and the Scaphopod Gadilina). Such a high degree of endemism may have been caused by geographical and climatic isolating mechanisms already operating in the Cretaceous, which repeatedly made Australia an endemic centre (Kauffman, 1973). The Late Eocene endemic forms probably arose from endemic ancestors which evolved in the Late Cretaceous (Kauffman, 1973) or from a younger, but earlier than Middle Eocene wave of forms which may originally have migrated from the Atlantic.

The post-Eocene geographical distribution of the Late Eocene

TABLE VI

POST EOCENE DISPERSAL OF LATE EOCENE AUSTRALIAN ENDEMIC TAXA

Endemic	New Zealand	Eastern Tethys & Pacific	Atlantic	Amphinoti
Ludbrookella	*Pronucula*	*Pinctada*	*Monia*	
Allasinazella	*Cosa*	*Salaputium*	*Stephopoma*	
Trichomusculus	*Divarilima*	*Semelangulus*		
Isolimea	*Salaputium*	*Myadora*		
Eotrigonia	*Dosina*	*Gadilina*		
Austroliotia	*Myadora*	*Mikadotrochus*		
Pedumicra	*Fossacallista*	*Crosseola*		
Jetwoodsia	*Fautor*	*E.harriettae group*		
Kosugeia	*Nobolira*	*Orbitestella*		
Isotriphora	*Haurakia*	*Inella*		
Sirius	*Orbitestella*	*Viriola*		
Nototrivia	*E.harriettae group*	*Granulotriforis*		
Ratifusus	*Stephopoma*	*Calyptropsis*		
Gemistyxus	*Clypeola*	*Cymatiella*		
Enantimene	*Archierato*	*Trophon*		
Brocchitas	*Willungia*	*Columbarium*		
Tectifusus	*Ectosinum*	*Siratus*		
Microcolus	*Austromitra*			
Austrolithes	*Vexithara*			
Notopeplum	*Notovoluta*			
Ternivoluta	*Anapepta*			
Cottonella	*Inglisella*			
Conuginella	*Alaginella*			
Marginella s.l.	*Comitas*			
Plicaginella	*Oamauria*			
Kaurnaginella	*Granulotriforis*			
Kaurnacteon	*Calyptropsis*			
	Trophon			

TABLE VII

POST-EOCENE DISPERSAL OF THE SOUTHERN AUSTRALIAN LATE EOCENE ENDEMIC TAXA

(Total percentages exceeding 100% are due to the presence of the same taxon in different dispersals)

Dispersal	Bivalvia		Gastropoda		Scaphopoda		Total	
	15 taxa	%	50 taxa	%	1 taxon	%	66 taxa	%
Endemic Australian	5	33.3	22	44.0	-		27	40.5
New Zealand	7	46.7	17	34.0	-		24	36.4
Amphinotic	-	-	-	-	-		-	-
Eastern Tethys & Pacific	4	26.7	10	20.0	1	100	15	22.7
Atlantic	1	6.7	1	2.0	-		2	3.0

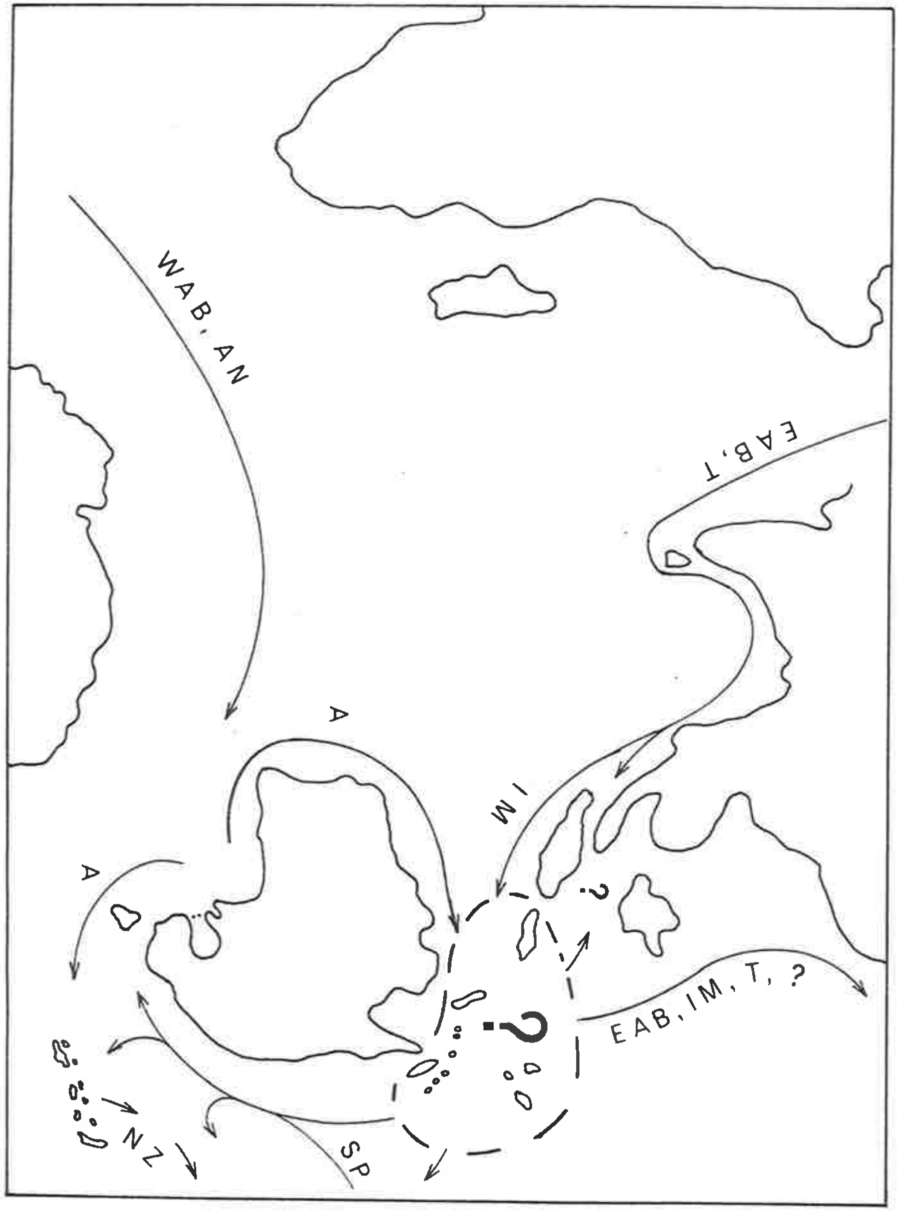
FIG. 21 Late Oligocene/Early Miocene Surface paleocirculation patterns in the Indian, Antarctic, and Southwest Pacific Oceans (Winter situations). Plate tectonic reconstruction after: Edwards, 1975; Stoneley, 1974; Kennett et al., 1975; Moberley, 1972. Extrapolation and interpretation of the paleocirculation patterns based on the present ones and on the interpretations by: Berggren & Hollister, 1974 and 1977; Davies & Kidd, 1977; Edwards, 1975.

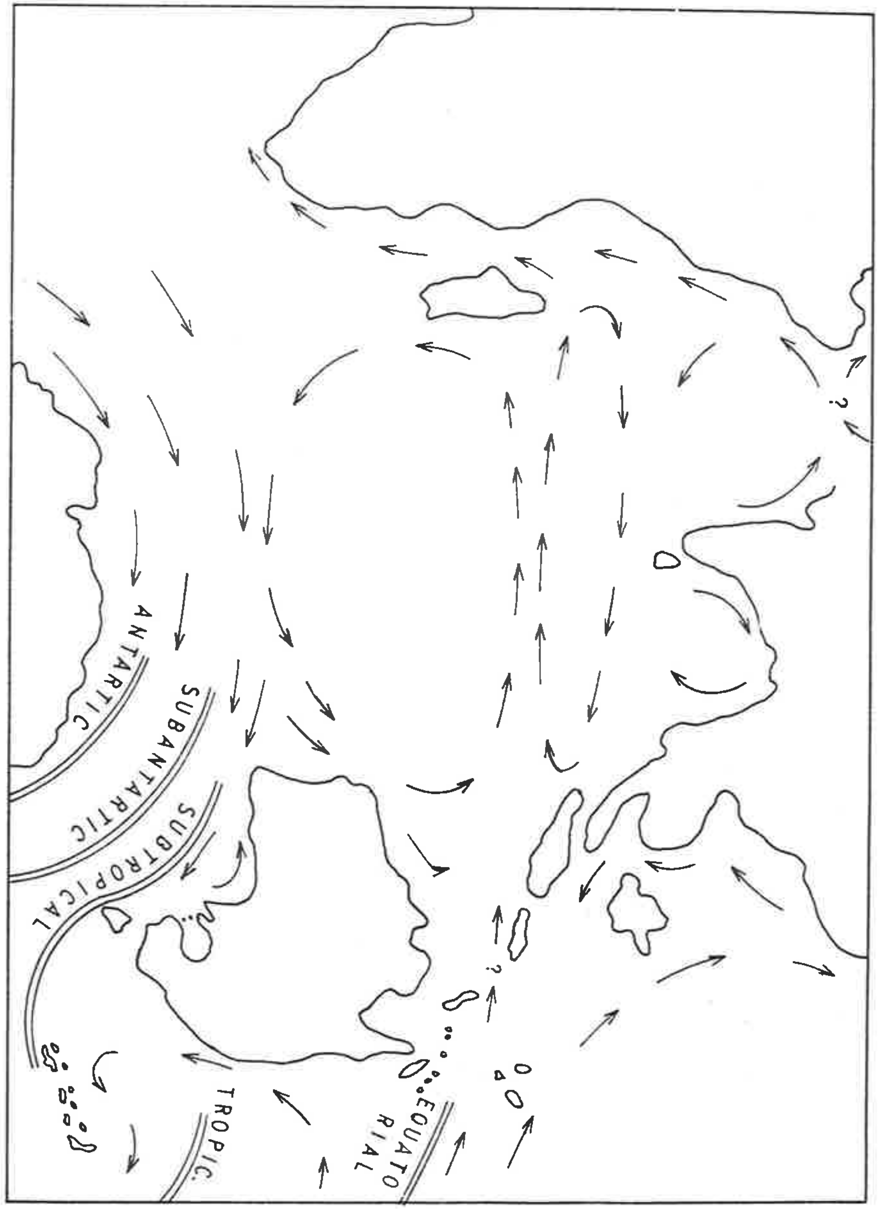
FIG. 22 Post-Eocene Molluscan dispersal routes in the Southern Hemisphere (Late Oligocene/Early Miocene).

<u>ROUTES</u>

EAB, Eastern Atlantic Boreal
T, Tethyan
IM, IndoMalayan
WAB, Western Atlantic Boreal

AN, Amphinotic
NZ, New Zealand
A, Australian
SP, South Pacific


WAB, AN
EAB, T
A
IM
A
?
?
EAB, IM, T, ?
NZ
SP


?
ANTARTIC
SUBANTARTIC
SUBTROPICAL
?
TROPIC.
EQUATO RIAL

endemic Mollusca may be useful in recognizing dispersal patterns which are obscured today by the sequential nature of later migrations of Mollusca into the Australian region. Of the 66 endemic taxa recorded in the Late Eocene, 40.8% remained precinctive to Australia throughout the Cainozoic 36.4% appear to have colonized New Zealand, and 22.7% seem to have migrated northward to the Indopacific and to the Eastern Tethys (Tables VI, VII). Only two genera (3%), Monia and Stephopoma, seem to have successfully used the Atlantic route in the opposite direction. This would therefore indicate that the major Post-Eocene dispersal patterns are an east-west route to New Zealand and the South Pacific and a south-north route towards the Indo-Malayan archipelagoes and the Eastern Tethys, which probably became active in post-Middle Oligocene times (Figs. 21-22).

PALAEOGEOGRAPHIC SIGNIFICANCE OF THE SOUTHERN AUSTRALIAN TERTIARY COMPOSITE SPECIES

During the preparation of this study it became evident that most species, considered by previous authors to be long lived, are actually composite. In some instances they represent lineages of discrete Australian Tertiary stocks; e.g. Limatula margaritata, Orbitestella margaritata, Conuginella muna, Notogrammatodon inexpectatus, Glycymeris kaurna, Crosseola princeps groups. In other instances, they represent congeneric but unrelated species or groups,which were lumped together because of superficial resemblance, e.g. the composite Lima bassi T. Woods and Siliquaria obtusa T. Woods. The incomplete fossil record of the genera to which these composite species belong allows only speculative hypotheses as to their significance. Although randomly studied, these species revealed one common factor - they have a representative in each climatic optimum episode in the Late Eocene, Late Oligocene/Early Miocene, Middle Miocene, Late Pliocene (the stratigraphic distribution of these species is detailed in the systematic part). Therefore, survival of warm water lineages throughout the southern Australian Tertiary, notwithstanding intervening cold periods, would suggest the probable permanence of a warm water region to the north of Australia in which these groups might have taken refuge during adverse climatic conditions with new species developing through this isolation mechanism (Scheltema,1977) or from the periodical expansion of the pantropical zone.

The presence of Tertiary species belonging to warm water congeneric but distinct lineages seems to give further support to Fleming's (1953) model of repetitive Cainozoic migrations and the existence of active faunistic exchange among different regions through dispersal during climatic optimum episodes (see also Fleming, 1978).

PART 2

SYSTEMATICS

INTRODUCTION

The Mollusca dealt with here and in Buonaiuto (1975; 1977a,b - Appendix F) only include Gastropoda, Bivalvia and Scaphopoda. 215 species are described; 81 were previously known, 82 are newly instituted, and 52 are informally described or discussed. 7 genera, 1 subgenus, and 2 subfamilies are recognized for the first time.

CLASSIFICATION

The classification adopted is composite. It is derived from several sources and integrates the updated taxonomic information with well established classifications.

The 'Treatise of Palaeontology' edited by R.C. Moore is adopted: Newell, Cox, *et al.* (1969) and Stenzel (1971) for the Bivalvia, and Cox, Knight, *et al.* (1960) for the Archeogastropoda. Wenz (1938-44) and Zilch (1959) were followed for the rest of the Prosobranchia and for the Euthyneura. The suprageneric classifications proposed by Taylor & Sohl (1962) and Ptchelintsev & Korobkov (1960) were consulted. The Scaphopoda were arranged according to Palmer (1974), but Ludbrook (1960) and Emerson (1962) were also taken into account.

The above classifications were modified on the basis of recent works in the following groups: Turritellidae by Marwick (1957); Pteropoda by Van der Spoel (1967); Triphoracea by Kosuge (1966); Vexillinae and Volutomitridae by Cernohorsky (1970); Turriculidae, Powell (1969); Caecidae by D.R. Moore (1962) and by Iredale & Laseron (1957); Orbitestellidae by Ponder (1967); *Baryspira* Fischer by Olson (1956).

Caon's classification of the Rissoacea (1964) and of the Marginellidae (1965) have been found wanting with respect to supporting information and diagnosis, and therefore, they were not adopted.

A new arrangement of the Siliquariidae Gray is proposed here, which takes into account Morton's works on this family (1951, 1953, 1955, 1965), Morton & Keen (1960) and Keen's studies on the allied Vermetidae (1961). Two new subfamilies are thus recognized, the Siliquariinae Gray and the Stephopominae subfam. nov.

The taxonomy and the morphology of the Striarcinae (Noetidae, Bivalvia) of *Limopsis sassi* (Limopsidae, Bivalvia), *Crossea* Adams (Skeneinae, Archaegastropoda), *Austroliotia* Cotton (Liotiinae, Archaeogastropoda), *Orbitestella* Iredale (Rissoacea, Mesogastropoda), and *Pseudomalaxis* Fischer are revised.

TERMINOLOGY

The terminology adopted in the descriptions is according to the 'Treatise of Paleontology' integrated with geometric terms qualitatively consistent with Raup's (1966),Stasek's (1963a,b) and Lison's (1949) approach. The taxonomic approach to the Pectinacea and, generally, the style of diagnosis in the Bivalvia are according to Allasinaz (1973).

PHOTOGRAPHY

Optical methods of shell photography, with particular emphasis on lighting, are outlined in Blaker (1963). In this present study all large specimens were photographed with diffused light from the NW, at 30^{o} incidence, with reflected secondary illumination from the SE.

Scanning Electron Microscope photography for minute specimens superseded the optical technique in the early stages of this research. Continuous problems of charging have led to the development of a method of coating completely similar to one previously proposed by Pfefferkorn (1970). The specimens are pre-treated by exposure to osmium tetroxide vapour for twelve hours and then coated by vacuum evaporation with carbon and gold-palladium (Buonaiuto, 1977a).

The gold sputtering method has also been tried. However, this method revealed two inherent causes of charging. The major cause was found to be the curved surface of the shell itself impedes a complete coating of the lower, covered part of the specimen. This is a regular problem encountered especially with large specimens. Laying down the stub on a side and then re-coating the specimen did not eliminate this inconvenience completely. The other cause of charging, which may perhaps explain in part the persistent residual charging in the previous case, is that the more irregular the surface of the specimen the less perfect is the coating with the sputtering method. Therefore, a longer time of coating was often required. However, in a number of cases charging still persisted. This residual charging might be caused by differential distribution of surface potential, caused by the irregular topography of the specimen (Prawley, 1972). The method recently suggested by Pfefferkorn, Gruter & Pfautsch (1972) of screening mounted specimens with aluminium foil, perforated to expose the specimen or that part of it which is to be examined,may further reduce or eliminate the charging in such extreme cases (window effect). The best results are still obtained by the evaporative coating method combined with rotation and tilting of the specimen during coating, thus allowing a wider deposition and a better penetration of the carbon and gold films on the specimen (see also Pfefferkorn, 1970).

SAMPLING

In sampling the Maslin and Aldinga Bay sections the method suggested by Sparks (In Ager, 1963, p. 186-88) is applied. 30-40 kg samples were taken from each microconglomeratic unit, 100 kg from each limestone bed of the Tortachilla Limestone, and about 10 kg of rock from each interval sampled from the Blanche Point Formation.

The samples were disaggregated by both mechanical and chemical methods. They were generally digested in H_2O_2 and/or in tensio-active solutions (e.g. R.B.S. 25). The samples from the Gull Rock and the Soft Marl Members were initially soaked in petrol, then dried out until the petrol was completely evaporated and then treated with H_2O_2 to facilitate disaggregation. Finally, they were washed as for micropalaeontological purposes, and their residua carefully examined.

The samples from the outcrops of Maslin and Aldinga Bays thus yielded more than 17,000 specimens of Mollusca. The other taxa found include echinoids, brachiopods, Cirripedia, Decapoda (crabs' claws), worms, fish remnants (otoliths, vertebrae, spines, teeth), Bryozoa, ahermatypic corals, crinoids, and siliceous sponge spicules.

PRESERVATION

The Mollusca generally display good preservation in the Gull Rock and 'Soft Marl' Members of the Willunga Sub-Basin outcrops, and in the material from the subsurface of the Adelaide Plains Sub-Basin.

They display bad preservation in the Tortachilla Limestone and 'Transitional Marls' of Maslin Bay and in the upper 'Soft Marls' at Blanche Point where their shells with the only exception of the Pterioida (Bivalvia) are completely dissolved. In these cases identification is rarely at a specific level, but commonly at a generic or suprageneric level, and in several instances it is only indicative and doubtful.

PARAMETERS

The parameters measured on the Gastropoda and Bivalvia are defined in Buonaiuto (1975, 1977b). However, particularly for the more minute species, special attention was given in orientating the specimens in photography and in determining the magnification of the photographs so that measurements of the major part of the species here described may be directly obtained from the figures.

COLLECTIONS

The specimens figured here are deposited in the Collections of the South Australian Department of Mines & Energy (GSSA), the South Australian Museum (SAM) and the Department of Geology, University of Adelaide (AUGD). Specimens were also examined from the Australian Museum, Sydney (AM), the British Museum (Natural History), London (BMNH), the National Museum of Victoria (NMV) and the Department of Geology, University of Melbourne (MDG) and the New Zealand Geological Survey (NZGS).

SYSTEMATIC

DESCRIPTIONS

CLASS SCAPHOPODA Bronn, 1862

In the last twenty years three classifications of Scaphopoda were proposed by Ludbrook (1960), Emerson (1962) and recently by Palmer (1974). The former two subdivide the class into two families, Dentaliidae Gray, 1847, and Siphonodentaliidae Simroth, 1894, but differ in their generic classification. On the other hand, Palmer institutes two new orders, Dentalioida and Siphonodentalioida, the former characterized by a conical foot and the latter by a vermiform foot and a distal crenulated disc. In Dentalioida, he recognizes two families:

-Dentaliidae Gray, 1847, with a conical foot and longitudinal costae (corresponding to Emerson's 1962 *Dentalium* s. l. group, plus *Prodentalium* Young, 1942);

-Laevidentaliidae Palmer, 1974, with a smooth shell, or having a concentric ornament but no longitudinal one (corresponding to Emerson's 1962 *Fustiaria* s. l. group, plus *Plagioglypta* Pilsbry & Sharp, 1897).

Siphonodentalioida is divided into:

-Siphonodentaliidae Simroth, 1894, including all Scaphopoda with shells without constricted anterior aperture (genera: *Entalina* Monterosato, 1872; *Siphonodentalium* M. Sars, 1859; *Pulsellum* Stoliczka, 1868);

-Cadulidae Grant & Gale, 1931, with adult shells with constricted aperture.

Palmer also adds a new genus, reclaims a few others from synonymy and integrates other genera instituted after Ludbrook's 1960 and Emerson's classifications (corresponding to Emerson's 1962 *Cadulus* s.l.). Palmer's model mainly differs from Emerson's and Ludbrook's in that it upgrades recognized taxonomic divisions.

ORDER DENTALIOIDA Palmer, 1974

FAMILY LAEVIDENTALIIDAE Palmer, 1974

GENUS *Gadilina* Foresti, 1895

Gadilina Foresti has been placed by Pilsbry & Sharp (1897) in *Dentalium* Linnaeus as a subgenus, and it was thus maintained by Ludbrook

(1960). Emerson (1962) transferred it into Fustiaria Stoliczka, again as a subgenus. Palmer (1974) raised it to generic rank and assigned it to Laevidentaliidae Palmer.

Gadilina is recorded from Late Eocene to Holocene.

G. tatei Pilsbry & Sharp here described represents its oldest known record. The palaeodistribution is restricted to Australasia in the Paleogene and in Eastern and Central Tethys in the Neogene. Today, it survives in the East Indies.

Gadilina tatei Pilsbry & Sharp, 1858

Figs. 1-4

1887c Dentalium ?triquetrum Tate, p. 193, pl. 20, fig. 3 (non Brocchi, 1814).
1898 Dentalium (Gadilina) tatei Pilsbry & Sharp, p. 3, p. 218 (nom. nov.)
1899 Dentalium (Gadilina) tatei Tate, p. 266.
1938 Dentalium (Gadilina)tatei -Cotton & Ludbrook, p. 227.
1959 Dentalium (Gadilina) tatei -Ludbrook, p. 144, pl. 1, fig. 5.
1961 Dentalium (Gadilina) tatei -Ludbrook, pl. 8, fig. 10.

MATERIAL. 4 specimens, GSSA collection; 8 silicified specimens; Holotype and 6 unnumbered paratypes (SAM T 252). 144 in various conditions.

DESCRIPTION. Shell small, very slender, slightly arched, with slowly increasing diameter. Inner shape subcircular, outer subtrigonal. Regions: dorsal elliptical; the two lateral subelliptical; ventral very elliptical. Region connections: dorso-lateral subangular; ventral-lateral rounded. Maximum shell thickness at the dorsal region.

Ornament. surface smooth with very fine annular growth lines, which slightly slope to the dorsal. Irregular annular faint rugae and constrictions. Irregular traumatic sutures are common.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16)(Blanche Point Formation); Buccleuch Beds (P16/17-17).

DISTRIBUTION. St. Vincent Basin, Adelaide Plains Sub-Basin: Adelaide Children's Hospital, Bore 5, 22.97-22.64 m and 24.60-24.28 m depth, Kent Town Bore. Willunga Sub-Basin: Maslin and Aldinga Bays. Murray Basin: Coonalpyn E & W Bore 2, sect. 56, hd. Coneybeer, 128.28-127.30 depth

FAMILY	DENTALIIDAE Gray, 1847
GENUS	Fissidentalium Fischer, 1885
SUBGENUS	Fissidentalium s. str.

Fissidentalium (Fissidentalium) sp.
FIGS. 5-12

1887c Entalis mantelli -Tate, Figs. 5-12, p. 190, (pars)

MATERIAL. 33 broken specimens from GSSA Collections; 6 silicified specimens very badly preserved; six specimens from Tate Collection (SAMT 254-3, T 248-6).

DESCRIPTION. Shell conical, subarched; inner cross shape circular; outer cross shape polygonal in younger stages, subcircular in older.

Ornament. Younger stages: prominent primary ribs; intercalated secondary costellae, developing into primary in older stages. In some specimens growth rings more marked in younger stages.

Morpha A: with subdued or less numerous tertiary costellae. (Fig. 5-7)

Morpha B: with fine tertiary costellae more marked in older stages. (Fig. 6-12)

OBSERVATIONS. These forms were included by Tate in Dentalium mantelli Zittel. New Zealand specimens from Oamaru Creek revealed differences of a more arched shell, narrower interspaces, and a lack of tertiary costellae, although the younger stages closely resemble those of Morpha A.

Fissidentalium sp. seems to be the oldest representative of a homogeneous group of forms present in the Australian Tertiary of which F. mawsoni Ludbrook (1956, p.2, pl. 1, figs 5-6) is the Middle Miocene-Pliocene representative. At this stage, bad preservation, paucity of material available and ornament variability make any further discussion of this group impossible.

Fissidentilium sp. differs from *F. mawsoni* in that it has much less prominent ribs.

STRATIGRAPHIC RANGE. Late Eocene. Blanche Point Formation (early P15-middle P16);Buccleuch Beds (P16/17-P17).

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin. Adelaide Children's Hospital Bore 5: 25.59 - 25.26 m, 24.60-24.28 m, 23.62-23.29 m, 22.97-20.34 m; Bore 1, 23.62 m depth. Adelaide (Kent Town) Bore. Willunga SubBasin: Maslin Bay, Blanche Point.

Murray Basin. Waikerie Bore 2, 228.02-226.38 m and 223.10 m depths.

CLASS	GASTROPODA	Cuvier, 1797
SUBCLASS	PROSOBRANCHIA	Milne Edwards, 1848
ORDER	ARCHAEOGASTROPODA	Thiele, 1925
SUBORDER	PLEUROTOMARIINA	Cox & Knight, 1960
SUPERFAMILY	PLEUROTOMARIACEA	Swainson, 1840
FAMILY	PLEUROTOMARIIDAE	Swainson, 1840.

In the Tertiary the Pleurotomariidae are represented by only four genera: the Eocene Paris Basin *Chelotia* Bayle in Fischer, 1885, the Eocene to Holocene *Entemnotrochus* Fischer, 1885; the Eocene to Holocene *Perotrochus* Fischer, 1885, and the Eocene to Holocene *Mikadotrochus* Lindholm, 1927 (Cox, 1960).

Recently Bayer (1963, 1965) revised the shell morphology and the taxonomy of the living species of *Entemnotrochus*, *Perotrochus* and *Mikadotrochus*. Fretter (1964, 1966) and Moreira Leme & Penna (1969) described the anatomy of the Atlantic species of *Mikadotrochus* and *Perotrochus*.

In Australasia, the Pleurotomatiidae are known only in the fossil record. The few described species are referable to *Mikadotrochus* and *Perotrochus*. The Australian fossil species are: the Late Eocene *M. purkabidni* sp. nov. from Willunga and Noarlunga SubBasins; *P. darraghi* sp. nov. from the Otway Basin, the Early Oligocene *Mikadotrochus* sp. nov. from Otway Basin, the Late Oligocene *Perotrochus* sp. from Point Turton and the Oligocene -? *Mikadotrochus* sp. from Stansbury (Yorke Peninsula), the Oligocene *Perotrochus* cf. *tertiarius* (McCoy) from the Gambier Embayment, the Early Miocene *Mikadotrochus bassi* (Pritchard,1903) and *Perotrochus tertiarius* (McCoy, 1876) from the Port Phillip and Bass Basins.

New Zealand fossil species are: the Eocene *Perotrochus allani* Marwick, 1928,from Chatham Islands (the Arnold Series, Fleming, 1966) and the Early Miocene *P. marwicki* Fleming, 1970,from Nelson.

Harris (1893 p. 286) records an internal cast from the Tertiary of Ardrossan (Yorke Peninsula) which shows the characteristic pleurotomariid sinus,but is too poorly preserved for specific description.

As a result of this study the stratigraphic range of *Mikadotrochus* Lindholm, hitherto considered no older than Miocene (Darragh, 1970), has been extended back to the Late Eocene, and it has also been shown to have a rather continuous fossil record in Australia. *Perotrochus* Fischer, considered by Cox (1960) no older than Oligocene, is confirmed as being as old as Late Eocene in Australasia with *P. allani* Marwick in New Zealand (Fleming, 1966) and *P. darraghi* sp. nov. in southern Australia. Furthermore, there are indications that *P. darraghi*, the Early Oligocene *Perotrochus* sp. nov. and *P. tertiarius* (McCoy) and the Oligocene *P.* cf. *tertiarius* might belong to the same lineage. The available specimens of *Mikadotrochus* generally are too poorly preserved for any phylogenetic consideration. It is observed that *M. purkabidni* sp. nov. is closer to *M. beyrichi* (Hilgendorf) in heavy ornament style than to *M. salmianus* (Rolle), but this similarity could very well be due to environmental causes.

The new material here described confirms Pritchard's 1903 opinion that the Australian fossil record of Tertiary Pleurotomariidae is exceptionally good in comparison with other countries. It is hoped that better preserved material supplying information on the evolution of *Perotrochus* and *Mikadotrochus* and their species lineages will be found in future.

GENUS *Mikadotrochus* Lindholm, 1927

Diagnosis. Shell large, trochiform, with total height slightly greater than maximum diameter. Suture flush in jevenile stages to adpressed in the adult and senile stages. Body whorl subtrapezoidal, wider than high. Margins: abaxial very steep, subconvex; abapical declivous, subconvex; adaxial subvertical, straight; adapical subconcave, declivous. Margin connections all angular. Selenizone in younger stages at the middle, in adult and seniles at the abapical 2/3 of the abaxial margin. Base wide, subconvex, with very narrow umbilicus. Peristome as body whorl. Columellar lip subvertical, thick. Columellar-abapical connection rounded, subangular.

Ornament. Growth lines and axial striae: adapical prosocline; in selenizone faint, deep, symmetrical opisthocyrt; middle prosocyrt; abapical prosocline subfalciform. Dashed spiral cords interrupted by the axial striae. Selenizone with one heavily beaded cord in younger and two in adult and senile stages. Neanic whorls cancellate with narrow subquadrate pits.

(Diagnosis based on direct observations of *M. beyrichi* (Hilgendorf) and *M. salmianus* (Rolle), and integrated with Bayer's (1965) observations).

HABITAT. The Recent M. *beyrichi* (Hilgendorf) is recorded at depth ranges between 36.6 and 183 m, with an optimal range of 36.6-55 m (Bayer, 1965). Bottom water temperature is constant and independent of the depth, with values around 23°C. The substratum is generally of coarse grained to gravelly sands in gently declivous banks.
It occurs in assemblages with Mollusca - in particular *Chlamys*-, Brachiopoda, Bryozoa, corals, and calcareous algae (Kanno, 1961; Okutani, 1963; Bayer, 1965).

Kanno (1961, p. 114-5) also considers that pleurotomariids gradually changed their niche throughout the geological times from very shallow waters, such as mangrove swamps, to deeper and deeper waters. This gradual change would be phylogenetically recorded in the migration from shallow to deep waters by the juveniles of *M. beyrichi* as they became adults.

M. purkabidni lived on very fine marls in which the coarse elements consist only of shells, glauconitic ?faecal pellets and siliceous sponge spicules. It is found associated with Brachiopoda, solitary corals (rare), Bryozoa (rare) and Mollusca, but except for *Chlamys* the molluscan assemblages are of shallower waters and have a different composition from those of the present day ones recorded by the authors cited above. Two moulds referable to *M. purkabidni* were found in the microconglomeratic sands of the Tortachilla Limestone at Christies Beach (Noarlunga SubBasin) but it could have been deposited through transport as well as the major part of the shells in Tortachilla Limestone assemblages. The Early Miocene *M. bassi* (Pritchard) occurs in the microconglomeratic sands of Freestone Cove Sandstone.

Mikadotrochus purkabidni sp. nov.

FIGS. 25-29, 31-35.

DERIVATION OF THE NAME. From *Purkabidni*, a legendary Aboriginal giant, because of its size.

HOLOTYPE. SAM P21267A, Figs. 25-28.

PARATYPES. SAM P21267B-C Figs. 31-34.

TYPE LOCALITY. Blanche Point, Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

This form was found only just above the *Phygraea tarda* level and in the upper part of the Gull Rock Member. The types from Blanche Point are from Blanche Point are from the lower level.

STRATIGRAPHIC RANGE. Late Eocene (P15-middle P16).

MATERIAL. 1 latex cast, 1 impression and 1 mould (the holotype), 3 moulds and 3 very deformed and badly preserved specimens. 1 specimen with remnants of shell (SAM P 13113).

DESCRIPTION. Shell very large (up to ~ 80 mm), trochiform, in younger stages coeloconoid, rather high spired; whorl overlapping up to just below the periphery. Suture flush to subimbricated. Abaxial margin regions: abapical and middle undifferentiated, convex very declivous; abapical convex subdeclivous. Region connections: middle-abapical rounded angular; middle-adapical imperceptible. Body whorl shape subtrapezoidal. Selenizone low on the abapical part of the middle abaxial region. Base flattened, ?umbilicate. Depressed Selenizone.

Ornament. Prosocline growth lines; spiral cords of spirally elongated beads. 5 cords above and 3 below the selenizone. On the holotype's last whorl a finer secondary cord in the spiral adapical interspaces. Selenizone bound by marked rims and with deep opisthocyrt growth lines.

OBSERVATIONS. The holotype is represented by three parts: an outer surface impression (Fig.25); its relative latex cast (Fig. 26); and the mould of the original shell (Fig.27). Though juvenile, it was chosen because it is the only undeformed specimen with well-preserved ornaments. The condition of the specimens makes a complete diagnosis impossible. The squashed specimens from Blanche Point, although their shells are partly preserved, show a deep, wide umbilicus. The undeformed moulds, on the other hand, show a very narrow umbilicus, partly closed by the S-shaped adaxial margin. The deformation of the specimens from Blanche Point was produced by compression associated with shearing. Therefore, the sliding between successive body whorls along the contact surfaces could have produced the broadening of the umbilicus and the obscuring of the columellar morphology (Figs. 31-34).

M. purkabidni differs from its nearest relative M. beyrichi (Hilgendorf) (Bayer, 1965, p. 783, fig. 31; Okutani, 1963, p. 78, fig.5) in its coeloconoid initial whorls and its lesser number of spiral cords on the middle and adapical regions of the abaxial margin. Bayer (1965, p. 788) considers the number of spiral cords to be significant at the species level. On the other hand, the two species display beaded cords of a similar style.

M. purkabidni represents the oldest record of Mikadotrochus Lindholm which therefore extends its stratigraphic range back to the Late Eocene.

OTHER LOCALITIES. St. Vincent Basin, Noarlunga SubBasin, Christies Beach (Tortachilla Limestone) (SAM 21268); Noarlunga Township, Onkaparinga River (Gull Rock Member).

Mikadotrochus sp. nov.

FIGS 42-44

1903 Pleurotomaria sp. -Pritchard, p. 87.

MATERIAL. 1 neanic specimen with only one damaged whorl preserved (NMV P 42704).

DESCRIPTION. Shell trochiform, body whorl subtrapezoidal wider than high, suture flush, margins subconvex except the adapical which is subconcave. Margin connections angular. Base wide, subconvex, declivous, with very narrow umbilicus. Columellar lip vertical subconcave, relatively thick. Other lips damaged. Selenizone very shallow at the middle of the abaxial margin.

Ornament. Traces of cancellate pattern of similar style to M. salmianus (Rolle) in the remnants of the preceding whorl. Growth lines and axial striae as described in the generic diagnosis. Spiral beaded cords: on the region adapical to the selenizone, three primary and three secondary; abapical to the selenizone, five primary and two secondary, at the selenizone and between the 2nd and 3rd primary; at the selenizone, one faint weakly beaded. On the base dense fine weakly beaded cords.

OBSERVATIONS. This form shows close similarities with the neanic whorls of M. salmianus (Rolle). It differs from the juvenile whorls of M. purkabidni in flush suture, finer cords. Steepness of the base, columellar lip, body whorl shape and selenizone morphology place it in Mikadotrochus. This is the specimen quoted by Tate & Dennant (1895) and mentioned by Pritchard (1903). Pritchard (ibid.) also reports of some very damaged high spired pleurotomariid specimens from Waurn Ponds Limestone (Late Oligocene-Early Miocene) which might belong to Perotrochus Fischer by analogy with the juvenile from the coeval Lower Maude Limestone.

LOCALITY. Otway Basin, Point Flinders, 2.5 km north west of Cape Otway.

FORMATION. Glen Aire Clay (T.A. Darragh, 1976, pers. comm.)

STRATIGRAPHIC RANGE. Latest Eocene-Early Oligocene (Abele *et al.*, 1976; O.P. Singleton, 1968, 1973).

Mikadotrochus cf. *bassi* (Pritchard, 1903)

FIGS 48-49

1903 *Pleurotomaria bassi* Pritchard, p. 85, pl. 13, figs 1-2.

MATERIAL. 1 very worn and damaged juvenile topotype (NMV P 42703).

DESCRIPTION. Shell trochiform, rather high spired. Body whorl subtrapezoidal, wider than high. Margins: abapical subconcave rather declivous; abaxial subconvex very declivous; abapical subconvex rather declivous; adaxial subvertical. Margin connections all angular. Base wide, declivous, with narrow umbilicus. Columellar lip thick, vertical, subconcave.

Ornament. traces of finely beaded cords on the base.

OBSERVATIONS. This specimen is referred to *Mikadotrochus* Lindholm on the basis of its body whorl shape, columellar lip, and declivity of the base. Furthermore, it shows close similarities with the initial whorls of the holotype of *Mikadotrochus bassi* (Pritchard) (Pritchard, 1903, pl. 13, fig. 1) and therefore it is here compared with this latter species. The specimen figured by Pritchard (1903, pl. 14, fig. 1-3) as *Pleurotomaria tertiaria* McCoy, which is from Corio Bay or Lower Moorabool Valley, shows closer affinities in general features with *Mikadotrochus* sp. cf. *M. bassi*, with which it is at least congeneric, than with the holotype of *Pleurotomaria tertiaria* (Pritchard, 1903, pl.14, fig. 4) or the other species of *Perotrochus* herein described.

LOCALITY. Fossil Bluff, Table Cape, Tasmania, BURNIE 1:250 000 geological map sheet 40^{0} 58'55"S, 145^{0}44'54"E, Bass Basin.

FORMATION. Freestone Cove Sandstone, Table Cape Group (as from the matrix still preserved).

STRATIGRAPHIC RANGE. Longfordian (Early Miocene N4/N5) (Quilty, 1974, p. 32).

Mikadotrochus sp.

FIGS 38-39

MATERIAL. 1 mould of bryozoal limestone (AUDG 1356)

DESCRIPTION. Shell large, trochiform, high spired; inner shape of the body whorl subtrapezoidal. Body whorl regions: adaxial margin straight, subvertical, with adapical high spired shallow columellar channel; adapical subconcave; abaxial subconvex, subvertical; abapical convex subhorizontal. Region connections: all angular. Umbilicus very narrow partly closed by the weak columellar channel. Selenizone just below the midpoint of the abaxial margin.

OBSERVATIONS. The flattened abaxial margin, the body whorl shape, and the vertical columellar margin place this form in Mikadotrochus. The Mikadotrochus sp. might be conspecific with M. cf. bassi (Pritchard). However, better material is necessary to resolve the problem of both the taxonomic and stratigraphic location of this form.

LOCALITY. Stansbury, Yorke Peninsula, St. Vincent Basin.

FORMATION. Pt. Vincent Limestone.

STRATIGRAPHIC RANGE. The age of the Port Vincent Limestone at Stansbury is Oligocene to Miocene (Stuart, 1970).

GENUS Perotrochus Fischer, 1895

DIAGNOSIS. Similar to Mikadotrochus. Differences: sutures always adpressed, body whorl subtrapezoidal much wider than high; abapical margin wider, subdeclivous; selenizone slightly more adapical, with deeper slit; base wide, flat, with wide and deeper umbilicus; parietal lip reduced; columellar lip declivous, shorter and thinner; abapical-columellar lip connection rounded nearly imperceptible.

Ornament. Growth lines and axial striae: adapical more prosocline; those of the selenizone markedly asymmetrical opisthocyrt, with adapical maximum concavity; middle prosocyrt; abapical prosocline subfalciform. Dotted spiral cords of rather short beads, interrupted by the axial striae. Spiral costae of selenizone: absent in neanic stages; in adult and senile stages an initial primary costa migrating from the middle to the adapical, together with the gradual appearance of few secondary costellae.

((Based on *P. hirasei* (Pilsbry), integrated with Bayer's 1965 observations))

HABITAT. Deeper than *Mikadotrochus*, recorded depths ranging between 70 and 500 m (Bayer, 1965).

Perotrochus darraghi sp. nov.

FIGS. 50-51

DERIVATION OF THE NAME. After Thomas A. Darragh, National Museum of Victoria, for his studies on Australian molluscs.

HOLOTYPE. NMV P 42702, figs. 50-51.

TYPE-LOCALITY. Otway Basin, Browns Creek, forked gully 400 m north west of Browns Creek mouth. COLAC 1:250 000 geological map sheet, Port Campbell Embayment, Otway Basin.

TYPE-FORMATION. Browns Creek Clay, top part.

STRATIGRAPHIC RANGE. Late Eocene (P16) (Abele *et al*., 1976; McGowran, 1978a).

MATERIAL. The holotype, very damaged.

DESCRIPTION. Shell very large, throchiform, whorls increasing more in diameter than in height. Whorl overlapping parallel to the c. axis, up to the periphery. Suture adpressed. Selenizone at about the middle of the abaxial margin.

Ornament. Growth lines and weak axial striae as in generic diagnosis. Fine spiral cords very numerous, very weakly beaded. Selenizone with 3 faint spiral costellae in adult and 4 in senile stages. In neanic whorls, cancellate pattern with rectangular pits, spirally elongated.

OBSERVATIONS. The direct comparison with specimens of P. hirasei (Pilsbry) which are kept in the S.A. Museum and the Australian Museum collections, revealed a similar ornament pattern, selenizone morphology and position, and neanic cancellate pattern. This form is therefore referred to as Perotrochus Fischer. The holotype is the only specimen of this species hitherto known.

Perotrochus ? darraghi sp. nov.

FIGS 40-41

MATERIAL. 1 mould with traces of ornaments and umbilical features. (SAM P 13113).

DESCRIPTION. Body whorl shape, declivity of the base, and dotted spiral cords, and wide umbilicus consistent with Perotrochus morphology. Abaxial margin shape similar to Perotrochus tertiarius (McCoy).

OBSERVATIONS. This form is doubtfully referred to the coeval P. darraghi sp. nov. Yet it must be noted that the very poor preservation of both P. darraghi's holotype and the specimen from Noarlunga SubBasin does not allow any safe comparison.

LOCALITY. Cliff on the left bank of the Onkaparinga River near Noarlunga.

STRATIGRAPHIC RANGE. Blanche Point Marls, Gull Rock Member, Late Eocene (middle P16).

Perotrochus cf. tertiarius McCoy

FIG. 32.

MATERIAL. 1 latex cast (SAM P21269).

DESCRIPTION. Shell very large, trochiform, high spired, whorls increasing more in diameter than in height; whorl overlapping up to just above the periphery. Suture adpressed. Abaxial margin regions: adapical flat, very narrow and declivous; middle subconvex and subvertical. Region connections: nearly imperceptible. Selenizone just below the mid-point. Protoconch and base not preserved.

Ornament. Traces of weakly spiral riblets more marked on the abapical middle region fading in senile stages (?). Growth lines and rugae prosocline above and opisthocyrt below the selenizone. Selenizone bound by two furrows, the abapical more marked, and bearing fine spiral costellae.

OBSERVATIONS. This form is referred to Perotrochus Fischer on the basis of its growth lines and beaded spiral riblets. It shows affinities with the Late Oligocene-Early Miocene Perotrochus tertiarius (McCoy), which is revised below,in whorl shape, ornament, and position of the selenizone. P. cf. tertiarius might represent either an ancestral species of P. tertiarius or just an older form of it. Perotrochus sp., from Point Turton Limestone and P. cf. tertiarius might belong to the same species. Better material is however needed to resolve both problems.

LOCALITY. Otway Basin, Gambier Embayment, Pritchard's Quarry, 14.5 km WNW of Mt. Gambier.

FORMATION. Gambier Limestone.

STRATIGRAPHIC RANGE. ?Oligocene -?

Perotrochus tertiarius (McCoy, 1876)

FIGS 45-47,53-54

1876 Pleurotomaria tertiaria McCoy, p. 23, pl. 25, fig. 1-1b.

1903 Pleurotomaria tertiaria -Pritchard, p. 83, pl. 14, fig. 4.

MATERIAL. 1 senile specimen extensively damaged (MNV P 42701) and a juvenile with protoconch and last whorl damaged (NMV P 42705).

DESCRIPTION. Shell very large, trochiform, high spired, higher in neanic stages; whorls increasing more in diameter than in height; whorl overlapping up to the periphery. Suture adpressed. Body whorl subtrapezoidal much wider than high. Margins: abaxial, with adapical region flat declivous, middle and abapical flat subvertical; abapical gently declivous subconvex. Selenizone at the middle abaxial margin.

Ornament. Growth lines and axial striae as in generic diagnosis spiral costae fine and numerous. Selenizone costae: traces of two in younger stages, worn out in the senile ones. Neanic whorls with cancellate pattern with very wide rectangular pits, spirally elongated. Selenizone growth lines asymmetrical and very marked.

OBSERVATIONS. The senile specimen is referred to *P. tertiarius* (McCoy) due to the similarities shown by the younger whorls with the type (Pritchard, 1903, p. 114, fig.4). The neanic specimen is also referred to the above species, although with some reservation because no early stage is well preserved in the other specimen. Yet, it displays the same cancellate pattern and the same selenizone morphology as in the living *P. hirasei* (Pilsbry) and in the Late Eocene *P. darraghi* sp. nov.

LOCALITY. Bass Basin, Freestone Cove (Table Cape, Otway Basin); Port Campbell Embayment, Maude.

FORMATIONS. Freestone Cove Sandstone, Table Cape Group; Lower Maude Limestone.

STRATIGRAPHIC RANGE. Late Oligocene-Early Miocene (late Janjukian-Longfordian) (Quilty, 1966, 1972, 1974; Abele & Page, 1974; Abele *et al*., 1976).

Perotrochus sp.

FIGS 30-36

MATERIAL. 2 moulds of bryozoal limestone. (GSSA M 3313, SAM P 21270).

DESCRIPTION. General shape similar to *Perotrochus* cf. *tertiarius*. It differs from the Christies Beach mould of *Perotrochus ?darraghi* in narrower coiling and more flattened whorls; it is similar in the body whorl shape and in the very pronounced columellar channel. It differs from the Stansbury mould of *Perotrochus* sp. in more convex whorls and in shorter and wider body whorl.

OBSERVATIONS. It is impossible at the present to establish any relationship with the coeval *Perotrochus* cf. *tertiarius*. They may be conspecific.

LOCALITY. Yorke Peninsula, unknown location (St. Vincent Basin), Point Turton.

FORMATION. Point Turton Limestone (Crawford, 1965; Ludbrook, 1967, fig. 3, 1969).

STRATIGRAPHIC RANGE. Late Oligocene (Ludbrook, 1967, 1969).

J.M. Lindsay (pers. comm., S.A. Department of Mines, December 1975) adds. "The most diagnostic foraminifer in the Point Turton Limestone (Ludbrook, 1963) remains the benthonic species *Victoriella conoidea* (Rutten) which was shown to characterize a thin zone of 'Oligo-Miocene' age in the adjacent St. Vincent Basin by Lindsay (1969). The Oligocene or Miocene age of the Limestone hinges on the upward stratigraphic limit of this species. Where the top of the range of *V. conoidea* can be tested against the ranges of planktonic foraminifera in the Otway, Murray, and St. Vincent Basins of South Australia, the evidence now available suggests that this range - top is no younger than Zone P 22 (N.3), i.e. Late Oligocene, and this in turn is taken to be the age of the Point Turton Limestone."

FAMILY SCISSURELLIDAE Gray, 1847

GENUS *Scissurella* d'Orbigny, 1824

SUBGENUS *Scissurella* s.str.

Scissurella (Scissurella) lamellularum sp. nov.
FIGS 55-58

DERIVATION OF THE NAME. from the latin *lamellula* minute lamina, because of its ribs.

HOLOTYPE. GSSA M3325, FIGS.55-58.

TYPE-LOCALITY. Willunga SubBasin, St. Vincent Basin, Bore WLG40, 68.00-68.10 m depth.

TYPE-FORMATION. Port Willunga Beds (lower part).

STRATIGRAPHIC LOCATION. Late Eocene (P16/17)

MATERIAL. The holotype well preserved.

DESCRIPTION. Shell minute, thin, pseudoplanispiral in younger stages, low helicospiral in older. Whorl overlapping: *parallel to the coiling axis,* complete in younger stages with body whorl height greater than whorl height, scarce in older stages with tangent successive whorls; *normal to the coiling axis*, in younger stages with tangent successive whorls and complete in older stages. Suture flush. Body whorl shape subrectangular. Margins: adapical subconvex, subdeclivous; abaxial subconvex, vertical; abapical convex, subhorizontal; adaxial subvertical, subconvex. Region connections: all broadly angular. Base with narrow deep umbilicus; peristome subrectangular. Lips: adapical thin, straight; adaxial, straight, extroflected; adaxial -adapical subconcave, thin, adherent; all the other lips damaged. Lip connections: all angular. Deep broad slit at the abaxial lip adapical/middle connection. Selenizone at the abaxial middle-adapical region connection, appearing after 2.5 whorls from the nucleus.

Protoconch. 1.5 whorls, deeply and densely punctated, pseudoplanispiral, homeostrophic with the initial teleoconch.

Ornament. Prosocline growth line and axial lamellose costae; deep opisthocyrt asymmetrical chevron-shaped growth rugae and lines on the selenizone. Faint spiral microcostellae and marked costellae at the selenizone edges.

OBSERVATIONS. Ornament pattern (primary axial costae and secondary spiral costellae), peristome and body whorl shape, position of the selenizone, and coiling place this form in *Scissurella* s. str. *Scissurella lamellularum* sp. nov. represents the oldest record of the genus in Australasia, and it is the first fossil species described in Australia. The oldest fossil form hitherto known was the Early Miocene (Otaian) *S. condita* Laws (Laws, 1939, p. 475, fig. 74). The living *S. ornata* May has been recorded in the roots of the giant kelp, *Macrocystis pyrifera* (Tasmania). Womersley, Botany Department, University of Adelaide, indicates a depth of attachment of 5-10 m for this kelp.

SUPERFAMILY FISSURELLACEA Fleming, 1822
FAMILY FISSURELLIDAE Fleming, 1822
SUBFAMILY EMARGINULINAE Gray, 1834
GENUS Emarginula Lamarck, 1801
SUBGENUS Emarginula s. str.

Emarginula (Emarginula) imbricata sp. nov.
FIGS 59-63

DERIVATION OF THE NAME. from the Latin imbricatus, imbricate because of its rib morphology.

HOLOTYPE. SAM P21271A, Figs. 59-60

PARATYPES. SAM P21271 B-C, Figs. 61-63

TYPE LOCALITY. Adelaide (Kent Town) Bore

TYPE-FORMATION. Blanche Point Formation, lower part, (green sands)

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16)

MATERIAL. 34 specimens from Tate Collections; 1 silicified juvenile (Maslin Bay).

DESCRIPTION. Shell planispiral conical with the only one teleoconch whorl representing nearly the entire shell. Suture impressed. Teleoconch body whorl characterized by a very high expansion rate. Whorl height lesser than body whorl height. Whorl overlapping; total, both parallel and normal to the coiling axis. Both the intersutural length and distance assume negative values. Body whorl shape ovoidal. Lips thin, crenulated. Lip connections imperceptible. Long deep abaxial slit; Selenizone flat, depressed, bound by two prominent sharp ribs. Horse-shoe shaped scar muscle, adaxially narrower.

Protoconch. one planispiral homeostrophic smooth whorl.

Ornament. Fine orthocline growth lines, striae, and lamellose costae; primary ribs, with in between finer secondary riblets; within primary-secondary interspace, tertiary fine microriblets present in some cases. On the ribs, pseudo-imbrication, by retroflection of the axial costae. Selenizone bears one spiral primary costa with two secondary costae; chevron shaped lamellose axial ribs. In the interior region, two spiral ribs bounding the selenizone.

Dimensions. (mm)

Spec.	no w	Hlw	Lis	HP	Dmx	N	Nis	DP
SAM P21271A	2	5.55	-5.10	1.00	14.00	13.60	-.75	13.75

OBSERVATIONS. This species was founded on subsurface material, because the only specimens referable to Emarginula from Maslin Bay are represented by poorly preserved moulds which still bear traces of the above described ornament. The selenizone morphology places this form in Emarginula s. str. Emarginula imbricata sp. nov. represents the oldest fossil record of the genus in Australia.

OTHER LOCALITIES. Willunga SubBasin, Maslin Bay ('Transitional Marl' Member).

SUBORDER	TROCHINA Cox & Knight, 1960
SUPER FAMILY	TROCHACEA Rafinesque, 1815
FAMILY	TROCHIDAE Rafinesque, 1815
SUBFAMILY	MARGARITINAE Stoliczka, 1868
GENUS	Margarites, Gray, 1847
SUBGENUS	Periaulax Cossmann, 1888

Margarites (Periaulax) rhysus sp. nov.

FIGS 64-71

1894 Eumargarita (Solariella) rhysa Tate, p. 185 (nom. nudum).

MATERIAL. 7 silicified specimens (Maslin Bay), badly preserved; 50 specimens in different state of preservation, (Tate collection); 2 specimens from GSSA Collection; 50 bady preserved from outcrops.

DESCRIPTION. Shell minute, thin, turbiniform; whorls increasing more in diameter than in height. Whorl overlapping: parallel to the coiling axis, up to the middle adapical connection; normal to coiling axis, total.

Suture impressed. Body whorl shape polygonal. Margins: abaxial adapical narrow, subconcave, subhorizontal; abaxial-middle declivous, convex; adapical adaxial subconvex; adaxial adapical thin, subconcave; abaxial abapical thin, subconvex; Margin connections: all angular. Base subconvex; bound at the periphery by an angularity; deep wide umbilicus; peristome polygonal. Lips, all thin and subconcave, except the adaxial-adapical subconvex; the adaxial-adapical lip slightly retroflected. Lip connections: all angular; the abapical and adapical adaxial-abaxial represented by shallow gutters.

Protoconch. 1 smooth pseudoplanispiral whorl, with nucleus variable in size, separated from the teleoconch by a faint cicatrix.

Ornament. Prosocline growth lines and rugae. Three spiral abaxial carinae, beaded at ruga-carina intersections. Beaded circumumbilical carina.

OBSERVATIONS. Peristome, body whorl shape, the three abaxial and the fourth circumumbilical carinae place this form in Cossmann. Several specimens of this undescribed species were found in the Tate Collections labelled as "Eumargarita (Solariella) rhysa, Adelaide Bore". In the same box were other specimens from an undetermined locality and from an undetermined horizon of a Mulgundawa Bore. Tate's above name, published in 1894 as nomen nudum, is adopted here. The specimens from Adelaide Bore are distinctly from two different lithologies; one of blackish gritty clay, the other of grey whitish marls, and both are referable to Blanche Point Formation. Examining the 50 specimens, it was possible to distinguish two main morphae:

Periaulax rhysum m. margaritatum (41 specimens well preserved). Shell with higher spire, and protoconch with small nucleus.

Ornament. First teleoconch whorl with spiral ribs, developing in the older stages into the main carinae and secondary costellae. Carinae prominent. Growth rugae well developed. Marked basal spiral costae. Umbilicus with marked axial costae and weak spiral costellae, fading with the number of whorls. Protoconch with microcostellae (Figs. 64-67). Periaulax rhysum m. laevigatum (10 specimens in different states of preservation). Shell with shorter spire, and larger protoconch nucleus (Figs. 68-71).

Ornament. Growth range generally faint to obsolete. Only the adapical and the circumumbilical carinae beaded, finer and smooth the others; the middle carina very faint in some cases. Spiral costae from faint to obsolete; basal spiral costae from partly to entirely obsolete. Protoconch with almost obsolete spiral costellae.

The direct comparison with specimens of P. spiratum (Lamarck), the type species, revealed similar variability from nearly smooth surface to weak axial and spiral ornament with beads at the adapical carina and very faint spiral costae; the umbilical spiral cord also shows variability, particularly in size.

The two morphae of P. rhysum are linked by transitional forms. The silicified specimens from Maslin Bay are too badly preserved to refer them to either of the morphae.

The Middle Eocene Claibornian specimen, figured by Van Winkle Palmer (1937, pl.78, fig.13) as Solariella cancellata (Conrad), shows close affinity with P. rhysum.

DISTRIBUTION. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore (type-locality). Willunga SubBasin: Maslin Bay; Blanche Point.

STRATIGRAPHIC RANGE. Blanche Point Formation, upper 'Transitional Marls' - 'Soft Marls' (early to middle P16).

GENUS *Olivia* Cantraine, 1835

Olivia sp. nov.

FIGS 72-73

MATERIAL. 4 specimens of which only one well preserved (SAM P21274 A-B)

DESCRIPTION. Shell small, thick, turbiniform, rather high spired; whorls increasing slightly more in height than in diameter; whorl overlapping: normal to the coiling axis, total; parallel to the coiling axis up to the middle-abapical connection. Suture flush to canaliculate. Abaxial margin regions: adapical rather wide, declivous, convex; middle subvertical, subconvex; abapical subdeclivous, convex. Region connections: adapical-middle imperceptible; abapical-middle angular. Base concave, anomphalous. Peristome subcircular-ovoidal, slightly higher than larger. Lips: adaxial-adapical thin, flattened; adaxial abapical thick, concave with two teeth, the abapical one very protruding; abaxial abapical thick, concave with 6 long spiral denticles, the adaxial one the most protruding; abaxial concave, with 5-6 denticles. Lip connections: adapical adaxial-abapical angular, producing a broad gutter; adaxial adapical-abapical angular; imperceptible all the others.

Protoconch. 1 homeostrophic whorl, smooth, separated from the teleoconch by a sharp irregular cicatrix.

Ornament. Prosocline axial costae; spiral protruding ribs. At rib-costa intersection, axially elongated sharp beads. In the teleoconch first whorl, axial ornament primary with vermiculate spiral microcostellae; in older stages, spiral ornament primary. Body whorl interior: spiral striations in younger stages; vermiculate pattern, in older stages, produced by the irregular shape of denticles (straight, bent, arborescent) and by other irregularities.

OBSERVATIONS. This form is referred to *Olivia* Cantraine because of the two prominent teeth on the adaxial lip.

Because of its inner striations, ornaments and suture,iit is possible that the specimens figured as *Basilissa cossmanni* Tate by Cossmann

(1918, pl. 8, figs. 59-63, pl. 10, fig. 34) could be juveniles of a form referable to Olivia and close to the species here described, from which it differs in number of spiral costae and in higher spire.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore.

STRATIGRAPHIC RANGE. Blanche Point Formation (late P15-middle P16).

GENUS Basilissa Watson, 1879

SUBGENUS Basilissa s. str.

Basilissa (Basilissa) cossmanni Tate, 1894

1894 Basilissa cossmanni Tate, p. 185, pl. 11; fig. 8-8a.
FIGS 74-80

MATERIAL. 14 damaged specimens, 1 silicified from outcrops; 13 damaged juveniles, 4 very well preserved specimens (GSSA); the holotype (SAM T1725).

DESCRIPTION. Shell minute, trochiform, rather high spired; whorls increasing more in diameter than in height. Whorl overlapping: normal to the coiling axis, total; parallel, up to the middle abapical connection. Suture flush. Body whorl shape subrhomboidal. Abaxial margin regions: adapical and middle undifferentiated, flattened, very declivous; abapical subconvex, subdeclivous. Region connections: adapical-middle imperceptible; abapical-middle very angular, keeled. Base flattened, with wide deep umbilicus; peristome subtrapezoidal. Lips: adaxial adapical very thin, subconvex; adaxial abapical concave, thick, inflected, with an abapical tooth, both limiting a deep broad notch; abaxial thick, subconvex, with an adapical tooth, innerly limiting a wide shallow notch.

Protoconch. One homeostrophic whorl irregularly latticed, separated by a varix from the teleoconch.

Ornament. Axial. Growth lines; basal opisthocyrt; abaxial orthocline sinusoidal. Fine microcostellae on the base and costellae on the abaxial margin. Spiral. 7 abaxial primary ribs: 1-7 intercalated by a secondary microriblet; between the 5th and 6th a broader interspace with two very fine tertiary microriblets; 6th and 7th prominent, producing the carina. Rounded beads at primary rib-costella intersections. Micropustulae in interspaces. Base with spiral smooth riblets. Umbilicus smooth on the interior, but bound by a heavily beaded cord.

OBSERVATIONS. The rediscovered holotype of Basilissa Cossmanni revealed that Cossmann figured as B. cossmanni specimens related to completely different genus and species, probably referable to Olivia Cantraine (Cossmann, 1918, p. 268, pl. 8, fig. 59-63; pl. 10, fig. 34). B. radialis (Tate), plesiogenotype of Basilissa Watson (Cossmann, 1818, p. 268, pl. 8, fig. 55-56; pl. 9 fig. 45), differs from B. cossmanni in crenulated basal spiral ribs, weaker beads of the circumumbilical cord, finer abaxial ornaments - spiny beads, axial and spiral ribs, absence of secondary and tertiary microriblets - and more sinusoidal growth lines.

STRATIGRAPHIC RANGE. Late Eocene. Blanche Point Formation ('Transitional Marls' - Gull Rock Member) (late P15-middle P16), Buccleuch Beds (P16/17-P17).

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; Adelaide Childrens Hospital Bore 5, 24.28-23.95 m, 20.67-20.34m depths, and Bore 1, 23.95-23.62 m depth. Willunga SubBasin; Maslin and Aldinga Bays (Blanche Point Formation). Murray Basin: Waikerie Bore 2, 228.02-226.38 m depth (Lower Buccleuch Beds).

INCERTAE SEDIS

Gastropoda gen. and sp. ind.

FIG. 81

MATERIAL. 1 worn specimen, with damaged peristome (GSSA M3447)

DESCRIPTION. Shell small, thick, trochiform, rather high spired; whorls increasing more in height than in diameter; whorl overlapping: parallel to the coiling axis up to the middle adapical region; normal, total. Body whorl shape subrohomboidal. Suture impressed, subcanaliculate. Abaxial margin regions: adapical and middle undifferentiated, convex, very declivous; abapical declivous, subconvex, Region connections: middle abapical sharply angular, carinated. Base convex, with very narrow umbilicus. Lips: adaxial adapical very thin, convex; adaxial abapical, thick, concave, with a narrow callosity partly obscuring the umbilicus. Adaxial adapical-abapical lip connection angular.

Protoconch. worn out (?)

Ornament. Prosocline faint rugae and growth lines. Marked spiral rib at the carina; faint circumumbilical funicle; axial costellae on the interior of the umbilicus.

OBSERVATIONS. This form shows some shell affinity with *Cithna angulata* Hedley (Cotton, 1959, p. 237, fig. 160) from which it differs at least in shorter spire. Because of its preservation it is impossible to reach a definite determination at species and generic level.

STRATIGRAPHIC RANGE. Late Eocene (Buccleuch Beds, lower part)

DISTRIBUTION. Murray Basin, Waikerie Bore 2, 228.02-226.38 m depth.

SUBFAMILY CALLIOSTOMINAE Thiele, 1924

GENUS *Calliostoma* Swainson, 1855

SUBGENUS *Fautor* Iredale, 1924

Calliostoma (Fautor) allasinazi sp. nov.

FIGS. 82-85.

DERIVATION OF THE NAME. After Professor Andrea Allasinaz, C.N.R. palaeontologist, Instituto di Paleontologia, Università degli Studi, Milano.

HOLOTYPE. SAM P 18345-A, Fig. 85

PARATYPES. SAM P 18345-B-F, Figs. 82-84

TYPE LOCALITY. Blanche Point, at Maslin Bay, Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. Tortachilla Limestone (early P15, Late Eocene).

STRATIGRAPHIC RANGE. Late Eocene (P15-P17)

MATERIAL. The holotype; 1 rubber cast; 13 specimens and (4 silicified) from outcrops; 20 specimens (paratypes) from Tate Collection; 3 specimens from GSSA Collections.

DESCRIPTION. Shell coeloconoid, rather high spired, suture grooved; whorl overlapping up to the middle-abapical connection; suture flush; abaxial margin flattened, very declivous. Base flat, abaxially bound by a double carina; umbilicus absent. Body whorl shape and peristome subtrapezoidal. Lips thin, straight; lip connections sharply angular; adaxial lip subcallous.

Protoconch. 1 whorl homeostrophic, latticed, separated from the teleoconch by a varix.

Ornament. Pronocline growth lines. 5 very fine crenulate spiral ribs alternating in the middle abapical region with 4 secondary smooth riblets; Base with smooth marked spiral ribs except the two circum-umbilical headed growth lines regularly developing in costellae; at costellae-rib intersections small round beads; abapical carina crenulated.

Dimensions (mm).:

No. spec.	No W	Ht	Hlw	Lis	Dmx	Hlw/Ht	K	Dm/Ht	Hlw/D
P-18345-c	7	8.20	5.10	1.85	6.80	.6219	.3627	.8292	.7500
P-18345-d	6	6.25	3.80	1.60	5.35	.6080	.4210	.8560	.7103
P-18345-e	6	5.00	2.75	1.30	4.10	.5500	.4727	.8200	.6707
P-18345-f	6	5.00	2.95	1.35	4.55	.5900	.4576	.9100	.6484

OBSERVATIONS. Though worn, the holotype was chosen because it is one of the few specimens stratigraphically well located and represents a senile individual. The other specimens from outcrops are a poor cast and too deformed or too fragmented to represent this new species adequately. The absence of umbilicus places this form in Calliostoma Swainson, and the coiling and the ornament pattern into Fautor Iredale. In the uncatalogued part of the Tate Collection more than 20 specimens were found in the same box labelled as "Calliostoma sp." and as being from Adelaide (Kent Town) Bore and from unknown levels of Tintinara and Kiki Bores. The specimens from the latter two bores are too fragmented for a definite diagnosis. Those from Adelaide Bore show variation in more pronounced carinae and concave margins, but the ornament is the same.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, 20.57-20.34 m, 24.28-23.95 m, and 24.60-24.28 m depths. Willunga SubBasin, Maslin Bay and Blanche Point (Tortachilla Limestone-Blanche Point Formation). Murray Basin, Waikerie Bore 2, 228.02-226.38 m depth (Lower Buccleuch A equivalent).

FAMILY	TURBINIDAE Rafinesque, 1815
SUBFAMILY	ASTRAEINAE Davies, 1933
GENUS	*Guildfordia* Gray, 1850
SUBGENUS	*Pseudastralium* Schepman, 1908

Guildfordia(Pseudastralium) maslinensis sp. nov.

FIGS 86-97

DERIVATION OF NAME. From Maslin Bay, locality of the oldest occurrence.

HOLOTYPE. SAM P18346B, Figs. 86-88.

PARATYPES. SAM P18346A,C-J, L-X; GSSA M 3448, Figs 89-97.

TYPE FORMATION. Blanche Point Formation.

TYPE LOCALITY: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore.

STRATIGRAPHIC RANGE. Late Eocene.

MATERIAL. The holotype , 1 rubber cast ; 23 specimens generally badly preserved and 13 opercula from Tate's collection.

DESCRIPTION. Shell turbinate, rather high spired with whorls scarcely overlapping and increasing more in diameter than in height. Suture very impressed. Outer margin angular with adapical region (sutural ramp) broad, flattened, and declivous and abapical region steep and narrow connected each other by a very protruding and sharp carina. Base flattened, with angular carinated periphery. Outer shape of the body whorl sub-polygonal, inner shape subcircular. Peristome subcircular with lips: abaxial very elliptical; abapical flattened; columellar very elliptical, callous with lobe covering completely the umbilicus; parietal thin, elliptical. Lip connections imperceptible but the abaxial-abapical and the columellar-abapical angular, the latter marked also by a short shallow spiral furrow.

Ornament. 4 spiral beaded cords on the adapical region; prominent sharp middle carina bearing long prorsiradiate spines; on the middle region two spiral cords beaded in juvenile and adult stages, spiny in the senile. Base in juvenile stage with axial riblets fading to the periphery; in adult and senile smooth.

Operculum. Oval, very thick, plano-convex, with juvenile spire increasing very slowly and adult one more abruptly ; inner surface with peripheral mounds, smooth otherwise.

Protoconch. One whorled, pustulate, pseudoplanispiral

Dimensions (mm):

No spec.	No w	Ht	Hlw	Lis	Dmx	Hlw/Ht	K	Dmx/Ht	Hlw/Dmx
P-18346-b	6	12.90	9.30	4.35	13.10	.7209	.4677	1.0155	.7099
P-18346-c	6	11.80	8.40	3.10	10.60	.7119	.3690	1.8983	.7925
P-18346-d	6	10.40	7.70	2.90	10.70	.7404	.3766	1.0288	.7196
P-18346-e	6	9.55	7.00	2.60	9.70	.7330	.3714	1.0157	.7216
P-18346-f	6	10.25	7.75	2.90	11.25	.7561	.3742	1.0976	.6889
P-18346-g	7	16.90	11.50	5.05	15.25	.6805	.4391	.9024	.7541

OPERCULA	No W	Ht	D	T	Ht/D	T/D	T/H
P-18346-l	8	5.95	5.10	2.50	1.1667	.4902	.4202
P-18346-m	8	6.45	5.65	2.60	1.1416	.4602	.4031
P-18346-n	8	5.50	4.75	2.15	1.1579	.4526	.3909
P-18346-o	8	5.80	5.05	2.60	1.1485	.5149	.4483
P-18346-p	8	5.50	4.75	2.10	1.1579	.4421	.3818
P-18346-q	8	5.35	4.65	1.85	1.1505	.3978	.3458

(continued ..)

OPERCULA (continued)

	No W	Ht	D	T	Ht/D	T/D	T/H
P-18346-r	8	5.50	4.70	2.25	1.1702	.4787	.4091
P-18346-s	8	5.95	4.95	2.25	1.2020	.3782	.4545
P-18346-t	7	4.50	3.95	1.70	1.1392	.4304	.3778
P-18346-u	8	4.50	3.90	1.65	1.1538	.4231	.3667
P-18346-v	7	2.90	2.65	1.25	1.0943	.4717	.4310
P-18346-x	7	3.50	3.10	1.50	1.1290	.4839	.4286

OBSERVATIONS. For lack of better material the best specimen from the Adelaide Bore material was chosen as the holotype. The stratigraphic range of this form is controlled by findings from other bores and from outcrops.

Protoconch, coiling, body-whorl, operculum, ornament and spine patterns are similar to those of the extant Guildfordia (Pseudastralium) henicus-gloriosa Kuroda & Habe (Japan, Tosa, Shikoku, SAM T D 14395) and, therefore, this form is placed in Pseudastralium Schepman.

In Tate's uncatalogued material some specimens of another form, referable to Pseudastralium, from the Late Oligocene-Early Miocene 'Spring Creek, were found. This form (SAM P 18346-K) seems to be a descendent of P.maslinensis sp. nov., differing from it in higher spire, narrow adsutural ramp, and subdued beaded cords adapical to the carina. Guildfordia Gray and Pseudastralium Schepman have hitherto been recorded from the Pliocene and from the Holocene, respectively. With the finding of P. maslinensis, the stratigraphic ranges of both the genus and the subgenus are extended far back to the Late Eocene.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; E & W S Bore 5, 59.13-66.45 m depth; Adelaide Childrens Hospital, Bore 5, 24.28-23.95 m, 23.95-23.62 m, 22.31-21.98 m, 21.65-21.33 m depths. Willunga SubBasin: Maslin Bay ('Uncle Tom's Cabin'). Murray Basin, B.Q. Butler Bore 4, 125.0-118.77 m depth.

STRATIGRAPHIC RANGE. Tortachilla Limestone-Blanche Point Formation (early P15-middle P16), Buccleuch 'A' Beds (P16/P17-P17).

SUBFAMILY LIOTIINAE H. & A. Adams, 1844

GENUS *Liotina* Fischer, 1885

OBSERVATIONS. *L. (Liotina) gervillei* Defrance, type of *Liotina* s. str., has 4 whorls variably coiled from pseudoplanispiral to helicospiral. Therefore, the whorl overlapping is variable too. Parallel to the coiling axis, it is total in neanic stages to scarce in senile stages. Normal to the coiling axis, it is just the opposite. Suture from flush to impressed. Body whorl shape inner subcircular, outer polygonal. The narrower umbilicus the older the stage. Two umbilical funicles: the former abapical circumumbilical, low spired, elevated, thick, nearly detached; the latter, inner high spired, thinner, adaxial. Lip varix in the senile stages with a circumoral crown-like ring.

Ornament. Axial prosocline. Primary costae and tertiary micro-costellae; secondary spiral costellae (Keen *et al*., 1960, p. I267, fig. 171-11; Cossmann, 1918, p. 26, pl. 1, fig. 13-4).

SUBGENUS *Austroliotia* Cotton, 1948

DIAGNOSIS. Coiling and overlapping as in *Liotina* s. str. Body whorl shape: inner subcircular; outer rounder than in *Liotina* s. str. Umbilical funicles absent or, at least, the circumumbilical is represented by a more developed spiral costa, similar to the others. Lip varix reduced with the circumoral ring very marked. Ornament pattern as in *Liotina* s. str. Operculum horny, multispiral, with a granular layer between inner and outer surfaces (Laseron, 1954; Cotton, 1948, 1959).

OBSERVATIONS. Austroliotia, instituted as genus by Cotton, is referred as subgenus of Liotina Fischer by Keen et al., (1960). The Patagonian Liotia scotti (Ortmann, 1902, p. 162, pl. 30, figs. 10a-c) of ?Early Miocene age (Feruglio, 1949) shows congeneric affinities with Austroliotia. The Australian fossil species of Austroliotia Cotton are poorly known. The Early Miocene A. roblini (Johnston) is the only described form, although unfigured. The form from Muddy Creek figured and described by Harris (1897, p. 284, pl. 8, fig. 4) is to be separated and referred to as a new species. The holotype of A. roblini is one of the lost types of the Johnston collection in the Tasmanian Museum (Ludbrook, 1967). A large sample, found in the Tate collection, and still kept in the Geology Department of the Univeristy of Adelaide supplied 2 topotypes of A. roblini, a juvenile and a broken senile. Two other topotypes from GSSA Collections are in no better condition. Thus, no available specimen is suitable as the neotype. The other specimens from the sample are from Muddy Creek, Murray River and Schnapper Point, but unfortunately they were initially mixed up by Tate himself, therefore they cannot be used for instituting the new species which they represent. Other specimens are unlabelled and from unknown locality. Another specimen representing a different species is labelled "Flinders River, Gippsland", an unidentifiable locality at present. The three latest Eocene species here described represent the oldest record of the subgenus.

The Late Eocene A. intermedia sp. nov. , the Early Miocene A. roblini (Johnston) (Johnston, 1880, p. 39) and the Recent A. botanica (Hedley) (Hedley, 1915, p. 710, pl. 81, fig. 46-48) appear to belong to the same lineage. The mixed specimens from Muddy Creek, Murray River and Schnapper Point represent at least one species, Austroliotia sp. nov. A, (?Middle Miocene- ?) and the specimen from Flinders River, another different one, Austroliotia sp. nov. B, (Neogene - ?). Both latter species belong to the A. intermedia stock. Notwithstanding the confusion in Tate's specimens, it is possible to draw some general conclusions on the evolutionary trends within this lineage.

From the Late Eocene to the Present: -

- in the third and fourth whorl, the whorl spire becomes higher and consequently the overlapping decreases;
- the diameter of the umbilicus varies, but tends to become wider in the younger form.
- the number of the spiral costae varies species by species, but shows some relationships with the diameter of the umbilicus; the narrower the latter the more numerous the costae;
- the axial-spiral costa intersections become more spiny the younger the form;
- the overall shell size increases the younger the form but the number of whorls remains constant;
- spiral microcostellae appear on the axial costellae from the Neogene to the extant forms; in _A. roblini_ they are present only in the adoral part of the last senile whorl;
- the secondary axial costellae become more and more lamellose the younger the form; their shape between spiral interspaces varies from very opisthocyrt in all the interspaces to less opisthocyrt in the middle-adapical regions, and straight or gently ondulating on the other regions; in the specimen from "Flinders River" these lamellae become imbricated and bent to the adoral.

Liotina (Austroliotia) intermedia sp. nov.

FIGS 98-102

DERIVATION OF THE NAME. From the Latin _intermedius_, intermediate, because of the dimension of its umbilicus in relation to the other species here described.

HOLOTYPE. GSSA M 3449, Figs. 98-99

PARATYPES. GSSA M 3450-51, Figs. 100-102

TYPE-LOCALITY. B. Q. BUTLER BORE 4, Hd Kirkpatrick, sec. 8,125.00-118.77 m depth.

TYPE FORMATION. Buccleuch 'A' Beds, lowermost part (Buonaiuto, in prep.) (topmost Knight Group of Ludbrook, 1969).

STRATIGRAPHIC RANGE. Latest Eocene, P16/17-P17.

MATERIAL. 34 specimens generally worn.

DESCRIPTION. Shell small, turbiniform, low spired. 4 whorls with variable coiling: in younger stages pseudoplanispiral with overlapping complete parallel to the coiling axis, little normal to it; in older stages low helicospiral with overlapping up to the middle-abapical connection parallel to the coiling axis, complete normal to it. Suture from flush to impressed. Margins all polygonal. Margin connections: all angular. Body whorl shape: inner subcircular; outer polygonal. Perit Peristome polygonal, base with wide deep umbilicus. Lip varix present in adult-senile stages, very thick except the adaxial-adapical (parietal) lip by far thinner.

Ornament. 11 protruding heavy spiral costae, all around the body whorl; regular axial orthocline rugae, just finer than the spiral; fine axial ondulating prosocline microcostellae, in the spiral interspaces opisthocyrt, Beaded ruga-costa intersections. The abapical circum-umbilical costa the most developed.

Protoconch. pseudoplanispiral, homeostrophic, paucispiral with axial costellae, indistinct from teleoconch.

OBSERVATIONS. The specimens of L. (Austroliotia) intermedia show that the lip varix appears only in the 4th whorl, the adult-senile stage.

L.(Austroliotia) stricta sp. nov.

FIGS 106-110

DERIVATION OF THE NAME. From the Latin strictus, narrow, because of its umbilicus narrowing with the age.

HOLOTYPE. GSSA M3452, Fig. 106-108.

PARATYPE. GSSA M 3453, Figs. 109-110.

TYPE LOCALITY. B.Q. Butler Bore 4, hd Kirkpatrick, sec. 8, 125.00-118.77 m depth.

TYPE+FORMATION. Buccleuch 'A' Beds, lowermost part (Buonaiuto, in prep.) (topmost Knight Group of Ludbrook, 1969)

STRATIGRAPHIC RANGE. Latest Eocene (P16/17-P17)

MATERIAL. 3 specimens, the holotype very well preserved.

DESCRIPTION. Like *A. intermedia*. It differs in higher spire, narrower umbilicus, which in senile stages is completely obscured by the body whorl. The lip varix is reflected aborally and adherent to the body whorl. The circumoral ring is reduced. The holotype, a senile specimen, displays 5 whorls.

Ornament. Wide asymmetric prosocline axial rugae with the wider flank in the growth direction. 13 spiral costae on the entire body whorl. Fine high prosocline axial costellae regularly interspaced.

OBSERVATIONS. The absence of the umbilical funicles and the type of lip varix place this form in *Austroliotia* Cotton.

L.(Austroliotia) ampla sp. nov.
FIGS 103-105

DERIVATION OF THE NAME. from the Latin *amplus*, wide because of its wide umbilicus.

HOLOTYPE. GSSA M3454, Figs 103-104.

TYPE LOCALITY. B.Q. Butler Bore 4, Hd Kirkpatrick, sec. 8, 125.00-118.77 m depth.

TYPE FORMATION. Lowermost Buccleuch 'A' Beds (Buonaiuto, in prep.) (= topmost Knight Group of Ludbrook, 1969).

STRATIGRAPHIC RANGE. Latest Eocene (P16/17-P17)

MATERIAL. 4 worn specimens.

DESCRIPTION. Very close and similar to *A. intermedia*. It differs in lower spire, wide umbilicus, reduced lip varix, and number of whorls, 3 instead of 4. Protoconch like in *A. intermedia*.

Ornaments. 8 spiral costae; axial prosocline rugae; between axial interspaces fine prosocline microcostellae separated by narrower interspaces. Beaded costa-ruga intersections. Both costae and rugae thicker than in *A. intermedia*. The circum-umbilical costa is very well developed and similar to the abapical one in *L. (Liotina) gervillei* Defrance.

OBSERVATIONS. This species shows some affinities with the Eocene Parisian *Liotina warni* Defrance (Cossmann, 1918, p. 26, pl. 1, fig. 10-12), but differs substantially in the absence of an umbilical funicle, which in the latter species is overdeveloped, normal to the coiling axis. The small size and the pseudoplanispiral shell cause *A. ampla* to be easily mistaken for *A. intermedia*.

GENUS *Cycloliota* gen. nov.

DERIVATION OF THE NAME. Composite from the Greek κύκλος, circle because of the circular inner shape of the body whorl, and *Liotia* name of the type-genus of Liotinae, the subfamily to which it is referred.

TYPE SPECIES. *Cycloliotia hyotis* sp. nov.

STRATIGRAPHIC RANGE. Late Eocene.

DIAGNOSIS. Shell small turbiniform, very thick. Coiling as in *Liotina* Fischer: pseudoplanispiral in younger stages, gradually changing into low helicospiral in adult-senile stages. Whorl overlapping: parallel to the coiling axis, total in neanic stages, gradually decreasing in adult-senile ones to just below the middle-adapical connection, with nearly evolute whorls; normal to the coiling axis, in neanic stages rather evolute with subtangent whorls, in adult-senile ones gradually increasing to total. Suture from flush in juvenile to impressed-subcanaliculate in older stages. Body whorl shape: outer subcircular; inner circular. Base concave, with deep narrow subcylindrical umbilicus. Peristome subcircular with very developed deep socket. Lips: all concave and thick, except the adaxial straight. Lips connections: adapical and abapical adaxial-abaxial angular; imperceptible the others. Peristome socket with radial furrows corresponding to the spiral costae.

Protoconch. 1-2 smooth whorls, pseudoplanispiral, homeostrophic with the initial teleoconch.

Ornament. Prosocline growth lines and secondary axial costellae; primary spiral costae.

OBSERVATIONS. This form does not appear to fall entirely into any turbinid genus. It shows closer affinities with *Liotina* Fischer in the variable coiling, shell thickness, protoconch, and body whorl inner shape. But it differs from it in having a wider umbilicus and an absence of umbilical funicles and double lip varix. The peristome is somewhat similar to *Pareuchelus* Boettger.

The coiling and the umbilicus resemble *Moelleria* Jeffreys (Homalopomatinae) but the latter's shell is thinner, its ornament pattern is axial and its growth lines are orthocline.

In conclusion, *Cycloliotia* gen nov. is placed into Liotinae H. & A. Adams by its type of coiling and protoconch, because of their close similarity to those of *Liotina*, but it is considered distinct from it because of the absence of umbilical funicles and lip varix, and presence of peristomial socket. At the present, only the type species is referred to this genus.

Cycloliotia hyotis sp. nov.

FIGS. 111-113

DERIVATION OF THE NAME. From hyotis, hyote, because of the type of spines(Stenzel, 1971).

HOLOTYPE. SAM P 21274, Figs. 111-112.

PARATYPE. SAM P 21275, Fig. 113

TYPE LOCALITY. Adelaide (Kent Town) Bore, Adelaide Plains SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation

STRATIGRAPHIC RANGE. Late Eocene (late P15-Middle P16).

MATERIAL. The holotype with damaged protoconch, and the worn paratype.

DESCRIPTION. See the above generic diagnosis.

Ornament. Prosocline growth lines and microcostellae marked in the spiral interspaces and weaker to absent on the spiral costae. Thick, protruding spiral costae producing regular subperpendicular pseudoimbricate hyote-like spines. Very weak spiral costae (at least one) and marked axial costellae inside the umbilicus.

OBSERVATIONS. Though it is still impossible to locate exactly within the Blanche Point Formation the horizon from which the two specimens were taken,it was decided to institute a new genus and species, since no other material is available. The types were found in the huge uncatalogued part of the Tate Collection, which is still kept in the Department of Geology, University of Adelaide.

SUBFAMILY	HOMALOPOMATINAE Keen, 1960
GENUS	?Homalopoma Carpenter, 1864
SUBGENUS	?Cantrainea Jeffreys, 1883

?Homalopoma (?Cantrainea) ancestralis sp. nov.

FIGS. 114-116

DERIVATION OF THE NAME. From the Latin ancestralis, ancestral, being the oldest known form.

HOLOTYPE. GSSA M 3455, Fig. 114

PARATYPE. GSSA M 3456, Fig. 115-116.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital, Bore 5, 23.95-23.62 m (holotype) and 21.98-21.65 m (paratype) depth.

TYPE FORMATION. Blanche Point Formation (Aldingan).

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. 2 specimens, with last whorl damaged (1 juv., 1 senile).

DESCRIPTION. Shell minute, turbiniform, rather high spired. Whorls increasing slightly more in diameter than in height. Whorl overlapping: normal to coiling axis, total; parallel,up to the middle abapical connection. Suture impressed. Body whorl shape subcircular. Margins: abaxial adapical narrow, flat, subdeclivous; abaxial middle subconvex, broader, very declivous; abaxial abapical subconvex very wide. Abaxial margin connections: adapical-middle angular; abapical-middle angular, carinated. Peristome subrhomboidal in younger, rounder in adult senile stages. Base concave, with a narrow umbilicus covered by a narrow concave callosity. Lips: adaxial adapical convex, thin; adaxial abapical with narrow subdetached lobe;

Protoconch. 1 homeostrophic smooth whorl, separated from the teleoconch by a varix; pustulae on the nucleus, developing into spiral costellae.

Ornament. Very prosocline growth lines, adsuturally slightly retroflected. Regular spiral flat costae, separated by narrower interspaces, the middle costae more marked.

OBSERVATIONS. This form is referred to Cantrainea Jeffreys, although with some reservation. Growth lines, body whorl shape, type of coiling, and peristome morphology are consistent with the diagnosis given by Cossmann (1918). Yet, this species has a shell convergent to Timisia Jekelius, particularly in the younger stages. Unfortunately, the only available illustration (Keen, in Moore, 1960, p. I 251, fig. 161-12a,b) does not show the umbilical morphology well and no diagnosis is given.

Nevertheless should this form belong to either genus, the stratigraphic range would be extended back to the LateEocene, and this species would represent the first record outside the Tethys.

Cantrainea Jeffreys (*Cantrainia, nom. incorrect.,* Cossmann, 1918) was referred as subgenus to *Leptothyra* Pease by Cossmann (1918) and to *Hopalopoma* Carpenter by Wenz (1939) and Keen (*in* Moore, 1960).

GENUS *Vexinia* Cossmann, 1918

Vexinia callosa sp. nov.

FIGS. 117-120

DERIVATION OF THE NAME. From the Latin *callosus*, callous, because of its columellar callus.

HOLOTYPE. GSSA M 3457, Figs. 117-118

PARATYPE. GSSA M 3458, Figs. 119-120.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, 24.28-23.95 m depth.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. 5 specimens well preserved (GSSA); 11 specimens from outcrops.

DESCRIPTION. Shell minute, turbiniform, low spired; whorls increasing more in height than in diameter, variable coiling. Whorl overlapping: normal to the coiling axis, total; parallel, up to the middle adapical connection in younger stages, up to the middle abapical connection in older ones. Body whorl shape guttiform. Suture adpressed. Abaxial margin regions: adapical subvonvex, from rather declivous in young stages to very declivous in senile ones; middle narrow convex, subvertical; abapical subconvex, gently declivous. Region connections: middle adapical rounded; middle-abapical subangular. Peristome drop-shaped with broad deep adapical gutter. Base subconvex with narrow umbilicus, in many specimens obscured by the callus. Lips: abaxial adapical straight; adaxial middle convex; abapical subconvex; adaxial abapical, with short, thick callus; adaxial adapical thick subconvex. Lip connections: adapical adaxial-abaxial very angular; rounded the others. At the adaxial abapical end an auriform callosity.

Protoconch. Smooth undifferentiated, homeostrophic, paucispiral.

Ornament. Fine prosocline growth lines; weak adsutural costa.

OBSERVATIONS. This form was referred to *Vexinia* Cossmann because of its coiling, growth lines, body whorl shape, peristome morphology and the more or less obscured umbilicus. Direct comparison with specimens of *Vexinia crassa* (Baudon), the type species, confirmed this determination. *V. callosa* sp. nov. differs from *V. crassa* in a thicker columellar lip and the presence of callus.

DISTRIBUTION. Type-locality, but at 24.93-24.60 m, 23.62-23.69 m, 20.67-20.34 m depths. Willunga SubBasin; Blanche Point, at Aldinga Bay (Gull Rock Member).

FAMILY CYCLOSTREMATIDAE Fischer, 1885

SUBFAMILY SKENEINAE Thiele, 1929

GENUS *Crossea* A. Adams, 1865

Iredale (1924, p. 251) distinguished two genera from *Crossea* Adams: *Crosseola*, type *C. concinna* Angas, 1868 (living); and *Dolicrossea*, type *C. labiata* T. Woods (living). However, Iredale,as usual, did not give any diagnosis of these two subgenera. The only available diagnoses are found in Cotton (1959) and in Keen (*in* Moore, 1960). Successively, *Crosseola* and *Dolicrossea* were synonymized to *Crossea* by Wenz (1938), restored by Cotton (1959) as distinct genera, and referred by Keen (1960) to *Crossea* as subgenera

Circumbilical cord, adapical and abapical gutters, sutures, body whorl shape, coiling and whorl overlapping differentiate these three taxa neatly,

TABLE VIII

COMPARATIVE SYNOPSIS OF THE MORPHOLOGICAL CHARACTERS IN THE SUBGENERA OF CROSSEA ADAMS

TAXA / MORPHOLOGY		*Crossea* Adams s.str.	*Crosseola* Iredale	*Dolicrossea* Iredale
SHELL SIZE		small	*idem*	*idem*
Whorl translation rate		very high	high to very high	lower to very high
Whorl departing rate		scarce	high	scarce
Whorl expansion rate		low	very high	high
Whorl overlapping rate (in relation to the coiling axis)	//	up to the middle-abapical connection	From as in *Crossea* to evolute (no whorl tangency)	up to the abapical middle margin
	⊥	total	total	total
Suture		impressed	from flush to no suture	from flush to adpressed
Body whorl shape		subcircular	subovoidal as wide as high (adaxial flattened	ovoidal higher than wide
Peristome and umbilicus morphology		very narrow umbilicus, simple peristome, marked circumumbilical cord, simple abapical gutter, at abapical-adaxial lip connection, no apparent adapical gutter	peristome simple or with socket, umbilicus narrow to wide, very prominent circumumbilical cord, adapical and abapical gutters, axial sulcus or cavity in the abapical adaxial margin between the inner and outer parts of the peristome	peristome simple, umbilicus wide, circumumbilical cord prominent to faint, faint inner umbilical funicle, adapical and abapical gutters
LIPS	adapical adaxial	concave adherent	subconvex, subdetached to completely detached	subconvex, adherent
	abapical adaxial	concave	subconcave	concave
	abaxial	concave	concave	subconcave
	abapical	concave	concave	subconcave
	lip varix	present	absent	very developed
LIP connections	adaxial adapical-abapical	imperceptible	subangular	subangular
	adapical adaxial-abaxial	"	"	very angular
	abapical adaxial-abaxial	marked by the gutter only	marked by the gutter only	very angular
Protoconch		?	1-2 whorls smooth, homeostrophic, distinct from teleoconch by absence of ornament	1-2 whorls, smooth, homeostrophic, indistinct from teleoconch
ORNAMENT	axial	varices, prosocline growth lines	prosocline growth lines and costellae cancellate pattern in younger stages, punctate interspaces in older	prosocline growth lines and oral varices
	spiral	primary costae on the middle region, secondary costellae	costellae	costellae

yet gradually (see Table VIII). Therefore, Keen's classification here appears to be justified.

Observations on *C. (Crosseola) princeps* Tate, *C. semiornata* Tate, *C. cancellata* T. Woods, *C. concinna* Angas, *C. (Dolicrossea) lauta* Tate, *D. sublabiata* Tate, *D. labiata* T. Woods revealed the following.

A) *C. princeps* is a composite species, including the Late Eocene *C. antiqua* sp. nov., the Early Miocene *C. evoluta* the Middle Miocene *C. princeps*, the ?Pliocene *C. intermedia*.

B) The above species show close affinities and changes in their characters are transitional to each other.

C) The living *C. cancellata* T. Woods appears to be very close to the Late Oligocene-Early Miocene *C. semiornata* Tate; the latter differing in wider pits and in adapical middle carina.

D) The younger stages of *C. concinna* repeat either *C. antiqua-C. princeps*'s or *C. semiornata-C. cancellata*'s ornament patterns.

In conclusion, the above mentioned species represent a possible evolutionary lineage, in which *C. semiornata* is the heavily ornamented representative. The characters of cancellate ornament and carina seem to be regressive and reappear only in the extant species. They differentiate three possible morphae in *C. concinna*: *C. concinna m. laevigata* with rather smooth neanic whorls; *C. concinna m. punctuata*, with punctuated neanic whorls; *C. concinna m. carinata*, with cancellate and carinate neanic whorls. All these morphae are linked by transitional forms. Therefore it is suspected that *C. cancellata* T. Woods represents only younger stages of the above morpha *carinata*. Specific differences are to be found in the characters of the umbilical cord, and in the more or less evolute coiling. The main differences between the fossil and the living species are a thinning of the shell, the reducing of the peristome from double to simple, and the weakening of the columellar cavity to a sulcus in most specimens. (Some seniles of the living *C. concinna* still show a relict cavity). It is very difficult to draw conclusions about the ornament at a specific level for the fossil forms because of the dearth of material.

E) The holotype of *Dolicrossea lauta* (Tate) is a very worn specimen but bears close resemblance to *C. labiata* T. Woods.

The types of *D. sublabiata* (Tate) from Muddy Creek, considered by Cotton (1959) as subspecies of *D. labiata*, are all worn, though traces of spiral riblets are still shown. The specimen SAM T 807J from Table Cape may represent another species which differs in a pronounced middle adapical carina. Other possible differences or similarities cannot be ascertained because of the conditions of the types from Muddy Creek. However, this specimen differs from *D. labiata* in thinner lip varix, broader spiral costellae, marked middle adapical carina, presence of an abapical socket in the abapical adaxial lip, thinner and wider adaxial adapical lip, and narrower umbilicus.

In conclusion, it is possible that *D. lauta* Tate, *D. labiata* T. Woods and *D. sublabiata* Tate might represent a lineage. But, again, more material is needed to confirm this hypothesis.

SUBGENUS *Crosseola* Iredale, 1924

Crossea (Crosseola) antiqua sp. nov.

FIGS. 121-123

DERIVATION OF THE NAME. from the Latin *antiquus*, ancient.

HOLOTYPE. SAM T 806, figs. 121-123

TYPE LOCALITY. Adelaide (Kent Town) Bore, Adelaide Plains SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. The holotype, with damaged last whorl.

DESCRIPTION. Shell minute, turbiniform, globose, rather high spired; whorl diameter and height increasing at the same rate. Whorl overlapping: normal to the coiling axis, total; parallel to the coiling axis, up to the middle abapical connection. Body whorl shape subovoidal. Suture flush to subcanaliculate. Abaxial margin regions: adapical rather narrow flattened, rather declivous; middle wider subconvex, subvertical; abapical wide, convex, declivous. Region connections both rounded. Peristome subovoidal, double with the inner part separated from the outer by a furrow. Base concave with a very narrow umbilicus. Lips: adaxial-adapical thin, convex, subdetached; adaxial abapical concave, detached, slightly reflected to the umbilicus; abaxial-abapical ?concave; abaxial adapical and middle concave. Lip connections: adapical adaxial-abapical sharply angular, producing a gutter; adaxial adapical-abapical angular; abapical adaxial-abaxial sharply angular, bearing a shallow reflected gutter. Adaxial abapical lip morphology: inner and outer part of the body whorl detached and producing an axial spoon-like cavity; cavity bound by a loop-like rim produced by the outer part of the body-whorl; abapical gutter formed by the rim and the abapical end of the circumumblical cord.

Protoconch. 1 whorl, smooth, homeostrophic.

Ornament. Spiral flat costellae and prosocline flat riblets and growth lines; costella-riblet intersection producing punctuate interspaces. The older the stage the fainter the ornament, to disappear completely on the last whorl. Weak spiral adsutural funicle. Circumumbilical cord: prominent, crenulated by marked growth rugae, and bound adaxially and abaxially by a sulcus.

OBSERVATIONS. The holotype, initially mistaken by Tate for *Crossea princeps* Tate, is the only specimen known. *C. princeps* differs from *C. antiqua* sp. nov. in cavity morphology and in coiling (see relative descriptions).

Crossea (Crosseola) semiornata Tate, 1893

FIGS. 124-125.

1893 Crossea semiornata Tate, p. 317, pl. 10, fig. 10.

MATERIAL. Holotype and juvenile paratypes with last whorl damaged (SAM T810 A-B).

DESCRIPTION. Similar to C. antiqua sp. nov. It differs in adapical abaxial concave region, very faint vertical adaxial abapical sulcus, thinner lips, wider umbilicus, straight adaxial abapical lip.

Ornament. Neanic whorls cancellate; prosocline growth lines and very faint axial costellae, fading on the middle region in adult stages; spiral costae very developed on the adapical and on the adapical middle region, marked on the abapical and abapical middle region. Middle adapical carina produced by a very developed costa. Terminal last whorl smooth after a traumatic cicatrix, except than very reduced main adapical and middle spiral costa and carina still extant. Flat wide circumumbilical cord with heavy axial rugae on the adaxial side.

DISTRIBUTION. Otway Basin, Bird Rock Bluff.

STRATIGRAPHIC RANGE. Jan Juc Formation, Janjukian, Late Oligocene.

OBSERVATIONS. The juvenile paratype shows a finer axial costellae and a cancellate pattern on the entire whorl surface. The disappearance of the major part of ornament in the terminal last whorl of the holotype, after the cicatrix, could represent a traumatic degeneration of the individual. Further comparative observations on the paratype of C. semiornata and on specimens of C. striata Watson from Cairns Reef, North Queensland, which are kept in S.A. Museum Collections, revealed that Crosseola's umbilicus is characterized by a system of two funicles similar to that of Liotina gervillei Defrance. One funicle is inner, high spired, normally obscured by the reflected adaxial lip. The other is represented by the circumumbilical cord. The origin of the hollowed adaxial lip may be explained by the growing edge of the adaxial lip gradually covering the cavity between the adaxial margin and the inner funicle.

Crossea (Crosseola) evoluta sp. nov.

FIG 126

DERIVATION OF THE NAME. from the Latin evolutus, unrolled, because of its coiling.

HOLOTYPE. SAM T 806 G, fig. 126.

TYPE LOCALITY. Bass Basin, Table Cape, Fossil Bluff.

TYPE FORMATION. Freestone Cove Sandstone, Table Cape Group.

STRATIGRAPHIC RANGE. Early Miocene (N4/N5, Quilty, 1974).

MATERIAL. The holotype only.

DESCRIPTION. Similar to C. antiqua sp. nov. It differs in: far more evolute coiling; disjunct last whorl; very developed adsutural funicle, faded on the disjunct last whorl; less prominent and broader circumumbilical cord, bearing faint spiral costellae; adaxial lip cavity migrated to the interior margin of the peristome; adaxial lip reflected on the adaxial body whorl; peristome socket very faint to imperceptible.

Ornament. Punctuations only on the neanic whorls, adult and senile stages smooth with prosocline growth lines and rugae.

Crossea (Crosseola) princeps Tate, 1890

FIGS. 130-132

1890 Crossea princeps Tate, p. 220.

1892 Crossea princeps -Tate, pl. 8, fig. 6,6a.

MATERIAL. Two syntypes (SAM T 806C - figured, and 806D)

DESCRIPTION. As in C. antiqua sp. nov. It differs in: higher spire but shorter than in C. evoluta; marked peristome socket; wide adaxial lip cavity, wider than in C. evoluta; very prominent circumumbilical cord, crenulated by axial rugae.

Ornament Heavy punctuations in neanic whorls, the fainter the older the stage in successive whorls, to disappear completely on the last whorl. Adsutural funicle well developed.

OBSERVATIONS. C. princeps Tate is very close to C. antiqua, differing chiefly in the adaxial lip cavity which is on the other hand very similar to C. evoluta. The coiling is intermediate between these two species. Ornament pattern appears to be similar.

DISTRIBUTION. Otway Basin, Muddy Creek.

STRATIGRAPHIC RANGE. Muddy Creek Marls, Balcombian-Bairnsdalian, late Early-early Middle Miocene.

Crossea (Crosseola) intermedia sp. nov.

FIGS. 127-179

DERIVATION OF THE NAME. From the Latin intermedius, intermediate, because it shows intermediate characters between C. princeps Tate and C. concinna Angas.

HOLOTYPE. SAM T 806 B, fig. 127-129.

TYPE LOCALITY. Muddy Creek, Otway Basin.

TYPE FORMATION. Muddy Creek Marls or Grange Burn Coquiña (doubtful)

STRATIGRAPHIC RANGE. ?Middle Miocene-Pliocene (Kalimnan). The doubtful stratigraphic location does not allow a sure dating.

MATERIAL. Holotype and two paratypes (SAM T 806, B, A, F).

DESCRIPTION. Similar to C. princeps Tate. It differs in: higher spire; less overlapping; narrower umbilicus; circumbilical cord, covered by spiral costellae with punctuated interspaces; peristome socket absent.

Ornament. Covering the entire whorl surface, but the weaker the older the stage. Punctuations axially elongated in the terminal part of the last whorl. Adoral growth rugae. Adsutural funicle, bearing a few spiral costellae.

OBSERVATIONS. The paratypes only differ in smoother last whorls and in shorter spire. These differences are probably due to individual variations. The holotype shows a cicatrix of traumatic origin on the terminal last whorl. *C. intermedia* displays transitional characters between *C. princeps* and *C. concinna*. *C. concinna* differs from it in shorter spire and presence of ornament on the entire shell surface and in its heavily cancellate and carinate neanic whorls.

OTHER LOCALITIES. Murray Basin, Murray River Cliffs (SAM T 806 F)

Crossea (Crosseola) concinna Angas, 1867

1867 *Crossea concinna* Angas, p. 911, pl. 44, fig. 14 (*non vidi*)

1924 *Crosseola concinna* -Iredale, p. 251.

1959 *Crosseola concinna* -Cotton, p. 228, fig. 149.

OBSERVATIONS. The living *Crossea concinna* represents the type species of *Crosseola* Iredale. Observations on specimens of *C. cancellata* (T. Woods) and worn juvenile paratypes of *C. consobrina* May,which are kept in the S.A. Museum collections, revealed that these two forms seem to represent probably juvenile stages of *C. concinna.* However, the material available is insufficient to clarify this problem. Should adults of more than 2-3 whorls display the same ornaments throughout their shells, then *C. consobrina* and *C. cancellata* may be maintained as valid species. Should they not, then they should be synonymized to *C. concinna* Angas.

Cotton's 1959 illustrations of *Crosseola*(and of *Dolicrossea*, too) are grossly misleading and they should not be used for any comparison. From observations on a rather worn specimen, referred to *C. carinata* (Hedley) and matching with the figure of Cotton (1959, p. 229, fig. 149) it should at least be transferred to another genus. It represents a juvenile shell with 3 whorled homeostrophic smooth protoconch and one teleoconch whorl bearing simple spiral costellae. Ornament pattern, coiling, peristome and umbilicus morphology are alien to *Crosseola.* Only the last two characters might bear some resemblance with *Dolicrossea*.

DISTRIBUTION. South Australia, New South Wales, Tasmania, from just below low tide down to 36 m depth (Iredale, 1924; Cotton, 1959).

STRATIGRAPHIC RANGE. Recorded only as living.

GENUS *Leucorhynchia* Crosse, 1867

Leucorhynchia bifuniculata sp. nov.

FIGS. 133-138

DERIVATION OF THE NAME. composite from the Latin suffix *bi-*, two and the adjective *funiculatus*, funicle bearing, because of its two funicles.

HOLOTYPE. GSSA M 3459-A, figs. 137-138.

PARATYPES. GSSA M 3460 A-B figs. 133-136.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, 21.98-21.65 m depth.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-P17).

MATERIAL. 3 silicified and 23 specimens badly preserved; 7 specimens from GSSA Collection.

DESCRIPTION. Shell minute, globose, turbiniform, short spired; whorls increasing far more in diameter than in height. Whorl overlapping: normal to the coiling axis, total; parallel, up to just above the middle adapical connection. Suture canaliculate in younger stages, adpressed in older ones. Body whorl shape: inner circular; outer wide semilunate. Base subconcave with a deep, narrow to neatly closed umbilicus, bound by a large funicle. Peristome circular. Lips thick. Lips connection imperceptible. The body whorl attached to the preceding one by two very thick adaxial adapical and abapical funicles.

Protoconch. 1 whorl, homeostrophic, smooth with rounded nucleus. separated from the teleoconch by a sharp cicatrix.

Ornament. Very fine prosocline growth lines, developing into rugae only at the two funicles. Smooth middle region. A Spiral weak stria limiting the adapical funicle.

OBSERVATIONS. This form appears to be very close to the Early Eocene Paris Basin *Leucorhynchia callifera* Deshayes (Cossmann, 1918, p. 141, pl. 4, fig. 21-23). It differs from the latter in more developed funicles, and consequently, in a narrower umbilicus, in a higher spire, and in shell size, the whorl number remaining constant.

In *Leucorhynchia bifuniculata* sp. nov. two morphae can be distinguished: Morpha *A*, wider umbilicus and more marked adsutural rugae; Morpha *B*, narrower umbilicus and weaker adsutural rugae and somewhat higher spire.

The co-occurrence in the same sample from the top of the Banded Marls of these two forms confirms them to be of significance at morpha rather than at species level. Direct observations on specimens of *L. callifera* show analogous variation in the umbilicus and adsutural rugae. In particular, one of these specimens is strikingly similar to *L. bifuniculata* morph A. This would suggest close relationships between these two species. *L. bifuniculata* represents the first record of this genus in Australasia. *Leucorhynchia* Crosse was referred by Cossmann (1918) to Turbininae, and by Wenz (1939) to Skeneidae. Keen *et al.*, (1960) lowered Skeneidae to subfamily and transferred them to Cyclostrematidae.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin: Adelaide Childrens Hospital Bore 5, 20.67-20.34, 22.64-22.31, 23.62-23.29, 24.28-23.95, 24.93-24.60 m depths. Willunga SubBasin: Maslin and Aldinga Bays (Blanche Point Formation). Murray Basin: Waikerie Observation Bore 2, Sec. 692, Hd Waikerie, 228.02-226.38 m depth (Lower Buccleuch A equivalent).

GENUS ?Parviturbo Pilsbry & McGinty, 1945

?Parviturbo dubius sp. nov.

FIGS. 139-142

DERIVATION OF THE NAME. from the Latin dubius, doubtful, because of its uncertain taxonomic position.

HOLOTYPE. GSSA M 3461, Figs. 139-142.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, hd Adelaide, 22.31-21.98 m depth.

TYPE FORMATION. Blanche Point Formation, Aldingan.

STRATIGRAPHIC RANGE. Late Eocene (Late P15-middle P16).

MATERIAL. The holotype, with last whorl damaged.

DESCRIPTION. Shell minute, trochiform, rather high spired; whorls increasing more in diameter than in height. Whorl overlapping: normal to the coiling axis total; parallel to the coiling axis, up to the middle adapical connection. Suture flush. Body whorl shape: outer subpolygonal; inner subcircular. Abaxial margin; adapical region narrow, subdeclivous; middle wider, subvertical; abapical subconvex, subdeclivous. Margin region connections, all angular. Peristome damaged; base broad flat; umbilicus absent.

Protoconch. 1 whorl, homeostrophic, smooth; at the end of the initial whorl, an irregular axial cicatrix, marking the beginning of the teleoconch.

Ornament. Fine prosocline growth lines, adsuturally reflected. 4 primary spiral costae on the abaxial region, the 2nd and 4th producing carinae, alternated with fine spiral costellae. Base with regular marked spiral costellae thicker than the one on the interspaces. Micropustulae, denser in the younger whorls.

OBSERVATIONS. This form is tentatively referred to Parviturbo Pilsbry & McGinty. It shows strong similarity with P. acuticostatus (Carpenter) (La Follette,1976, p. 70, fig. 15-18). However, it differs from the latter in much finer basal spiral costellae and absence of axial costellae.

This form might as well be referred to Hopalopoma Carpenter (Turbinidae) since some living species appear to have very strong shell convergence with Parviturbo, which is interpreted by La Follette (1976) as a case of mimicry.

ORDER MESOGASTROPODA Thiele, 1925

SUPERFAMILY RISSOACEA H. & A. Adams, 1854

The classification of this superfamily is still in a very fluid state. Its marine, brackish, and fresh water families are difficult to study or poorly known, particularly due to the minute size of the shell.

Coan (1964) reviewed the history of this superfamily (to which the reader is referred) and he also proposed a new classification, which is not much more than a list of names. Successively, Taylor (1966), and Thompson (1968) and Climo (1974) dealt with the higher classification of the non marine Rissoacea. Currently W.F. Ponder, Australian Museum Sydney, is carrying out a series of anatomical and systematic studies on marine Rissoacea which have already deeply altered Coan's classification.

Finally, three other families have recently been transferred to Rissoacea, as soon as their anatomy was studied: Ctiloceratidae and Caecidae, formerly included in Cerithiacea, now close to Vitrinellidae (Moore, 1962); and Orbitestellidae, formerly placed in Trochacea (Ponder, 1967).

FAMILY RISSOIDAE H. & A. Adams, 1854

SUBFAMILY LIRONOBINAE Ponder, 1967

GENUS Lironoba, Iredale, 1915

SUBGENUS Nobolira Finlay, 1926

Nobolira was split by Powell (1930, p. 537) with the institution of

Adolphinoba for forms without lip varix and ovoidal peristome.

Wenz (1939) referred *Nobolira* and *Adolphinoba* to *Cingula* Fleming as subgenera. Coan (1964) restored *Nobolira* to generic rank, and referred to it *Adolphinoba* as a subgenus. Ponder (1967) synonymized *Adolphinoba* to *Nobolira*, on the basis of anatomical characters. As to the subfamilial location of these genera Wenz (1939) referred *Nobolira* to Rissoinae, Coan (1964) to Anabathroninae Coan, and lately, Ponder (1967) transferred it to a new subfamily, Lironobinae and referred it as subgenus to *Lironoba* because of similarities in radula characters and absence of eyes.

Protoconch. Spiral costae of the initial whorl distinguish *Nobolira* from *Lironoba* (Ponder, 1967).

Lironoba (Nobolira) costata sp. nov.

FIG. 143-145

DERIVATION OF THE NAME. From the Latin *costatus*, ribbed because of its spiral ornaments.

HOLOTYPE. SAM P 21276, figs. 143-145.

TYPE LOCALITY. Blanche Point, Aldinga Bay.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. The holotype only.

DESCRIPTION. Shell minute, turriculate, very high spired; whorls increasing much more in height than in diameter, whorl overlapping up to the middle-abapical region connection. Suture impressed. Body whorl ovoidal. Abaxial margin regions: adapical narrow, concave; middle broad, convex; abapical broad, convex. Region connections: obscured by ornaments. Last whorl: base narrow, subconvex; peristome holostomatous, ovoidal, inclined backward. Lips: parietal thin, subconcave, adherent; columellar thick, concave, slightly detached; abaxial very concave and thick; abapical very concave and thick. Lip connections: parietal-abaxial subangular; imperceptible the others. Lip varix present, thicker to the adapical.

inner peristome socket absent.

Protoconch. 2 whorls, low spired, dome like, with spiral microcostellae.

Ornament. Prosocline growth lines, 10 prominent spiral costae, with spiral microcostellae in the interspaces.

OBSERVATIONS. This form is referred to *Nobolira* Finlay because of its ornamented protoconch; heavy spiral costae and lip varix; shape of the peristome, with its more flattened inner lip; the absence of the peristome inner socket; and the coiling of the protoconch. The living *Nobolira finlayi* (Powell), type species of *Adolphinoba*, was dredged at 110 m depth (Powell, 1930).

SUBFAMILY RISSOINAE H. & A. Adams, 1854
GENUS *Rissoa* Fréminville, 1813
SUBGENUS *Haurakia* Iredale, 1915

Wenz (1939) synonymized *Haurakia* to *Turboella* (Leach) Gray, 1847 (type: *Turbo parva* Da Costa, Holocene). Coan (1964) synonymized *Turboella* to *Pusillina* Monterosato (type: *Rissoa pusilla* Philippi), restored *Haurakia* to generic rank and attributed three subgenera to it: *Haurakia* s. str. *Haurakiopsis* Powell, and *Subestea* Cotton. Ponder (1967) referred *Haurakia* to *Rissoa* as a subgenus, and synonymized *Haurakiopsis* and, doubtfully, *Subestea* with it.

Rissoa (Haurakia) costata sp. nov.

FIGS. 146-148

DERIVATION OF THE NAME. From the Latin *costatus*, ribbed, because of its ornaments.

HOLOTYPE. GSSA M 3462, figs. 146-148.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, Hd Adelaide, 24.60-24.28 m depth.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. The holotype with peristome damaged.

DESCRIPTION. Shell very minute, thick, turriculate subtrochiform, short spired. Whorls increasing in diameter about the same as in height. Whorl overlapping: normal to coiling axis, total; parallel to it, just below the middle-adapical connection. Suture Grooved. Body whorl shape: outer subtrapezoidal; inner subovoidal. Abaxial margin regions: adapical and middle subconvex, subvertical; abapical subconvex, very declivous. Adaxial margin regions: adapical subvertical straight; adapical subconvex declivous. Base subconvex, with a very reduced umbilicus. Peristome damaged.

Protoconch. Large, obtusely conical with 2 homeostrophic whorls; the transition to teleoconch marked by the appearance of the axial costae. Irregular spiral series of pustulae on the last whorl.

Ornament. Heavy axial costae, widely interspaced; growth lines: orthocline on the abaxial adapical and middle; prosocyrt on the abapical region. Spiral costae very faint on the middle, marked at the periphery, and gradually fading to the coiling axis.

OBSERVATIONS. Body whorl shape, suture and protoconch place this form close to the Holocene *H. hamiltoni* (Suter) which is the type of *Haurakia* (Suter, 1913, p. 200; 1915, pl. 12, fig. 1). Secondary spiral ornaments are displayed by other species, such as *H. aupouria* Powell (Powell, 1937a, p. 191, pl. 52, fig. 4) or the early Middle Miocene New Zealand *H. buccella* (Marwick) and the late Early Miocene *H. oamarutica* (Finlay) (Fleming, 1966, p. 236, pl. 69, figs. 806-807).

GENUS Turboella (Leach) Gray, 1847

SUBGENUS Turboella s. str.

Turboella (Turboella) flexilis sp. nov.

FIGS. 149-150

DERIVATION OF THE NAME. from the Latin *flexilis*, wavy, because of the shape of its costae.

HOLOTYPE. GSSAM 3463, figs. 149-150

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, Hd Adelaide, 24.60 - 24.28 m depth.

TYPE FORMATION. Blanche Point Formation

STRATIGRAPHIC RANGE. Late Eocene (early P15-middle P16)

MATERIAL. The holotype with peristome damaged.

DESCRIPTION. Shell very minute, thick, turriculate, subtrochiform short spired; whorls increasing in diameter about the same as in height. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Suture flush, ondulate. Body whorl shape: inner subovoidal; outer, subtrapezoidal. Margin regions: abaxial middle and adapical undifferentiated, subconvex, subvertical; abaxial abapical subconvex, declivous; adaxial abapical subconvex, subvertical; adaxial adapical subconcave, declivous. Region connections: adapical abaxial-adaxial very angular; abapical adaxial-abaxial broadly angular; rounded the others. Peristome damaged, with narrow adapical and broad abapical gutters.

Protoconch: similar to the protoconch of *Haurakia costata* sp. nov., but smooth.

Ornament. Growth lines and regularly interspaced axial costae: adapical and middle opisthocyrt, abapical prosocyrt. Axial costae weaker on the base. Basal spiral riblets, the more marked the nearer to the periphery.

SUBFAMILY RISSOININAE STOLICZKA, 1868

GENUS *Merelina* Iredale, 1915

SUBGENUS *Merelina* s. str.

Merelina kaurna sp. nov.

FIGS. 151-154

DERIVATION OF THE NAME. From the Kaurna, the people of the Eastern Gulf St. Vincent.

HOLOTYPE. SAM P 21277A, figs. 151-153

PARATYPE. SAM P 21277B, Fig. 154

TYPE LOCALITY. Blanche Point at Aldinga Bay.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member)

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. 6 well preserved specimens.

DESCRIPTION. Shell minute, thick, turriculate, high spired; whorls increasing much more in height than in diameter. whorl overlapping: normal to the coiling axis, total; parallel to it up to the middle-abapical connection. Body whorl shape ovoidal. Suture impressed. Abaxial margin regions: all convex, undifferentiated. Region connections: all imperceptible. Base narrow, subconvex; peristome holostomatous, ovoidal with inner socket, slightly inclined backward. Lips: adaxial-adapical wide, subconcave, thin, adherent; adaxial abapical thick, adherent, short; abaxial abapical concave, very thick; abaxial adapical and middle subconcave, very thick. Lip connections: adaxial adapical-abapica and adapical abaxial-adaxial, subangular; rounded the others.

Protoconch. 2 whorls, dome like, rather high spired, with spiral pustular cords separated from the teleoconch by a cicatrix.

Ornament. Prosocline growth lines and prominent rounded axial costae; 9-11 spiral costellae.

OBSERVATIONS. Protoconch, peristome, and ornament pattern include this form in *Merelina* Iredale. The 6 specimens show variability in spire height, and in the number of spiral costellae (9-11) of which the adapical ones are weaker in some specimens.

Wenz (1939) referred to Merelina several subgenera. Coan (1964) separated them as distinct taxa, but of uncertain systematic position and rank. Ponder (1967) recognizes in Merelina only Merelina s. str., Promerelina Powell, and Mereliniopsis Ponder. He transferred Scalaronoba Powell to Pyramidellacea, and Linemera and Awanuia to Alvinia Monterosato. Ihungia Marwick remains 'incertae sedis'.
Living species of Merelina were dredged at depths of 11-274 m (Cotton, 1944a).

FAMILY CAECIDAE Gray, 1847

This little known and puzzling group was generally referred to Cerithiacea and close to Vermetidae. In recent times, Iredale & Laseron (1957) revised it and distinguished two families: Caecidae Gray and Ctiloceratidae, which was newly instituted. They also added to them two new subfamilies, Watsoniinae and Pedumicrinae, which are in relation to the above families, of close affinity but of uncertain taxonomic position.
Ptchelintsev & Korobkov (1960) referred Caecidae to Turritellacea. Taylor & Sohl (1962) restored them in Cerithiacea, in which they included Turritellidae again as a family. Ptchelintsev (1968) still included Caecidae in Turritellacea and referred both to the new Order Murchisoniata Ptchelintsev. Yet, D.R. Moore (1962) demonstrated close anatomical relationships of Caecidae to Rissoacea and closer affinities to Vitrinellidae. According to Moore's classification, Ctiloceratidae occupy an intermediate position between Vitrinellidae and Caecidae.

GENUS Strebloceras Carpenter, 1858

Strebloceras darraghi sp. nov.

FIGS. 155-157

DERIVATION OF THE NAME. After T.A. Darragh, National Museum of Victoria, Melbourne, for his studies on fossil and living mollusca.

HOLOTYPE. GSSA M 3322, FIG. 155

PARATYPES. GSSA M 3323A-B, Figs. 156-157.

TYPE LOCALITY. WLG 40, 73-75 m depth, Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. Port Willunga Beds (lower part).

STRATIGRAPHIC LOCATION. middle Late Eocene (top P16)

MATERIAL. 3 protoconchs, well preserved.

DESCRIPTION. Shell very minute, thick, dextral; pseudoplanispiral; whorls increasing more in diameter than in height; whorl overlapping: parallel to coiling axis total, with body whorl height greater than whorl height; normal to coiling axis scarcely overlapping in the initial whorl to completely evolute in the successive. Suture flush. Body whorl shape and peristome subcircular. The teleoconch separated by a thick cicatrix.

Ornament. Smooth surface. Fine growth rings on the initial teleoconch.

OBSERVATIONS. This form, which is similar to *Strebloceras* Carpenter (Wenz, 1939, p. 682, fig. 1953) in the neanic coiling and relative size of its body whorl and the fine growth rings, shows some resemblance with the Oligocene Paris Basin *S. edwardsi* Deshayes (Cossmann, 1912, p. 155, pl. 10, figs. 33-34). The only other fossil known in Australasia is the late Early-Middle Miocene *S. hinemoa* Finlay, from which *S. darraghi* is distinguished by the marked protoconch/teleoconch cicatrix. Aside from the newly discovered late P15-middle P16 *Strebloceras* sp. from the Adelaide Plains SubBasin (Appendix D-1), *S. darraghi* represents the oldest record of *Strebloceras* and of the Caecidae s.l. in Australasia. According to D.R. Moore (1961, 1962) the living Caecidae are active bottom crawlers and flourish in the sea grass communities (*Thalassia*). According to Iredale & Laseron (1957), Caecidae are warm temperate to tropical forms.

OTHER LOCALITIES. Murray Basin, Padthaway Ridge, Tintinara Area School Bore 12, Co Cardwell, Hd Coombe, 88-86 m (27 specs), 86-84 m (71 specs); 84-82.50 m (54 specs), 81.50 m (6 specs), 80-78 m (5 specs). Coonalpyn E & W Bore 2, Hd Coneybeer, Sect 56, 72.83-71.52 m (3 specs).

FAMILY ORBITESTELLIDAE

Iredale (1917, p. 327) gave the following diagnosis for both the family and genus: 'Shell thin, pellucid, discoidal, dextral, of few whorls, and of peculiar sculpture, widely umbilicate, columella vertical, aperture never variced, irregular in shape, edge thin'.

Keen (*in* Moore, 1960) duplicated this diagnosis, and also, she doubtfully referred *Helisalia* Laseron (type: *H. liliputia* Laseron, 1954) to this family. *Helisalia* differs from *Orbitestella* in smooth surface and round peristome (Laseron, 1954; Keen, *in* Moore, 1960).

Subsequently Iredale & McMichael (1962, p. 36) included in Orbitestellidae a third genus, *Microcarina* Laseron, 1954, but gave no reason. Recently, Ponder (1967) on the basis of anatomical observations transferred Orbitestellidae from their usual superfamily, Trochacea, to Rissoacea. He also added *Microdiscula* Thiele (type: *M. vanhoffeni* Thiele, 1912) to this family which till then had generally been located in Skeneopsidae (Wenz, 1938; Ponder, 1967). Thus Ponder synonymized Microdisculidae Iredale & McMichael, 1962 (incorrectly dated 1964 in Ponder, 1967), another of the taxa too summarily instituted in Iredale's style.

In this study, *Helisalia* Laseron and *Microcarina* Laseron are doubtfully maintained in Orbitestellidae until anatomical studies can resolve their taxonomic location.

Another genus of recent institution, *Pleuromalaxis* Pilsbry & McGinty, 1945, appears to have strong shell affinities with *Orbitestella* Iredale.

On a conchological diagnosis Pilsbry & McGinty (1945) instituted for their living Caribbean *P. balesi* (*Pleuromalaxis* as a new section of *Pseudomalaxis*), and arbitrarily transferred it to Cyclostrematidae (Buonaiuto, 1975). However, coiling, body whorl shape, the two carinae, and ornament pattern bear striking resemblance to the Australian Orbitestellidae. Successively, Olsson & McGinty (1958) referred *Pleuromalaxis* to Vitrinellidae and raised it to generic rank. However, they referred a new species, *Pleuromalaxis pauli* Olsson & McGinty to it which should more properly be included in the *?Elachorbis plicatella* group (see further).

Since the original and subsequent generic diagnoses based on shell morphology are quite unsatisfactory, the following species were here examined.

On specimens.

Orbitestella bastowi (Gatliff, 1906) type species, Holocene, southern Australia (Figs. 166-167).

Orbitestella sp. nov. *B*. Muddy Creek Marls, Middle Miocene;

Orbitestella sp. nov. *A*. Gellibrand Clays, Pt. Ronald, Early Miocene;

Orbitestella rugosa sp. nov., Pt. Willunga Beds, late Late Eocene (P16/17-P17).

O. spinosa sp. nov., Pt. Willunga Beds, late middle Late Eocene (late P16)

O, margaritata sp. nov., Blanche Point Marls, Late Eocene (late P15-middle P16).

On illustrations and diagnosis

O. mayi (Tate, 1899),(Tate, 1899a, p. 218, pl. 6, fig. 4a-c; *nom. correct pro Cyclostrema mayii* Tate, 1899, *nom. imperf.*), Holocene.

O. iredalei May, 1920 (May, 1920, p. 65 pl. 16, fig. 23), Holocene.

O. decorata Laseron, 1954 (Laseron, 1954, p. 18, fig. 43), Holocene.

O. aura Laseron, 1954 (Laseron, *ibid*, fig. 44), Holocene.

O. praetoreuma Laws, 1939 (Laws, 1939, p. 481, figs. 15-16), Otaian (Early Miocene).

O. praehinemoa Laws, 1939 (Laws, ibid., figs. 20-21), Otaian (Early Miocene).

All these species showed the following common characters: Shell very minute, thin, pseudoplanispiral; whorls scarcely overlapping normal to the coiling axis, completely overlapping parallel to the coiling axis; body whorl height greater than whorl height. Body whorl shape and peristome subtrapezoidal. Suture from flush to subadpressed. Adapical gutter at middle to adaxial position; columellar lip with abapical falciform sinus. Margin regions: from convex to subconvex in the oldest species, from subconvex to flat in the younger species. Protoconch: 1 whorl smooth, anastrophic, distinct from teleoconch.

Ornament. Growth rugae, carinae at region connections. Beads at carina-rugae connections, generally present. Growth lines: adapical orthocline sinusoidal, abaxial prosocline, adaxial opisthocyrt, abapical prosocyrt.

The only evolutive trend in the observed species is the increasing flattening of the margins from the Late Eocene to the Holocene. Beads, rugae and carinae are displayed in various combinations in the different species. These characters also vary in size and presence-absence.

The species herein described seem to belong to the same evolutive lineage ending with the Holocene O. bastowi (Gatliff), the type species of the genus, although insufficient material and lack of continuous fossil record could be misleading.

A series of specimens sent for an opinion by Le Renard, Institut National de la Recherche Agronomique, Versailles revealed some living forms of Orbitestella from Hao, French Polynesia. Therefore, the present distribution of the family, hitherto recorded only in Australasia (Keen, in Moore, 1960) is extended to the Pacific Ocean and the Caribbean Gulf.

HABITAT. The living species of Orbitestella are from very shallow waters; O. bastowi, at 16 m depth (Gatliff, 1906), with preference for fine sands (Iredale, 1917); O. mayi (9-73 m, but frequent at 9 m (May, 1920);

O. iredalei May, from kelp roots (May, 1919, 1920) (ca.5-10 m); O. decorata Laseron and O. aura Laseron on algae, in rock pools, or under stones (Laseron, 1954).

GENUS Orbitestella Iredale, 1917

Orbitestella margaritata sp. nov.
FIGS. 158-160

DERIVATION OF THE NAME. From the Latin margaritatus, beaded, because of its ornament.

HOLOTYPE. GSSA M 3323A, Fig. 158

PARATYPE. GSSA M 3323B,C. Figs. 159-160.

TYPE LOCALITY. St. Vincent Basin; Adelaide Plains SubBasin, Adelaide Childrens Hospital, Hd Adelaide, Bore 2, 22.56-22.25 m depth.

TYPE FORMATION. Blanche Point Formation ('Transitional Marl' to 'Soft Marl' Members).

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. 3 well preserved types, 13 specimens from GSSA Collections.

DESCRIPTION. See generic diagnosis.

Ornaments. Growth lines: adapical orthocline; abaxial prosocline; adaxial opisthocyrt; abapical prosocyrt. Similar growth rugae, weaker on the abaxial. Beaded spiral carinae, the adapical with heavier beads.

OBSERVATIONS. This form represents the oldest record of Orbitestella Iredale. The only fossil species hitherto known are the Early Miocene (Otaian) New Zealand O. praetoreuma Laws and O. praehineomoa Laws (Laws, 1939, p. 481, figs. 15, 16, 20-21). O. margaritata differs from O. bastowi (Gatliff) in broader beads much less prominent carinae, and consequently less concave abaxial region.

OTHER LOCALITIES. Kent Town, E & W Bore 5, Hd Adelaide, 59.13-66.45 m depth. West End Brewery Bore Ch 2, 48-46 m and 46-44 m depths. South Parklands Bore Ch-1A, 95-93 m, 91-89 m, 69.3-69 m, 62-60 m depths.

Orbitestella spinosa sp. nov.

FIGS. 161-162

DERIVATION OF THE NAME. From the Latin *spinosus*, spiny, because of its spiny carinae.

HOLOTYPE. GSSA M 3321A, Fig. 161.

PARATYPE. GSSA M 3321B, Fig. 162.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Bore WLG40, 73-75 m depth.

TYPE FORMATION. Port Willunga Formation, Aldinga Member, lowermost part.

STRATIGRAPHIC LOCATION. Late Eocene (late P16) (Cooper, 1976, pers. comm.).

MATERIAL. 2 adults and 2 juveniles well preserved and 1 specimen damaged.

DESCRIPTION. Similar to *O. margaritata*. It differs in: more overlapping whorls, normal to the coiling axis; narrower adapical adaxial region; more adaxial adapical gutter. Whorl region outline: adapical wider; abaxial concave; abapical more convex.

Ornament. Growth lines similar to *O. margaritata*. Growth rugae adapical more interspaced; abaxial absent; abapical finer, more numerous and weaker. Much more pronounced abaxial carinae. Spines at the adapical carina-ruga intersection. Adsutural beads; very marked peripheral abapical sulcus.

OTHER LOCALITIES. Type locality, but at 68.00-68.10 m depth.

Orbitestella rugosa sp. nov.

FIGS. 163-165

DERIVATION OF THE NAME. From the Latin, rugosus, wrinkled, because of its ornament.

HOLOTYPE. GSSA M 3319A, Fig. 165

PARATYPE. GSSA M 3319B-C, Fig. 163-164

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Bore WLG40, 57 m depth.

TYPE FORMATION. Port Willunga Formation, lowermost part.

STRATIGRAPHIC RANGE. Late Eocene (P16/17-P17).

MATERIAL. 11 specimens generally well preserved

DESCRIPTION. Very close to O. spinosa. It differs in somewhat shorter spire and more flattened adapical and abapical regions. Suture subadpressed. More anastrophic protoconch.

Ornament. Growth rugae: adapical primary, with abaxial and adaxial beads, and secondary, of increasing size and with abaxial beads only; ababaxial fainter; abapical coarse and more interspaced. Beaded adsutural spiral cord. Both the carinae less beaded and prominent than in O. spinosa. Faint beads on the adaxial-abapical connection. Faint spiral microcostellae on the adapical interspaces.

OTHER LOCALITIES. Type locality, but at 56.60-56.65 m depth. Murray Basin: Kiki Town Bore, 116.13-103.63 m depth. Tintinara School Area Bore 12, 88-78 m depth (Buccleuch Beds).

SUPERFAMILY	INCERTAE SEDIS (?Trochacea, or ? Rissoacea)
FAMILY	INCERTAE SEDIS (?Cyclostrematidae, or ?Vitrinellidae)
GENUS	?*Elachorbis* Iredale, 1915
GROUP	?*Elachorbis* s.l. *plicatella*

Elachorbis Iredale (type: *Cyclostrema tatei* Angas) is in great need of revision. The species currently referred to this genus can be lumped in 2-3 distinct homogeneous groups, which have little affinity to each other. To complicate the problem, some Australian species, which are referred to other minute pseudoplanispiral genera, show at least strong shell convergence to one or another of these groups. Furthermore, the classification of these and other pseudoplanispiral forms is in a chaotic state due to either a complete lack of or incomplete information. In addition the Australian genera are poorly described and illustrated.

In this study, the group of ?*Elachorbis plicatella* (Cossmann) is of particular interest. It includes the Anglo-Paris Paleocene-Oligocene *Pseudomalaxis plicatella* Cossmann, s.l. (Gougerot & Le Renard, 1977; Le Renard, 1978, writt. comm.), the Australian Late Eocene ?*E. pentagonalis* sp. nov., the New Zealand Oligocene ?*E. duplicarina* (Marwick), the Australian Holocene ?*E. harriettae* (Pettard) and *Cyclostrema homalon* (Verco). To this group also belong a living form from Hao (French Polynesia) which is from Le Renard Collection, and the Caribbean Holocene *Pleuromalaxis pauli* Olsson & McGinty.

In particular, *P. pauli* was referred by the two authors to *Pleuromalaxis* Pilsbry & McGinty (type: *P. balesi* Pilsbry & McGinty). However, body whorl shape, coiling, ornament pattern, and position of the carinae separate *P. balesi* from *P. pauli*, and place the latter in the ?*E. plicatella* group. As already mentioned, *P. balesi*, initially placed in Cyclostrematidae (Pilsbry & McGinty, 1945), was later referred to Vitrinellidae (Olsson & McGinty, 1958); but it shows strong shell affinities with

Orbitestellidae, and it seems to be closer to *Orbitestella* Iredale than to any other genus.

In conclusion, in this study the familial and generic location of the ?*E.plicatella* Group is considered uncertain and in need of further clarification. The referral of its species to *Elachorbis* Iredale is merely a matter of temporary convenience. From the above discussion, this group appears to be of Tethyan origin; although, at the present it has an Australasian, Pacific and Caribbean distribution.

?*Elachorbis pentagonalis* sp. nov.

FIGS. 168-169

DERIVATION OF THE NAME. From the Latin *pentagonalis*, pentagonal, because of its body whorl shape.

HOLOTYPE. GSSA M 3320 A, Fig. 168

PARATYPE. GSSA M 3320 B, Fig. 169.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Bore QA 16, 57 m depth.

TYPE FORMATION. Pt. Willunga Beds (lowermost part).

STRATIGRAPHIC LOCATION. Latest Eocene (P16/17-P17).

MATERIAL. 3 well preserved specimens, with damaged peristome.

DESCRIPTION. Shell minute, thin, few-whorled, pseudoplanispiral; whorls increasing much more in diameter than in height. Whorl overlapping: parallel to the coiling axis, total in younger stages - with whorl height about the same as body whorl height, less overlapping in older stages; normal to coiling axis, very slight. Suture adpressed. Body whorl shape pentagonal. Margins: all flattened, with adapical sub-horizontal. Margin connections all angular. Base with deep and wide umbilicus.

Protoconch. 1 smooth whorl, heterostrophic, coiled normal to the teleoconch with nucleus abapically submerged, and gradually developing into teleoconch.

Ornament . Growth lines and rugae: abaxial orthocline; adapical and adapical middle opisthocyrt; abapical middle and abapical prosocyrt. Spiral carinae: adustural, faint beaded; adapical-middle marked, beaded; prominent faintly beaded middle abapical; beaded abapical; crenulated adaxial abapical.

OBSERVATIONS. *?E. pentagonalis* represents the oldest record in Australasia of the *?E. plicatella* group, and its first fossil record in Australia. The living species are recorded at a depth range of 36-248 m (Cotton, 1959, May, 1923), in southern Australia.

OTHER LOCALITIES. Murray Basin: B.W. Butler Bore 4, 116.13-110.34 m depth. Tintinara School Area Bore 12, 88-78 m depth (Buccleuch Beds).

SUPERFAMILY	CERITHIACEA Fleming, 1822
FAMILY	TURRITELLIDAE Woodward, 1851
SUBFAMILY	TURRITELLINAE Woodward, 1851
GENUS	*Spirocolpus* Finlay, 1927
	Spirocolpus aldingae (Tate, 1882)

FIGS. 170-175,180a,b.

1882 *Turritella aldingae* Tate, p. 45.
1893 *Turritella aldingae* -Tate, p. 336, pl. 8, fig. 1a,b.
1961 *Turritella aldingae* -Ludbrook, pl. 8, fig. 9.
1969 *Turritella aldingae* -Ludbrook *in* Parkin, p. 192, fig. 94-96.

MATERIAL. Several thousand specimens.

DESCRIPTION. Shell thin, turriculate, high spired, with whorls increasing rapidly more in height than in diameter. Suture grooved,less in the younger stages. Abaxial margin: subconvex,nearly flattened in the younger whorls, more convex in the older ones. Base subconcave, bounded by a peripheric angular carina. Peristome subquadrate; parietal lip subelliptical; forming with the elliptical outer lip by a broad gutter; the abapical lip subelliptical connected with the outer by angularity; the straight columellar lip with the abapical one forms a narrow channel. The columellar lip is reflected.

Ornament. Growth lines opisthocyrt with a very deep sinus with the maximum concavity in the adapical middle region. Very fine spiral microriblets on all the surface, four primary, the second adapical crenulated, the abapical on the peripheric carina; secondary ribs; in the interspaces between the primary: three in the adapical region; two in the medium region, slightly crenulated; four in the abapical region. In the senile whorls the adapical secondary ribs may fade, the growth lines developing into rugae, and the microriblets disappearing.

OBSERVATIONS. Because of the condition of the specimen from Tortachilla Limestone, the above diagnosis was derived from the paratype, and from the specimens collected from Blanche Point Formation.

The original series of specimens of S. aldingae (Tate) is kept in the S.A. Museum on two tablets SAM T1405 and SAM T1406, which bear 22 specimens from Aldinga and Adelaide Bore. Riedl, former curator of the Museum, remarks in his catalogue that the specimens T 1406 B and T 1406 G were used by Tate for the composite instituting illustration of S. aldingae; the former being senile, with the younger whorls not preserved; the latter being juvenile, with a better preserved shell. However, a close examination reveals that the holotype's protoconch was broken afterwards. Thus the specimen T 1046 B is confirmed as the holotype and Adelaide Bore as the type-locality. The tablet SAM T1405 bears two specimens (T 1405 C and T 1405D) which have to be referred to the genus Gazameda Iredale because of the outline of the abaxial margins of the whorls, and the shape of the growth lines. Both specimens represent a probable new species.

Some of the others borne on both the tablets seem to differ somewhat in ornaments, in depth of the grooved sutures, and in adapical angle.

However, because of a similar variability displayed in the above cited sample of *S. aldingae* from Blanche Point Formation, they are here referred for the moment to the same species. A further more specialized research will have as topic the quantitative definition of its variability and the relationships among *S. aldingae*, the N. Zealand *S. waihaoensis* (Marwick) (Marwick, 1924, p. 328, pl. 6, fig. 9), and *Turritella (Zaria) pritchardi* Cossmann from Cape Otway (Balcombian), which seems to resemble *S. aldingae*.

S. aldingae (Tate) was referred by Cossmann (Cossmann, 1912, 9^{o}, p. 118) to *Haustator* Montfort; by Finlay (1927, p. 387-388), Marwick (1957, p. 153), and Cotton (1959, p. 358) to *Spirocolpus* Finlay; by Cotton & Woods (1935, p. 380, 384) to *Colpospira* Donald. Gerrard (*ibidem*) illustrates as *S. aldingae* a form clearly not related to this species or to *T. (Zaria) pritchardi* Cossmann. On the contrary it bears closer resemblence to the specimens of *Gazameda* SAM T 1405B and T 1405C.

DISTRIBUTION. ST. VINCENT BASIN, Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; Adelaide Childrens Hospital Bore 5; West End Brewery CH 2. Willunga SubBasin: Maslin and Aldinga Bays. Noarlunga SubBasin: Witton Bluff, Fleming Bridge, Noarlunga Oval. YORKE PENINSULA: Ardrossan. MURRAY BASIN: B.Q. Butler Bore 4, Old S.A. Railway, Tintinara Bore, Tintinara Area School Bore 12, Coonalpyn Bore 2, Kiki Town Bore. Waikerie Bore 2W. OTWAY BASIN: Browns Creek.

STRATIGRAPHIC RANGE. ST. VINCENT BASIN: ?Tortachilla Limestone - Blanche Point Formation; Aldinga Member, Port Willunga Formation; Muloowortie Formation (Yorke Peninsula). MURRAY BASIN: Top Knight Group; Buccleuch Beds. OTWAY BASIN: Browns Creek Clay. Late Eocene (P15-P17).

SUBFAMILY PAREORINAE Finlay & Marwick, 1937

GENUS *Sigmesalia* Finlay & Marwick, 1937

Sigmesalia stylacris (Tate, 1893)

FIGS. 183-186

1893 *Mesalia stylacris* Tate, p. 341, pl. 9, fig. 2.

MATERIAL. 7 specimens (6 silicified) in various conditions; 7 specimens from Tate's uncatalogued material; 3 syntypes (SAM T 1442 A-C) and 10 non numbered paratypes. About 100 from GSSA Collections.

DESCRIPTION. Shell small, turriculate, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis total; parallel to it, up to the middle abapical connection. Body whorl shape ovoidal; Suture impressed. Abaxial margin convex. Base sub-convex, abaxially bound by an angularity; peristome ovoidal. Lips: adaxial-adapical thin, straight; adaxial abapical subelliptical, concave,adaxially bound by a rim; abaxial adapical and middle elliptical concave; abaxial abapical very elliptical. Lip connections: all angular, the abapical adaxial-abaxial represented by a broad gutter.

Protoconch. 4 smooth homeostrophic styliform whorls; the beginning of the teleoconch marked by a suture.

Ornament. Opisthocyrt growth lines. Spiral costae, the middle one in younger stages more prominent.

OBSERVATIONS. Following Ludbrook (1973) and Darragh (1970) this form is confirmed in *Sigmesalia* Finlay & Marwick, because of its growth lines and body whorl shape (Marwick, 1957 , p. 163, fig. 31).

DISTRIBUTION. St. Vincent Basin, Adelaide (Kent Town) Bore: Willunga SubBasin, Maslin and Aldinga Bays. Tintinara Area School Bore 12, B.Q. Butler Bore 4, Coonalpyn Bore 2. Dennant & Kitson (1903) quote other localities which today are considered as being of younger age. Therefore, it is preferable to restrict *S. stylacris* to the above mentioned localities from which specimens were available.

STRATIGRAPHIC RANGE. Blanche Point Formation, Buccleuch Beds. Late Eocene -? (Late P15-P17).

FAMILY SILIQUARIIDAE Gray, 1857

INTRODUCTION.

In the preparation of this study composite species were frequently encountered. Siliquaria occlusa (T.Woods) falls into this category. Dennant & Kitson (1903) quoted this species as occurring throughout the Australian Tertiary and the Pleistocene. However, a wide range of siliquariid forms found in the uncatalogued part of Tate collection, which is still kept in the Department of Geology, University of Adelaide, and which includes possible topotypes of S. occlusa (T.Woods), revealed that Dennant & Kitson referred to S. occlusa a number of different species which rightfully should be classified in different siliquariid groups. The consequent revision of S. occlusa initiated this discussion.

Upon ascribing the various forms to the proper genus, it was discovered that not only were the existing generic diagnoses never completely matched with the shell characters observed in the specimens here described, but also the diagnosis and illustrations of the same genus and the same species differed from author to author. Hence, this study gradually developed from a simple revision of a composite species into a nomenclatural and systematic revision of the family. However, it is not comprehensive, because of the lack of all the necessary material and because it does represent a major project too much outside of the range of this study.

This discussion has been divided into three parts. The first deals with the nomenclature and the controversial history of the family and its genera, and in particular, with the intriguing problem of the familial type species, Serpula anguina Linnaeus vs Serpula anguina Born. The second gives a systematic outline of the morphological characters and the revised diagnosis of some new siliquariid genera, and is concluded with a brief speculation on their evolution and dispersal. The third and last part contains the revision of the species hitherto ascribed to Siliquaria obtusa (T. Woods).

NOMENCLATURE AND CONTROVERSIES IN SILIQUARIIDAE.

SERPULA ANGUINA LINNAEUS AS TYPE SPECIES OF TENAGODES GUETTARD, 1770, AND OF SILIQUARIA BRUGUIÈRE, 1789.

Serpula anguina Linnaeus is one of the species with long prelinnean history, which had already been described by Buonanni, Gualtieri, Rumphius, Lister and others, and in some cases, under its own specific name. Hence, it is not surprising that in his 1758 edition of Systema Naturae, Linnaeus described a species that was already composite, due to misinterpretations by the earlier authors. In particular, Linnaeus referred two forms to this species: the "Indian" one figured by Rumphius as Solen anguinus (Rumphius, 1711, p.9, pl.41, fig.H.) (FIG.187); the mediterranean form figured by Lister (Lister, 1685-92, 4, sect. 3, fig. 2) (Fig. 188) as variety β. Therefore, Rumphius's form represents the typical Serpula anguina Linnaeus, 1758. Guettard (1770), (p.128, pl.71, figs. 3-4) when instituting Tenagodes quoted Linnaeus and figured and referred to his new genus the Rumphius's form as S. anguina (Figs. 190-191). Therefore, Rumphius's form of 'Serpula anguina' represents the type species of Tenagodes Guettard, 1770.

Later, Born (1780, p.440, pl.18, figs.15,16) revised S. anguina and distinguished Rumphius's form from Lister's as different species. However, he incorrectly transferred the name "anguina" to Lister's form (fig. 15) (Fig. 192) and instituted the new name "muricata" for Rumphius's form (fig. 16) (Fig. 193). The origin of the existing confustion in Siliquariidae is due to Born's 1780 mistake.

Following Born, Bruguière (1789) instituted Siliquaria on Lister's form, Siliquaria anguina Born, non Linnaeus. Therefore, Lister's form of Serpula anguina represents the type species of Siliquaria Bruguière, 1785.

Later on, Schumacher (1817) founded on Lister's form the species Anguinaria obtusa for his new genus Anguinaria. Therefore, A. obtusa

Schumacher represents the type species of Siliquaria Bruguière, and correctly, a new name for Serpula anguina Born, non Linnaeus. Unfortunately, Dillwyn (1817), Lamarck (1818), Blainville (1825-7), Deshayes (1832), H. & A. Adams (1856), Gray (1857), Chenu (1859), Sacco (1896), Tryon (1883), Clessin (1902), Davies (1935), Glibert (1962), Eames (1971), etc. perpetuated Born's mistake. Yet, at the same time Guettard (1770), Schumacher (1817), Hanley (1855), Mörch (1860), Sowerby (1878), Tryon (1886), Sowerby (1884) and Wenz (1939) correctly interpreted *Serpula anguina* Linnaeus.

It must be added that Dillwyn (1817), Schumacher (1817), Hanley (1855) and Sacco (1896) noted the inconsistency between Linnaeus's and Born's *Serpula anguina*. In particular, Hanley (1855) clarified Born's mistake by showing that the typical *S. anguina* Linnaeus is represented by Rumphius's "prickly" form.

Considering the above situation, one is not surprised at the present chaos in the classification of Siliquariidae. For instance, H. & A. Adams (1856) synonymized *Siliquaria* with *Tenagodes*, although they figured as *S. anguina* Linnaeus Lister's form. Sacco (1896) referred to *S. anguina* a number of different Tertiary forms as its "varieties". Clessin (1902) figured *S. anguina* as *Siliquaria lactea* Lamarck. Gould (1966) figured and discussed as *Siliquaria squamata* Blainville a form that has nothing to do with the specimen figured by Chenu (1859, p. 322 Fig. 2309). Tryon figured in 1883 *Anguinaria obtusa* Schumacher as *Siliquaria anguina*, and in 1886 a true *Serpula anguina*; but he was biased by Born's mistake and confused by Mörch's 1860 invalidation of *Siliquaria* Bruguière and his use of *Siliquarius* Montfort. Thus Tryon referred *S. anguina* to *Agathyrsos* Montfort. Cossmann's 1912 revision of *Tenagodes* displays serious inconsistencies due to the compounded confusion. Finally, Glibert (1962) referred to *Tenagodes* fossil species of *Siliquaria*.

Concluding and summarizing the above discussion:

(a) The true *Serpula anguina* Linnaeus, 1758, was instituted on and is represented by the form figured by Rumphius, *non* Lister;

(b) *Tenagodes* Guettard, 1770, was instituted on Rumphius' form;

(c) Born (1780) incorrectly transferred the name "*anguina*" from Rumphius's to Lister's form;

(d) *Siliquaria* Bruguière, 1789, is founded on Lister's form, *Serpula anguina* Born, non Linnaeus - that is *Anguinaria obtusa* Schumacher.

Consequently it appears that:

(e) *Anguinaria obtusa* Schumacher, 1817, also founded on Lister's form, is the type species of *Siliquaria* Bruguière;

(f) *Anguinaria* Schumacher, 1817, is a junior objective synonym of *Siliquaria* Bruguière;

(g) From this study, Rumphius's and Lister's forms also represent two different genera; therefore, both *Tenagodes* and *Siliquaria* are valid names and not mutual synonyms.

TENAGODES Guettard, 1770.

Notwithstanding that *Tenagodes* has been established since early Linnean times, a great deal of nomenclatural confusion still exists among authors, particularly in regard to:

(a) Original paper and date, and spelling of the name;

(b) Validity of the name "*Tenagodes* Guettard, 1770".

(A) *Tenagodes* appears for the first time in Guettard, 1770, with the spelling "*Tenagodus*" (p. 128-32). In this paper, generic characteristics are given and two species are referred to it: the gastropod *Serpula anguina* Linnaeus which is also figured (*loc.cit.*, pl.71, fig. 3-4) and *Serpula vermicularis* Linnaeus, which probably is an Anellid (Dodge, 1952, p. 259). For both species Guettard gives clear bibliographic references and a synthetic diagnosis, the one of *Serpula anguina* being a replica of Linnaeus's and matching with Guettard's generic diagnosis.

Later, Herrmansen (1846, *fide* Cossmann, 1912, p.146), H. & A. Adams (1856, p. 360) and Chenu (1859, 1,p. 321) quote the name, the date, and the spelling "*Tenagoda* Guettard, 1760". Yet, in Guettard's 1760 uninomial paper on "*tuyaux marins*", such a name is nowhere mentioned, although Guettard described some forms he later referred to *Tenagodes*. Subsequently, Mörch (1860) contributed to the confusion by misquoting the date of Guettard's 1770 paper as 1774. Fisher (1885, p.692) was the first to amend the spelling to *Tenagodes*, which is the correct transliteration of the Greek τεναγώδης, meaning of shallow waters. Harris (1897) doubtfully quoted two dates: "Guettard, 1770 (or 1774)".

Cossmann (1812, p.146, footnote 2) briefly discussed this nomenclatural problem, but overlooked two inconsistencies: (a) he indicated as institutive Guettard's 1760 paper: (b) he misquoted the date of 1770 paper as 1774. From the content of the footnote, it seems that he did not check the original papers.

Based on the above findings, the correct name should be:

Tenagodes Guettard, 1770 (*nom. correct*.
Fischer 1885, *pro*. *Tenagodus* Guettard, 1770,
nom. imperf.)

(B) From the above series of misquotations, it was consequential that some authors considered *Tenagodes* as an invalid uninomial name, if they were unable to check the original papers.

For instance, also being misled by the confused definition of *S. anguina* Linnaeus, Gray (1857), Chenu (1859), Tryon (1883), Gould (1866) etc. considered *Tenagodes* as an invalid name and adopted *Siliquaria* Bruguière. On the other hand, H. & A. Adams (1856, p.360), Mörch (1860), Fischer (1885, p. 652), Sacco (1896), Harris (1897 , p. 233), Cossmann, (1812), Van Winkle Palmer (1937, p.210), Davies (1935), Wenz (1939 p. 679), Ludbrook (1954) and Eames (1971) considered Tenagodes as quite valid and Siliquaria Bruguière as a junior objective synonym. To complicate the picture Gould (1966) considered Guettard's 1770 paper non-Linnean and his designation of Tenagodes non-binomial. On the other hand B.J. Smith (1972), dealing with a similar problem (i.e. the validity of Brechites Guettard, 1770) quotes an opinion by a staff member of the British Museum (Natural History) who is also a member of the International Commission of Zoological Nomenclature, as follows:

> "Guettard, in this work (Mem. Diff. Sci.), gives acceptable generic names. His species are given only vernacular names. He may therefore be considered binomial. Any Latin specific names, polynomial or binomial, are only quoted from other authors, and are not adopted by Guettard".

In conclusion, and summarizing the above discussion, in the case of Tenagodes Guettard, 1770:

(a) the name of the genus is in classical Greek although it has a Latin ending;

(b) its diagnosis has been given;

(c) both the species referred to it were quoted by their own Latin names along with a brief diagnosis;

(d) the illustration of the type species has been given, and

(e) bibliographic references are given for both the species.

Hence, notwithstanding Gould's 1966 conclusions, and supported by the previously quoted opinion, the institution of Tenagodes does not appear to be invalid, but to comply with the ICZN:

- art. 11(c)(i,ii), which enlarge the concept of binomialism for names published before 1931;
- art. 12, which indicates further requirements for an available published name;
- art. 16, which defines acceptable indications which should accompany an

available name.
Therefore, *Tenagodes* Guettard 1770 should be restored as a valid name.

SILIQUARIA Bruguière, 1789

The name *Siliquaria* appears in both the botanical and zoological literature and has been used for different taxa: in 1775 by Forskål for a plant genus of the Capparidaceae (Baillon, 1874); in 1789 by Bruguière for *Serpula anguina* Born, non Linnaeus(=*Anguinaria obtusa* Schumacher); in 1817 by Schumacher for a Bivalvia genus. It has also been subjected to mispelling by a few authors: *Silicaria*, in Daudin (1860) and Blainville (1827); (see Schulze, Kukenthal, et al., 1954, p.3185). In zoological literature, *Siliquaria* has been frequently used in Bruguière's sense, and generally and incorrectly, instead of *Tenagodes* Guettard. Furthermore, Mörch (1860) considered *Siliquaria* Bruguière, 1789 invalid because it was preoccupied by Forskål, 1775, and therefore, adopted *Siliquarius* Montfort, 1810, for a group of species he divided into two sections and in which he included *Anguinaria obtusa* Schumacher.

In conclusion, *Siliquaria* Bruguière, 1789, appears to be a valid name notwithstanding the older *Siliquaria* Forskål, 1775, on the basis of the independence of Zoological nomenclature (ICZN, Art.2). *Silicaria* Daudin, 1800 and *Silicaria* Blainville, 1827 are to be treated as subsequent incorrect spellings. From earlier discussion, the genus *Siliquaria* Bruguière is represented by *Anguinaria obtusa* Schumacher as a type species.

SILIQUARIUS Montfort, 1810

In 1810, Montfort instituted the name *Siliquarius*, changing to masculine gender the name *Siliquaria* Bruguière. He gave a sort of diagnosis, a brief discussion, a rather poor illustration and a reference, and he indicated as type a living *S. anguilus* Montfort, 1810, from the Indian Ocean (Borneo).

Mörch (1860), p.400-401) revealed about Montfort's diagnosis that "one part of his description is taken fron an Anellide, and the other is founded on a fragment of a shell found on the deck after a storm in the Bornean Sea - very likely the *Janthina exigua* ..."

Notwithstanding these remarks, Mörch accepted *Siliquarius* Montfort as a valid subgenus of *Tenagodes* Guettard for forms with transversely cracked body whorls, and matching with Davila's 1767 illustration (p.4, fig. E) quoted by Montfort (Fig. 189). He judged *Siliquaria* Bruguière invalid because it is preoccupied by *Siliquaria* Forskål, a plant genus (see previous discussion).

It is necessary to point out that Montfort's 1810 and Davila's 1767 illustrations represent two different forms altogether (Figs. 195,189). Montfort's bears some resemblance to Lister's and Born's form, whereas Davila's is referable to the *S. ponderosus* Mörch group. Probably for this reason, Mörch (1860) referred to *Siliquarius* Montfort *S. cumingi* Mörch, *S. tostus* Mörch; *Siliquaria australis* Quoy & Gaynard, *A. obtusus* Schumacher, *S. trochlearis* Mörch, *S. encausticus* Mörch, *S. incisus* (Chemnitz) and *S. ponderosus* Mörch. Furthermore, he lumped these species in two groups: *A* and *B*, both seemingly within Montfort's conception of *Siliquarius*. The former is represented by *A. obtusa* Schumacher and the latter by *S. ponderosus* Mörch.

It appears that since Mörch (1860) *Siliquarius* Montfort has nowhere been mentioned by subsequent authors. The species referred by Mörch to *Siliquarius* were subsequently restored by them to *Siliquaria* Bruguière. Recently, it has only been quoted by Schulze, Kükental, *et al.*, (1954, p.3185) as a misspelling of *Siliquaria* Bruguière. In support of the latter opinion, it is here noted that Montfort gave the same vernacular name, *Siliquaire,* as the other French authors did to *Siliquaria* Bruguière (see Lamarck, Chenu, Blainville, Deshayes, etc.) and that Montfort's name differs from Bruguière's only in gender.

The type species of *Siliquarius* raises some points for discussion in regard to the spelling of its name, its synonyms and to its type.

The spelling "*anguilus*" appears to be incorrect and should be amended. The closest Latin word with similar meaning to the French vernacular name "*anguille*", indicated by Montfort, is "*anguilla, ae", eel*, which is of the feminine gender. Subsequently, Mörch (1860) doubtfully related "*S. anguilus*" to the junior *S. australis* Quoy & Gaimard, 1834, because Montfort's illustration bears some resemblance to one of the two forms commonly referred to *S. australis* (Chenu, 1855; Clessin, 1902). Finally, since the type of the species does not even represent a siliquariid form, as has already been mentioned, this species should be revised and, if found valid, a new type should be instituted. Should this happen, then its taxonomic location should be revised as suggested by the present discussion.

ANGUINARIA Schumacher, 1817

The name *Anguinaria* Schumacher, 1817 is to be rejected as junior homonym of *Anguinaria* Lamarck, 1816 (Bryozoa).

The genus does not need a replacement of its name, because it is a junior objective synonym of *Siliquaria* Bruguière, since it was founded on the same type, *Serpula anguina* Born, *non* Linnaeus. Its type species *Anguinaria obtusa* Schumacher then becomes the type species of *Siliquaria* Bruguière.

AGATHYRSOS Montfort, 1808

(*nom. correct.* herein, pro *Agathirses* Montfort, 1808;
pro Agathyrsus Cossmann, 1912)

The spelling of the generic name *Agathirses* Montfort, 1808 is herein revised to *Agathyrsos* according to ICZN recommendations (App. II, 11).

According to Cossmann (1912, p. 148, footnote) the name is a composite from the Greek αγαθός, good, excellent, and θύρσος thyrsus.

Adhering to the normal rules of composition of names and to the meaning of the words, it would appear more probable that the former component should rather be ἀγά - curve, bend.

Another point needing clarification regards the type species of *Agathyrsos*, Montfort (1808) indicated *Agathyrsos furcellus* Montfort, 1808 (Fig. 194) as the type and raised it to a distinct species. This form was considered by Lamarck as a variety of *Serpula anguina* Born (*non* Linnaeus) and it was named by him with the vernacular name of "furcelle". Subsequently Lamarck (1818) instituted the name *S. spinosa* for the same form, as it appears from Montfort's and Lamarck's references. Since then, the name *S. spinosa* has been generally adopted by successive authors. However, as already pointed out by Van Winkle Palmer (1937), *A. furcellus* Montfort has priority, and therefore it is to be considered the valid name, whereas *S. spinosa* Lamarck is its junior objective synonym. The only possible objection to its restoration might come from a possible rejection of Montfort's name as a "*nomen oblitum*".

THE FAMILY SILIQUARIIDAE J.E. Gray, 1857.

Until Lamarck (1818), *Siliquaria* Bruguière, including the tenagodid species, was referred to Anellida.

First, Blainville (1825) transferred it to Mollusca for its affinities with *Vermetus* Daudin. Thus, since Blainville and until recent times, Siliquaria and Tenagodes were generally placed in Vermetidae.

However, the first suprageneric distinction of these genera can be found in J.E. Gray (1847, p.128), who subdivided Vermetidae into two sections: *Vermetina* and *Siliquariana* (*Siliquarina* Gray, in Mörch, 1860, p.401). Subsequently, Chenu (1860) formalized these two sections into families. Stoliczka (1868) and Sacco (1896) accepted Gray's and Chenu's distinction, but Tryon (1883), Fischer (1885), Cossmann (1921), and Wenz (1939) restored this genus to Vermetidae.

Since Wenz, Vermetidae have been subjected to a thorough revision. Morton (1951, p.39-41) studying the New Zealand Vermetidae, recognized two phyletic groups, and without previous knowledge of Gray's prior action, distinguished two families: Vermetidae d'Orbigny, 1840, and Siliquariidae Morton, 1951. He also found a strong affinity of Siliquariidae to Turritellidae, and later, he (1953, p.84-86) removed *Vermicularia* Lamarck from Vermetidae to Turritellidae, and considered it as being a transitional form to Siliquariidae. Ptchelintsev & Korobkov (1960, p.133) transferred *Pseudomesalia* Douvillé to Glauconiidae Ptchelintsev, 1953. Keen (1961) further restricted Vermetidae Gray, 1828 (*syn*. Vermetidae d'Orbigny, 1840) and referred several of the 27 genera and subgenera listed by Wenz to Anellida. Taylor & Sohl (1962, p.15, note 16) although acquainted with the above papers of Morton and Keen, inconsistently referred to Turritellidae other genera and subgenera from Vermetidae and also all the genera referred by Morton to Siliquariidae (see synoptic table). Morton (1965), discussing the form, function and evolution in Vermetidae, maintained Keen's classification unaltered. Gould (1966), dealing with shell morphology and classification of Siliquariidae, accepted Morton's classification.

Vermetidae s.l. is generally included in Cerithiacea Fleming, 1822, and Morton (1951, 1955) confirmed them in this superfamily. However, Ptchelintsev & Korobkov (1960) placed Siliquariidae and Vermetidae in their Turritellacea. Taylor & Sohl (1962) restored Vermetidae, Siliquariidae and Turritellidae to Cerithiacea.

With Morton's 1951 re-establishment of the family Siliquariidae, and because the existing *Siliquaria* vs *Tenagodes* controversy might be extended to the familial name, it is opportune to clarify a few points.

(a) *Tenagodes* Guettard and *Siliquaria* Bruguière represent two different genera (this study).

(b) Gray's 1857 institution of *Siliquariana* is founded on *Anguinaria obtusa* Schumacher (=*Serpula anguina* Born, *non* Linnaeus) that is, on the type of Siliquaria Bruguière (see the references quoted by Gray).

(c) Siliquariidae Chenu, 1853, and Siliquariidae Morton, 1959, are junior objective homonyms of Siliquariidae Gray, 1857 (=Siliquariana).

(d) The name Siliquariidae has already been accepted by Chenu (1859), Stoliczka (1968), Sacco (1896), Clessin (1902), Morton (1951, 1955, 1958, 1960, 1965) and Gould (1966).

Therefore, the familial name, here considered as correct and here proposed is:

Siliquariidae Gray, 1857
((nom. transl. Chenu, 1859 ex Siliquariana Gray, 1857
(syn: Siliquarina Mörch, 1860,
Siliquariidae Chenu, 1859;
Siliquariidae Morton, 1951;
ex eodem typo))

SHELL MORPHOLOGY IN SILIQUARIIDAE

Although the anatomy of some siliquariids has been described by Morton (1951, 1955) and by Morton & Keen (1960), the shell morphology and the variability and the taxonomic significance of the characters are still poorly known. The only information hitherto available is by: Gould (1966) on slit and protoconch morphology of two siliquariid species, S. bernardi Mörch and S. squamata Gould, non Blainville; Morton (1951) and Morton & Keen (1960) on the protoconch of Pyxipoma and Stephopoma Mörch; and by Morton (1955) as a vague indication on the distinguishing value of the general mode of coiling.

Mörch (1860) and Cossmann (1912) have produced the most accurate description of siliquariid morphology, but unfortunately both their revisions show serious and confusing discrepancies which are biased by the general conditions of siliquariid classification.

The availability of crucial material in the South Australian Museum Collections and the kind of collaboration of J. le Renard, Versailles, allowed a series of comparative observations which bring some order and some understanding to the siliquariid morphology.

A) Shell Coiling

Whorls evolute from entirely disjunct to tangent, helicospiral, from rather regularly to irregularly coiled; last whorl generally disjunct and/or straightened.

Observations: The irregular coiling might find explanation in the anti-geotropic direction of growth, due to the shell life position, and in a further adaptation to allow growth around possible inamovable obstacles present in the sponges or in the matrix in which they are imbedded.

B) Slit

Pending further observations and studies, it has been possible to identify 6 morphological types of slit:

1) Slit open wide from adult to senile stages, with smooth regular edges, and closed by an inner lamina only in juvenile stages (*Pyxipoma*).
2) Slit open narrow from adult to senile stages, with wavy slit edges, becoming smooth in senile stages, close in juvenile stages by an inner lamina (*Siliquaria kaurna* group).
3) Slit open narrow from adult to senile stages but with touching edges; edges densely crenulated, simulating a series of holes; the crenulations disappear in senile stages (*Siliquaria ponderosa* and *S. obtusa* groups, *Tenagodes*).
4) Slit close, only adorally open, reduced to a depressed wide groove for the entire shell length (*Campylothyrsos*).
5) Slit represented by a series of holes, which can be successively closed (*Agathyrsos*).
6) Slit absent (*Stephopoma*, ?*Laxispira*) or reduced to a very shallow oral sinus.

C) Slit position

Three positions were observed:

1) at the very adapical end: *P. weldi* (T. Woods), *S. australis* Quoy & Gaimard, *S. striata* (Deshayes), *S. claibornensis* Lea, *S. mitis* Deshayes, *S. multistriata* Defrance, *Tenagodes anguinus* (Linné).

2) at the abaxial-adapical connection: S. occlusa (T. Woods), S. cumingi (Mörch), S. ponderosa (Mörch) etc. This position seems restricted to Siliquaria obtusa (Schumacher) and S. ponderosa (Mörch) only.

3) adaxial adapical ((Agathyrsos lima (Lamarck), A. furcellus Montfort)).

The slit position seems to be dictated by a) the type of coiling; b) the slit morphology; c) the body whorl shape. The slit position appears to coincide with or to oscillate around the adapical intersection point of the maximum diameter of the body whorl.

D) Growth lines

6 types were observed in relation to the coiling axis:

1) Orthocline with adapical retroflection at the slit, with very narrow angle of incidence, becoming sub-parallel to the slit edges; this subparallel part covers a very narrow adsutural region, or just the edges. Ex. T. anguinus (Linné).

2) Similar to the above type, but prosocline and with the subparallel part covering a slightly wider region. Ex. P. weldi (T. Woods).

3) Very prosocline with an about 90^{0} reflection at the adapical middle region, becoming subparallel to the slit; the sub-parallel part covering from a third to a quarter of the abaxial margin. Ex. S. occlusa (T.Woods), S. cumingi (Mörch) etc.

4) prosocline with 90^{0} retroflection restricted to the adapical region (S. striata group).

5) prosocline, with 90^{0} retroflection; the retroflected part restricted abaxially to a very narrow belt, but adaxially embracing a third of the margin. This type is characteristic of the S. kaurna group and intermediate between the S. obtusa and S. ponderosa and the S. striata groups.

6) simple orthocline, with angle of incidence to the slit of 90^{0}. Ex. S. multistriata (Defrance) Chenu, S. mitis Deshayes. According to Cossmann (1912) they should be characteristic of Pyxipoma Mörch; on the contrary, as it will be discussed further, they are characteristic of a new taxon, Campylothyrsos gen. nov.

E) Spiral ornament

Absent or represented by either simple costae or costae bearing hyote-like spines or squamae.

F) Body whorl

Shape: generally subcircular, both outer and inner; but also ovoidal inner and outer as in *T. anguinus*, *S. occlusa* T. Woods and *S. cadelli* sp. nov.

Thickenss: shell thin or thick, but constant in the forms with subcircular body whorl; abapical region with maximum thickness and adapical slit region with minimum thickness in the forms with ovoidal body whorl - *S. ponderosa* (Mörch), *S. cumingi* (Mörch), *S. occlusa* (T. Woods), *S. cadelli* sp. nov.

Cracks: the narrowly coiled living *S. ponderosa* and *S. cumingi* and *S. obtusa* display from the early adult to the senile stages a dense series of axial cracks on the abaxial margins, similar to the ones displayed by the fossil species belonging to the same group. Therefore, these cracks should be considered of biological origin, and not overimposed by diagenesis. They are characteristic of the *Siliquaria obtusa*, *S. ponderosa* and *S. kaurna* groups.

Expansion rate: two types have been observed:

(a) slow and gradual throughout the entire shell growth, characteristic of the major part of the siliquariids.

(b) very rapid in the initial 1-2 whorls and very low, almost nihil, throughout all the successive whorls, observed only in the *S. ponderosa* group.

F) Protoconch

The protoconchs of the major part of siliquariid genera and species are as yet unknown due to the particular life habit of this family which is to embed themselves in sponges or soft substrata by the adapical part of the shell, and which only rarely allows for preservation of the protoconch and of the early juvenile whorls.

Nevertheless, Morton (1951), Morton & Keen (1960), and Gould (1966) have figured protoconchs of *Pyxipoma* Mörch, *Stephopoma* Mörch, and of *Siliquaria* s.l. *squamata* Gould, *non* Blainville, and of *Siliquaria* s.l. *bernardi* (Morch).

The protoconch of *Pyxipoma* and *Stephopoma* are very similar. Both are composed of 1-1.5 pseudoplanispiral whorls, covered by a spiral series of pustules and separated from the teleoconch by a sharp cicatrix.

The two types of protoconch differ in pustule size: very fine and minute in *Pyxipoma* (Morton, 1951); coarse and large in *Stephopoma* (Morton & Keen, 1960); Olsson & McGinty, 1958).

The protoconchs of *Siliquaria* s.l. *squamata* Gould and of *Siliquaria* s.l. *bernardi* (Mörch) are composed of two high spired turriculate whorls with spiral costellae and are separated from the teleoconch by a sharp cicatrix.

Siliquaria s.l. *ponderosa* (Mörch) is characterized by a clumsy large sized pseudoplanispiral initial whorl, which may represent either:

(a) an adaptive loss of the more fragile initial whorls to improve mechanical resistance and stability within the host sediment or sponges in which they are embedded; or,

(b) an actual protoconch, thus suggesting a possible non-pelagic development (Thorson, 1950) in the *Siliquaria ponderosa* group.

GENERIC AND SUPRAGENERIC CLASSIFICATION OF THE SILIQUARIIDAE

Because of the dearth of information on siliquariid anatomy and of the incomplete picture offered by the material here studied, all the supra specific taxa, except the Siliquaria groups, are treated as genera, although more complex relationships at genera and subgenera level cannot be excluded.

At suprageneric level, Siliquariidae are divided here into two subfamilies, Siliquariinae Gray s. str. and Stephopominae subfam. nov. This subfamilial institution is nothing else than the formalization of Morton's 1951 and 1955 Stephopoma and Siliquaria Groups.

Stephopominae subfam. nov.

Type-Genus: Stephopoma Mörch, 1860

Shell slitless; operculum chitinous, multispiral, very short spired, discoidal, outwardly concave, bearing a spiral finge of long setae; brood pouch absent.

Stephopoma Mörch, 1860

Syn. Lilax Finlay, 1927; Tenagodes H. & A. Adams, 1856, pro parte; Siliquaria Gray, 1857, pro parte.

Type. Vermetus roseus Quoy & Gaymard, 1834.

Diagnosis. Shell minute, high spired with disjunct whorl in solitary individuals, short spired with tangent whorls in colonial individuals. Body-whorl subcircular. Slit area marked by a V-shaped sinuosity in the growth lines at the adapical-abaxial connection and by a spiral lamellar process, producing a sharp, hollow carina and periodical blunt tubercula. Carina absent in senile stages.

Observations. According to Morton (1955), Stephopominae represent a distinct lineage within the Siliquariidae, derived from a common ancestral "Turritella-like stock". The slitless Stephopoma, the Eocene embryonic-slit-bearing Campylothyrsos gen. nov., and the affinity of Stephopoma to Vermicularia Lamarck - genus intermediate to both Turritellidae and Siliquariidae (Morton, 1955),support the possibility of common

A N E L L I D A

Segmentella Thiele, 1925

Lemintina Risso, 1826
(*non Auctorum*)

Burtinella Mörch, 1861

Spiroglyphus Daudin, 1800

Discovermetulus Rovereto, 1904

Tubulostium Stolickza, 1868

VERMETIDAE Gray, 1828

Vermetus Daudin, 1800

Vermetus s.str.

Vermetus s.l.

Thylaeodus Mörch, Jan. 1860
(*syn: Bivonia* Auctt., *non* Gray, 1847
Thylacodus Mörch, July 1860)

Serpulorbis Sassi, 1827
(*syn: Lemintina* Auctt., *non* Risso, 1826;
Anguinella Conrad, 1846;
Atina Gray, 1847;
Serpuloides Gray, 1847;
Aletes Carpenter, 1857;
Tetranemia Mörch, 1859;
Thylacodes Morch, 1862)

Serpulorbis s. str.

Cladopoda Gray, 1850

Tripsycha Keen, 1961

Petaloconchus Lea, 1843

Petaloconchus s.str.

Macrophragma Carpenter, 1857
(*syn: Polyphragma* Vaillant, 1871
non Quatrefages, 1866;
Petaloconchus s. str. Auctt.)

Dendropoma Mörch, 1861
(*syn: Spiroglyphus* Auctt., *non* Daudin, 1800; *Stoa* Auctt., *non* De Serres, 1846, *anellid;*
Bivonia Gray, 1847, *non* Cocco, 1832;
Siphonium Mörch, 1859, *non* Link, 1807;
Magilina Verlain, 1877(?);
Vermitoma Kuroda, 1828;
Veristoa iredale, 1937)

Dendropoma s. str.

Novastoa Finlay, 1927

Elliptovermetus Cossmann & Peyrot, 1922

FAMILY SILIQUARIIDAE GRAY, 1857
(*nom. transl.*, Chenu, 1859; *ex* Siliquariana Gray, 1857) (*syn:* Siliquariidae Chenu, 1859; Siliquarina Mörch, 1860; Siliquariidae Morton, 1951)

SUBFAMILY SILIQUARIINAE GRAY, 1857
(*nom. correct.*, Stoliczka, 1868, p.244, *pro* Siliquariana Gray, 1857) Misspellings: Siliquarina Morch, 1860; Siliquarinae Stoliczka, 1868, p.236)

°*Tenagodes* Guettard, 1770
(*nom. correct.*, Fischer, 1885, *pro Tenagodus* Guettard, 1770)

(*syn: Siliquaria* Auctorum, *pro parte;*
Agathyrsos Auctorum, *pro parte.*

Misspellings: *Tenagoda* Herrmannsen, 1846, *fide* Cossmann, 1912. *Tenagoda* H. & A. Adams, 1856; *Tenagoda* Paetel, 1887; *Tenigodes* lhering, 1907 (typographical mistake).
Misdatations: Guettard, 1760; Guettard, 1774.)

Type: *Serpula anguina* Linnaeus, 1758, *non* Born, 1780.

°*Siliquaria* Bruguière, 1789, s.l.

(*Syn: Tenagodes* Auctorum, *pro parte; Agathyrsos* Auctorum *pro parte; Anguinaria* Schumacher, 1817, *non* Lamarck, 1816; *Montfortia* Della Campana, 1890, *non* Recluz, 1843; *Hemitenagodes* Rovereto, 1899, *nom. nov.*, *pro Monfortia* Della Campana.

Non: *Siliquaria* Schumacher, 1817 (Bivalvia)
Siliquaria Forskål, 1775 (Plant genus)

Misspellings: *Siliquarius* Monfort, 1810; *Silicaria* Daudin, 1800; *Silicaria* Blainville, 1827.)

Type: *Anguinaria obtusa* Schumacher, 1817 (=*Siliquaria anguina* Born, 1780, *non* Linnaeus, 1758)

Agathyrsos Montfort, 1808
(*nom. correct.*, herein, *pro Agathyrses* Montfort, 1808)

(Syn: *Agathyrses* Auctorum *pro parte.*

Misspellings: *Agathyrsis* Paetel, 1875; *Agathyrsus* Scudder, 1882; *Agathyrsus* Cossmann, 1912.

Type: *Agathyrsos furcellus* Montfort, 1810 (= *Siliquaria spinosa* Lamarck, 1818)

°*Pyxipoma* Mörch, 1860

(Syn: *Siliquaria* Auctorum *pro parte.*

Non: *Pyxipoma* Fischer, 1885; *Pyxipoma* Cossmann, 1888, 1912; *Pyxipoma* Wenz, 1939; *Pyxipoma* Glibert, 1962.

Misspellings: *Pixypoma* (*fide* Cossmann, 1888)
Type: *Siliquaria lactea* Lamarck, 1818

Campylothyrsos gen. nov.
(Syn: *Pyxipoma* Auctorum, *non* Mörch, 1860)
Type: *Siliquaria multistriata* (Defrance) Chenu, 1841.

SUBFAMILY STEPHOPOMINAE subfam. nov.

°*Stephopoma* Mörch, 1860a

(Syn: *Tenagodes* H. & A. Adams, 1856; *pro parte;*
Siliquaria Gray, 1857, *pro parte;*
Litax Finlay, 1927.
Misspellings: *Stephostoma* Clessin, 1902

Type: *Vermetus roseus* Quoy & Gaymard, 1834

?*Laxispira* Gabb, 1877

(Syn: *Turrispira* Pethö, 1906, *non* Conrad, 1866;
Fallaciturris Tomlin, 1929)

Type: *Laxispira lumbricalis* Gabb, 1877, *non* *Vermicularia lumbricalis* (Linnaeus, 1758)

TURRITELLIDAE Woodring, 1851

Vermicularia Lamarck, 1799

Vermicularia s. str.

?*Provermicularia* Kittl, 1899

?*Laxispira* Gabb, 1877

Cassimiria Cossmann, 1899

Anguillospira Cossmann, 1912.

GLAUCONIIDAE Pchelintsev, 1953

Pseudomesalia Douvillè, 1917.

INCERTAE SEDIS

Diheliae Smith, 1906

°*Pseudobrochidium* Grupe, 1907

°*Cryptobia* Deshayes, 1863

°*Magilia* Vélain, 1877

TABLE IX

SYNOPSIS OF THE PRESENT TAXONOMIC LOCATION OF THE GENERA AND SUBGENERA LISTED BY WENZ (1939) IN VERMETIDAE AND REVISED CLASSIFICATION OF THE SILIQUARIIDAE GRAY (AFTER STOLICZKA, 1868; ROVERETO, 1904; MORTON, 1951, 1953, 1955; MORTON & KEEN, 1960; KEEN, 1961; TAYLOR & SOHL, 1962, PCHELINTSEV & KOROBKOV, 1960; HOWELL, 1962; GOULD, 1966; this study)

THE GENERA AND SUBGENERA ARBITRARILY REFERRED TO TURRITELLIDAE BY TAYLOR & SOHL (1962) ARE MARKED °

Pre-Eocene slitless ancestors.

From Olsson & McGinty's 1958 observations, *Stephopoma* displays two different types of coiling: high helicospiral with disjunct whorls in solitary individuals; shorter with tangent whorls, except the last one being straightened, or irregularly coiled, in colonial individuals. This observation finds further support from the examination of the specimens of *S. rosea* (Quoy & Gaimard) which are kept in the S.A. Museum Collections.

At the present stage, the fossil record is very doubtful. Given the strong reciprocal shell convergence displayed by these groups, the possibility of fossil species older than the Pliocene cannot be excluded as yet until a revision of the fossil Vermetidae and Anellida is carried out.

Stephopoma s. str. is recorded from the Australian Pliocene (Wenz, 1939). The Late Eocene St. Vincent Basin *Thylacodes actinotus* Tate, referred by Darragh (1970) and Ludbrook (1973) to *Lilax* (=*Stephopoma*) has to be ascribed to Anellida since it shows an annelid shell structure and no stephopomid character. Older records quoted in literature are those species currently referred to *Laxispira* Gabb (Stoliczka, 1868) and the "Eocene" Egyptian *Serpula (Spirorbis) laterecristata* Oppenheim and *Adeorbis cristatus* Mayer-Eymar (Ivolas & Peyrot, 1900, p. 153, pl. 7, fig. 35,39) which are doubtfully referred by Rovereto (1904) to *Stephopoma.*

Adeorbis cristatus, thought by de Boury (Ivolas & Peyrot, *ibid.*) to be an embryo of *Basilissa*, appears to be more close to *Orbitestella* Iredale (Rissoacea), a genus recently recognized by Le Renard in the Middle Eocene Paris Basin, which was hitherto known in the Australian Tertiary (this study) and as living in the Australasian and Pacific regions.

Spirorbis laterecristatus remains an *incertae sedis* at least until the paper in which it was instituted becomes available. The Maastrichtian *Laxispira* Gabb, placed by Tryon (1883) in Trochidae and by Cossmann (1912) and Wenz (1939) in *Vermicularia* Lamarck as a subgenus, displays shell coiling and general features very close to many high-spired and narrowly coiled siliquariids and solitary stephopomids. Therefore, *Laxispira* might represent either a Vermiculariid converging to siliquariid shell, or an ancestral slitless form of both Stephopominae and Siliquariinae, or it might be congeneric with *Stephopoma*. Since the protoconch of *Stephopoma* is quite characteristic and well described, a comparative examination of it and of all the other morphological characters with those of *Laxispira* should shed some light on the relationships between these two genera and, as a consequence, on Siliquariidae.

In view of the above discussion, *Laxispira* is here considered an *incertae sedis*, either belonging to Siliquariidae or to *Vermicularia* Lamarck.

Distribution. The living forms are recorded from Australasia, Senegal coasts, Caribbean Gulf, Panama and Peruvian Pacific coasts.

Stratigraphic Range. The genus has hitherto been recorded from Pliocene to Holocene (Wenz, 1939).

Siliquariinae Gray, *1857, s. str.*

Slit-bearing shell, operculum multilamellate, chitinous, high spired, conical to cylindrical, in some taxa, bearing short peripheral setae; brood pouch present.

Type genus: *Siliquaria* Bruguière, 1789

Observations. The opercula of the living *Pyxipoma weldi* (T. Woods) (Morton, 1951), *Siliquaria bernardi* (Morch) (Fischer, 1885), and *Siliquaria obtusa* (Schumacher) (Sowerby, 1878; Clessin, 1902) show similar morphology but quite distinct from *Stephopoma*. The different style of opercula, the presence of a slit and the development of a brood pouch in *Pyxipoma* in contrast with the utilization of the mantle cavity for eggs and larvae in *Stephopoma* are here considered characters distinctive enough to justify such a subfamilial distinction.

Tenagodes Guettard, 1770

Type species: *Serpula anguina* Linnaeus, 1785, s. str.

Diagnosis. Shell high spired, loosely but rather irregularly coiled, whorls disjunct, last whorl still coiled. Body whorl shape subcircular. Slit: in adapical position, open, narrow; edges finely crenulated in young and adult stages, smooth in senile ones; opposite crenulations tangent simulating pitting.

Protoconch. Unknown.

Ornament. Spiral costae, bearing hyote-like spines. Growth lines orthocline to the coiling axis, sharply retroflected at the slit, with very narrow angle of incidence, becoming subparallel to the slit edges.

Observations. Aside from *S. anguina* Linnaeus, only one other species may at present be referred to *Tenagodes* Guettard, i.e. the Middle to Late Oligocene ProtoAdriatic *Tenagodes* promuricatus Sacco (1896, p.19, pl.2, fig. 19), which might represent a primitive form of *Tenagodes*.

Geographical distribution. Fossil Central Tethys: extant, Indian Ocean, Northern and Western Australia, Great Australian Bight (dwarf).

Stratigraphic Range. Middle to Late Oligocene-Holocene.

Siliquaria Bruguière, 1789

Type species: *Anguinaria obtusa* Schumacher, 1817)

Diagnosis. Shell high spired, rather regularly coiled; whorls disjunct, nearly tangent, very slowly increasing in diameter; last whorl completely loose and straightened. Body whorl subcircular. Slit: open in adult to senile stages, with edges more or less regularly crenulated in juvenile and adult stages, smooth in senile ones; closed in juvenile stages by a secondary inner lamina (*S. obtusa* group), or initially by soldered edges and, subsequently, by a secondary lamina (*S. ponderosa* group). Slit position at the abaxial-adapical connection. Adapical margin wide and flattened.

Protoconch. Broken off.

Ornament. prosocline growth lines 90^{0} retroflected on the middle adapical region. Fine spiral costae may be present. Deep axial cracks present throughout the entire shell.

Observations. In *Siliquaria* s. str., two homogeneous groups are at present recognizable.

Siliquaria obtusa Group: smaller shell; more slender slowly expanding body whorl; more whorls; juvenile stage with many whorls and minute protoconch; a pseudo-pore bearing slit; initially closed by a secondary lamina; growth lines more prosocline.

This group is represented by: *S. anguina* and *S. obtusa* of H. & A. Adams (1856), Gray (1857), Sowerby (1878 *pars*., pl.1, fig.1a), Sowerby (1884), Clessin (1902, *pars*, pl.4, fig.5); *S. australis* of Sowerby (1878), Tryon (1886), and Fischer (1885); *Hemitenagodes ligusticus* Della Campana (Sacco, 1896, p.18, pl.2, fig.17) etc.

Siliquaria ponderosa Group: shell larger, heavier subcylindrical, few whorled, larger body whorl, expanding in juvenile stages with a very high rate and in adult to senile stages with a very low, almost nihil rate. One large clumsy, rudimental initial whorl. Adapical margin wider, slit in juvenile stages initially closed by completely soldered edges and later by an inner lamina. Apical region is flattened. This group is represented by: *S. ponderosa* (Mörch); *Siliquaria obtusa* of Sowerby (1879, pars, pl.1, fig.1b); *T. anguina* of Sacco (1896, pars, pl.2, fig.14); *S. anguiniformis* Oppenheim (Oppenheim, 1896, pl.f, fig.1); and, probably, *S. obtusa* of Mörch, (1860).

The *S. obtusa* group, as defined above, represents *Siliquaria* s. str. and it corresponds to *Siliquarius* Montfort (*pars*); to Mörch's 1860 'Group A' of *Siliquarius* ('Rima porosa'), and to *Hemitenagodes* Roverto (*nom. nov.*, *pro Montfortia* Della Campana, *non* Recluz, 1843).

The *S. ponderosa* Group corresponds to *Siliquarius* Montfort, 1810 (*pars*) and *Siliquarius* 'Group B' of Mörch (1860) (Rima simplice, apice haliotideo).

It may belong to Siliquaria s. str. or may represent a different subgenus of its own. The difference in protoconch appears to indicate a direct development (non pelagic) mode in the S. ponderosa group and a pelagic development mode in the S. obtusa group.

Their exact relationships can only be clarified by anatomical studies. Should S. ponderosa group be recognized as a distinct taxon a new name should be instituted for it.

Pyxipoma Mörch, 1860

Type: Siliquaria lactea Lamarck, 1818

Since its institution, Pyxipoma Mörch has been subjected to confusion by successive authors on its type species and, consequently, on its definition. Mörch in his 1860 institution did not fix any type species for Pyxipoma, although he referred to it Siliquaria lactea Lamarck, Pyxipoma tahitensis Mörch, P. anguillae Mörch, P. cylindracea Mörch, all of which are living.

Successively, S. multistriata Deshayes has been given as type species of Pyxipoma by Fischer (1885, p.693), Cossmann (1912, p.149), and Wenz (1939, p.681). No reason for Fischer's 1885 designation was found. Indeed, Mörch mentioned in his 1860 monograph a 'Tenagodus multistriatus Defrance' as a fossil species from Marquemont but he referred it to his section β of Agathyrsos Montfort (Mörch, 1860, p.411, 414). As a consequence, Cossmann (ibid) based his diagnosis on Fischer's type species which has a quite different morphology. In fact, he remarked on the strong difference between the Eocene species and the living ones figured by Tryon (1896) which he considered a true Tenagodes.

Mörch's 1860 diagnosis of Pyxipoma is as follows: 'Rima hians, marginibus utrinque acutis, postice lamina interna clausa sed non repleta. Operculum spirale, margine ciliato, axis dissepimentis simplicibus'.

Meanwhile this diagnosis is consistent with the figures of the species referred to Pyxipoma and figured by Tryon and with Morton's 1951 brief description of the operculum of P. weldi (T. Woods), on the other hand the above diagnosis has no relation to that of Cossmann's (1912). Direct observations on specimens of the Eocene Siliquaria multistriata De France and S. mitis Deshayes, Cossmann's geno- and plesiogenotype respectively, confirmed a closed slit for the entire shell, except at the adoral region.

Furthermore, these two species, and P. lactea and P. weldi show substantial differences in growth lines (annular orthocline in the former two; prosocline and retroflected at the slit in the latter two) and in the coiling (paucispiral very loose in the former two; multispiral evolute in the latter two). It is therefore necessary to designate a type species for Pyxipoma in order to obtain a better concept of this genus. Siliquaria multistriata (De France) Chenu and S. mitis Deshayes have both to be excluded because: a) they do not belong to the original nominal series, and as mentioned above, they show characters inconsistent with Mörch's 1860 diagnosis. On the other hand, S. lactea Lamarck, the first listed species, is consistent with Mörch's diagnosis and is the only one of the original series in Mörch (1860), which had previously been figured (Mörch's monograph is without any illustration), and the other species referred to Pyxipoma were instituted by Mörch in that paper.

Therefore, S. lactea Lamarck is here designated as type-species of Pyxipoma Mörch, 1860, in agreement with art.69 of ICZN.

From the designation of the above type species, two points now arise:

a) the validity of Pyxipoma Mörch as against Tenagodes Guettard.
b) the validity and, consequently, a new name for the genus mistaken for Pyxipoma by Fischer (1885), Cossmann (1912) and Wenz (1939).

Validity of *Pyxipoma* Mörch. As already mentioned, Cossmann (1912) considered as true Tenagodes the living species referred by Tryon (1886) to Pyxipoma Mörch. However, direct observations on specimens of P. weldi (Tenison Woods) and T. anguina Linné revealed the following differences:

- Slit open with wide gap and thin regular edges; closed in early stages only by an inner lamina in Pyxipoma; open with a very narrow gap and periodical crenulations on both the edges, just touching each other and gradually fading in adult-senile stages in *Tenagodes*.

- *Growth lines* (in relation to the coiling axis) prosocline with an adapical retroflection at the slit, in *Pyxipoma*; orthocline with an adapical retroflection at the slit, in *Tenagodes*.
- *Coiling* rather regular, with a trend to a low whorl translation rate and to a more regular coiling axis, in *Pyxipoma*; very irregular with a trend to a very high whorl translation rate and to a more irregular coiling axis in *Tenagodes*.
- *Protoconch* difference indeterminable because no tenagodid protoconch was available.
- *Shell size* much smaller in *Pyxipoma* than in *Tenagodes*.

Therefore, *Pyxipoma* is here retained as a valid genus, distinct from *Tenagodes*.

Validity of new name of *Pyxipoma* Fischer, 1885 (non Mörch, 1860)

The morphological characteristics of *S. multistriata* (De France) Chenu and of *S. mitis* Deshayes - completely closed slit, annular orthocline growth lines, uncoiled or paucispiral shell - support their retention in a genus distinct from *Tenagodes*, *Pyxipoma*, *Agathyrsos* and *Siliquaria*. For this new genus the following name is instituted here and the following diagnosis is given.

Campylothyrsos gen. nov.

Pyxipoma Fischer, 1885
Pyxipoma Cossmann, 1888
Pyxipoma Cossmann, 1912
Pyxipoma Wenz, 1939
Pyxipoma Glibert, 1962 (*non* Mörch, 1860)

Derivation of the name. From the composition of the Greek καμπύλος, bent, curved, and θύρσος, thyrsus; masculine gender.

Type species: *Siliquaria multistriata* (Defrance) Chenu, 1841, Fischer's type of *Pyxipoma* (Cossmann, 1912, p.149, pl.10; fig.6) (Figs. 196-197). It is pointed out that two authors are mentioned as instituting this species - Deshayes and Defrance, no date indicated.

However, Deshayes (1864, p.297) remarks that the first mention of this species had been found in Chenu (1841, p.2, pl.2, fig.2) as Defrance's species.

Other Species. Siliquaria mitis Deshayes (Cossmann's plesiogenotype of Pyxipoma Fischer, (Fig.198), S. brevifissurata Deshayes (Figs.199-200), S. gracilis Deshayes (Cossmann, 1888, p.321-322); Tenagodes plitus De Gregorio (fide Cossmann, 1912, p.150).

Diagnosis. Shell uncoiled and twisted, or paucispiral; body whorl shape subcircular; slit close, reduced to a marked, wide, flat groove, except than in the adoral region; simple orthocline annular growth lines; ornament of spiral beaded costae (from direct observations on specimens of S. multistriata Defrance and S.mitis Deshayes from the Late Eocene of Auvers; see also Cossmann; 1912, p.149).

Stratigraphic Range. Hitherto known only in the Eocene.

Geographical Distribution. North America and Europe (Western and Central Tethys) (Cossmann, 1912).

Agathyrsos Montfort, 1808

Type species: Agathyrsos furcellus Montfort, 1808 (Fig. 201)

Diagnosis. Shell evolute, high spired, whorls disjunct or loosely coiled. Body whorl subcircular. Slit represented by a series of pores round or elongated, communicating or not with the shell interior. Slit position adapical-adaxial to adapical.

Protoconch. Unknown.

Ornament. Growth lines annular orthocline or just retroflected at the slit. Spiral costae bearing hyote-like spines or spoon shaped squamae.

((Diagnosis from direct observations on specimens of A. furcellus Montfort, A. lima (Lamarck)).

Observations. The presence of spoon-like squamae in a specimen of A. lima confirms Cossmann's 1888 and Le Renard's 1977 opinion that A. millipeda (Deshayes) represents a form conspecific with A. lima.

After Tryon's 1886 mistake, Agathyrsos has often been used by the authors for living species of Siliquaria and Tenagodes referred by Tryon to Agathyrsos. Fischer (1885) also ascribed to it Siliquaria striata Defrance, which is rather related to Siliquaria s.l.

Other species. Siliquaria lima Lamarck (Figs. 205-206); Siliquaria millepeda Deshayes (Figs. 202-204); Agathyrsos texana Van Winkle Palmer; S. faujasi Deshayes.

Stratigraphic Range. Eocene.

Geographical Distribution. Western Tethys and Anglo-Paris Basin.

NOTES ON THE EVOLUTION AND THE TERTIARY DISPERSAL OF SILIQUARIIDAE

The following discussion has to be treated as a speculative basis for possible lines of research which are founded on shell characters of the genera here redescribed and integrated with the often too scanty information offered by previous authors. Furthermore, it is here assumed and accepted that a thorough anatomical and morphological study of the Siliquariidae may result in a total revision of what is dealt with in this paragraph.

EVOLUTION

Until recently, Siliquariidae were considered related to or lumped with Vermetidae Gray. Morton (1951, 1955) on the basis of anatomical studies, separated Siliquariidae from Vermetidae and referred them to stocks unrelated, but strongly convergent in shell and anatomy.

In Morton's 1951 and 1955 conception, Siliquariidae and Turritellidae both derive from a common "primitive *Turritella*-like stock" in which:

a) *Vermicularia* Lamarck (Morton, 1953, 1955) represents a transitional form between these two families, displaying anatomical and morphological characters close to both *Turritella* and *Stephopoma*; and,

b) the Maastrictian *Laxispira* Gabb might represent a further step toward Siliquariidae (this study).

Following Morton (1955), the Stephopominae are here considered an independent and more primitive lineage within the Siliquariidae. To support this opinion, there are four points.

a) *Stephopoma*'s shell is slitless and displays simple annular growth lines, aside from an adapical-abaxial sinuosity, similar to the most primitive Eocene Siliquariinae;

b) The most primitive Siliquariinae is *Campylothyrsos*, which displays embryonic slit.

c) The strong affinity of *Stephopoma* to *Vermicularia*; and,

d) The strong shell convergence of *Laxispira* to Stephopominae and, in general, to Siliquariinae.

It is worthy of note that the origin of Vermetidae still remains obscure (Keen, 1961; Morton, 1965).

The Siliquariinae offer a more complicated picture. They seem to have reached their critical point of maximum generic differentiation sometime during the Early Paleogene. Furthermore, all the genera seems to have appeared before the end of the Oligocene. During the Middle Eocene, the largest number of genera co-occurred in the Anglo-Paris Basin: the short lived *Campylothyrsos* gen. nov. and *Agathyrsos* Montfort; the Paleogene *Siliquaria* s.l. *striata* Group, which seems closely related to many of the extant genera; and an ancestral form of *Pyxipoma* Mörch. All these forms display generic characters not fully stabilized within their species, particularly slit and growth lines. In fact, it is possible to trace through these Middle Eocene genera and species the gradual development of the slit:

hypothetical slitless ancestor --- *Agathyrsos lima* ---
A. furcellus --- *Siliquaria striata* --- ancestral *Pyxipoma* sp.

Analogously, it is possible to determine the gradual specialization of growth lines in the Middle Eocene forms: from annular, as in *Campylothyrsos* and *Agathyrsos*, to the internal development of the 90° reflected growth lines in a very narrow adapical belt on both the sides of the slit, as in *Siliquaria* s.l. *striata* and in the ancestral *Pyxipoma* sp. Furthermore, *Agathyrsos* shows hypertrophic characters like oversized hyotid spines or spoon-like squamae.

Both *Campylothyrsos* and *Agathyrsos* do not seem to survive beyond the Eocene. The *Siliquaria striata* stock seems to disappear before or at the end of the Oligocene and to be replaced by the *S. kaurna* stock, which is already present in the Australian Late Eocene and by the Tethyan *S. obtusa* and *S. ponderosa* stocks through a further specialization of the 90° reflected growth lines and a return to a pseudo-pore-like slit. The oldest records of these two latter lineages are the Middle-Late Oligocene ProtoAdriatic *S. anguiniformis* Oppenheim from Veneto for the *S. ponderosa* stock, and "*T. anguinus*" from Liguria-Piedmont Basin, for the *S. obtusa* stock (Oppenheim, 1896; Sacco, 1896).

Analogously, the oldest record of *Tenagodes* seems to be the "Tongrian" ProtoAdriatic *T. promuricatus* Sacco, 1896 (Middle to Late Oligocene). This particular species seems to display transitional characters between the *S. striata* group and the living "*T. muricatus* (Born)" that is *T. anguinus* (Linnaeus).

DISPERSAL

Today, Stephopominae appear to be restricted to the Central Atlantic, Central and South American Pacific coasts, South Africa (Tomlin, 1918), and to Australasia. Transposed into a palaeobiogeographical framework, the possible past distribution might have been restricted to Western Tethys and to the amphinotic regions. *Laxispira* Gabb has a similar but more restricted, distribution, having been recorded only in Western Tethys.

Siliquariinae seem to have a Tethyan origin and to have dispersed very rapidly throughout Tethys and to Australasia within Eocene times, with the exception of the Eocene *Campylothyrsos* and *Agathyrsos* which have been recorded only in the Anglo-Paris Basin and in the Western Tethys. The youngest *Siliquaria obtusa* and *Siliquaria ponderosa* groups and ancestral forms of *Tenagodes* appeared before the isolation of the Central from the Eastern Tethys, and seem to have reached Australasia through an eastward migration, the first two groups already during the Late Oligocene-Early Miocene climatic optimum.

The *Siliquaria kaurna* group has hitherto been found restricted in Australian warm temperate-subtropical Tertiary waters; one extant dwarf species, possibly referable to this group, was found off Bermuda at 540-720 m depth. (*Siliquaria squamata* Gould, non Blainville)

The *Siliquaria striata* group occurred during the Paleogene in both tropical and warm temperate waters.

The *Siliquaria obtusa* and *S. ponderosa* groups appear to display similar climatic distribution.

Tenagodes, *Campylothyrsos*, and *Agathyrsos* appear to be restricted to tropical waters, with the exception of a dwarf form of *T. anguinus* (Linnaeus) which today lives in the deeper waters of the Great Australian Bight.

In conclusion, Siliquariidae seem to have dispersed very rapidly over very great distances, and their different taxa seem to have invaded in a very short time after their earliest appearances in all the regions with climatic conditions favourable to them. Such a rapid long range dispersal might find an explanation in a teleplanic larval stage of Siliquariidae as in many families of the Prosobranchia (Scheltema, 1971).

GENUS *Pyxipoma* Mörch, 1860

Pyxipoma squamigera sp. nov.

FIGS. 207-211

DERIVATION OF THE NAME. From the Latin *squamiger*, *gera*, scaly, scale bearer, from its squamose spiral costae.

HOLOTYPE. SAM P 21166, Fig. 207

PARATYPES. SAM P 21167A-B, GSSA M 3464, Figs. 208-211.

TYPE LOCALITY. Adelaide (Kent Town) Bore, Adelaide Plains SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. The Holotype, and 26 specimens, generally fragmented.

DESCRIPTION. Shell thin, high spired with disjunct whorls, narrowly coiled; whorls tangent in early stages in some specimens. Body whorl subcircular. Slit at the adapical end,with smooth edges, closed by an inner lamina in early stages, open in adult and senile whorls. Slit region very narrow.

Protoconch. 1 pseudoplanispiral whorl, rather evolute, with spiral series of minute, prominent pustules, separated from the teleoconch by a cicatrix.

Ornament. Prosocline growth lines with 90° retroflection; squamose spiral costae, not always present in juvenile stages.

OBSERVATIONS. The holotype was chosen from Tate's uncatalogued material because it is the best preserved specimen available.

The protoconch and the slit morphology place this form in *Pyxipoma* Mörch.

P. squamigera is closely allied to a Middle Eocene Paris Basin form, generally included in *Siliquaria striata* Deshayes with which it is generally found. Both forms display much larger size than the extant species.

DISTRIBUTION. Adelaide Plains SubBasin: the type locality; West End Brewery Bore CH 2, 50.30-50.00 m depth. Willunga SubBasin: Maslin Bay, Blanche Point (southern cliffs).

GENUS *Siliquaria* Bruguière, 1789

GROUP *Siliquaria obtusa* Schumacher, 1817

(*Siliquaria* s. str.)

Siliquaria occlusa (Tenison Woods, 1877)

FIGS. 226-278, 231-232

1877 *Tenagodus occlusus* Tenison Woods, p. 100.

?1962 *Tenagodus occlusus* -Glibert, p. 108.

NEOTYPE. SAM P 21174, Fig. 226-278

PARANEOTYPES. SAM P 21175 A-B, Figs. 231-232.

TYPE LOCALITY Bass Basin, Table Cape, Fossil Bluff.

STRATIGRAPHIC RANGE. Freestone Cove Sandstone, Table Cape Group, lower Early Miocene N4/N5 (Ludbrook, 1967; 1973; Quilty, 1966, 1972, 1974).

MATERIAL. The Neotype and 4 paraneotypes.

DESCRIPTION. Shell medium sized, slender, high spired, with disjunct whorls; whorls generally increasing more in height than in diameter; last whorl completely loose. Body whorl: inner subcircular, outer ovate, the shell thicker at the abapical adaxial-abaxial connection. Whorl overlapping scarce both normal and parallel to the coiling axis. Slit open with regularly crenulated edges; slit at adapical-abaxial position. Margins: adapical wide, subconvex, subhorizontal; abaxial middle subconvex, vertical; abapical subconvex subdeclivous; adaxial convex, declivous. Margin connections: adapical-adaxial rounded, subimperceptible; adapical-abaxial angular (slit); imperceptible the others. Base narrow; umbilicus narrow.

Ornament. Growth lines prosocline, 90^{0} retroflected at the middle abaxial region and gradually converging to the slit. Weak abapical spiral costae; fine and large axial cracks covering the shell surface.

OBSERVATIONS. The specimens here figured and described are from the type-locality of S.occlusa T. Woods., and their morphology is consistent with the description given by the author. Since the holotype appears to be lost (Ludbrook, 1967) the specimen SAM P 21174 is selected as neotype, and the other topotypes as paraneotypes. The types show variable coiling and the higher the spire the lesser the whorl diameter. However, the umbilicus width remains constant.

The slit morphology places S. occlusa (T. Woods) in the S. obtusa Group (Siliquaria s. str.).

Siliquaria rugosa sp. nov.

FIGS. 233-236

DERIVATION OF THE NAME. From the Latin rugosus, wrinkled, because of its axial rugae.

HOLOTYPE. sam p 21177, Fig. 233-234.

PARATYPES. SAM P 21178A-B,Figs 235-236

TYPE LOCALITY. Otway Basin, Port Campbell Embayment, 'Gellibrand River'.

TYPE FORMATION. Gellibrand Marl.

STRATIGRAPHIC RANGE. Latest Early Miocene. "The matrix, a bluish grey bryozoal marl, contains an assemblage with the biostratigraphically significant, planktonic foraminifera, Globigerinoides sicanus and Praeorbulina glomerosa curva. The presence of these two species and the absence of Orbulina sp. place this assemblage in the Praeorbulina glomerosa curva zone of McGowran et al., (1971), which correlates with the upper part of the tropical standard zone N8". (R. Heath, 1976, writt. comm.)

DESCRIPTION.Similar to S. occlusa (T. Woods). It differs in having a much higher spire, wider slit, and coarser crenulations, narrower umbilicus, more slender body whorl, finer and denser abapical spiral costae in some specimens and well developed growth rugae.

OBSERVATIONS. *S. rugosa* displays a slit of a type intermediate between *S. occlusa* and the Middle Miocene *S. cadelli* sp. nov. However, the morphological characters still place it in the *S. obtusa* Group.

GROUP *Siliquaria striata* Deshayes

Siliquaria altispira sp. nov.

FIGS. 212-213

DERIVATION OF THE NAME. From the Latin *altus*, high and *spira*, spire, because of its coiling.

HOLOTYPE. SAM P 21168, Fig. 212.

PARATYPE. GSSA M 3465, Fig. 213.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Blanche Point (Southern cliffs).

TYPE FORMATION. Blanche Point Formation, Gull Rock Member.

STRATIGRAPHIC RANGE. Late Eocene, late P15-middle P16.

MATERIAL. 13 damaged specimens (holotype included), 1 juvenile, 9 silicified specimens.

DESCRIPTION. Shell large, very high spired, narrowly coiled; whorls increasing much more in height than in diameter. Last whorl completely evolute, straightened. Body whorl subcircular, slender.

Slit slightly to the adaxial, open, with regular crenulation in younger stages and smooth edges in older whorls. Very narrow adaxial and abaxial slit region, produced by reflected growth lines.

Ornament. Fine, dense spiral costellae. Growth lines prosocline, 90^0 reflected close to the slit.

OBSERVATIONS. This form is very close to the Middle Eocene Paris Basin *S. striata* Deshayes and North American *S. claibornensis* Lea (=*S.vitis* (Conrad)) from which it only differs in finer and more numerous spiral costellae. These three species clearly form a very homogeneous group.

OTHER LOCALITIES. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; West End Brewery Bore CH 2, 50.30-50.00 m depth ('Transitional Marls').

Siliquaria sp. nov. *A*

FIG. 221

MATERIAL. 4 broken specimens (SAM P21172)

DESCRITPION. Similar to *S. altispira* sp. nov. It differs in less numerous faintly nodulose spiral costae.

OBSERVATIONS. This form results very close to *S. altispira*. It is here preferred to defer a formal institution of species to a time when better and more material is available to facilitate a more precise definition of differences between these two species.

LOCALITY. Otway Basin, Torquay Embayment, "Spring Creek", Bird Rock.

STRATIGRAPHIC RANGE. Undifferentiated Jan Juc Formation - Puebla Formation, Late Oligocene-Early Miocene (Ludbrook, 1973).

GROUP *Siliquaria kaurna*

Siliquaria kaurna sp. nov.

FIGS. 214-220.

DERIVATION OF THE NAME. After the Kaurna, the tribe of the Eastern St. Vincent Gulf.

HOLOTYPE. SAM P 21169, Figs. 214-215.

PARATYPES. SAM P 21170 A-C, 21171, Figs. 216-220.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Blanche Point (southern cliffs).

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. ?early-middle P16.

MATERIAL. The holotype, and 6 paratypes, badly preserved.

DESCRIPTION. Shell thin, rather large, rather low spired; whorls from tangent to disjunct, increasing more in diameter than in height. Body whorl oval. Adapical slit initially wide and closed by an inner lamina, open but with touching edges in the older whorls; slit edges with wavy crenulations in young and adult stages, smooth in senile whorls. Base broad, umbilicus wide. Margins convex. Margin connections imperceptible. Narrow abaxial and wide adaxial belts at the slit, produced by the reflected growth lines.

Protoconch. One smooth whorl, about homeostrophic, separated from the teleoconch by a sharp varix.

Ornament. Prosocline growth lines, 90^{0} retroflected at the slit, and gradually convergent to the edge. Traces of axial cracks. Spiral costae interupted by growth lines.

OBSERVATIONS. This form shows close affinities with S. cadelli, the Middle Miocene species, but it differs in less evolute coiling, in slit morphology, in spiral costae and thinner shell. It also differs from the extant Bermuda S. squamata Gould, 1966 (non Blainville), in one-whorled smooth protoconch, because the latter is characterized by one with two whorls and spiral costae. S. kaurna might represent an ancestral form of S. cadelli sp. nov. and perhaps, of S. squamata of Gould, but more material and a direct examination of the specimens are needed for a satisfactory conclusion.

OTHER LOCALITIES. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore.

Siliquaria s.l. *cadelli* sp. nov.

FIGS. 222-225

DERIVATION OF THE NAME. From Cadell, the name of the Hundred, in which the type-section of the Cadell Marl is situated.

HOLOTYPE. SAM P 21173, Fig. 222-223, 225.

PARATYPES. GSSA M 3466, Fig. 224.

TYPE-LOCALITY. Murray Basin, 6.4 km S of Morgan, type-section of Cadell Marl Lens, Sect. G, Hd Cadell (Ludbrook, 1961).

TYPE-FORMATION. Cadell Marl Lens.

STRATIGRAPHIC RANGE. early Middle Miocene (Batesfordian) (Ludbrook, 1961)

MATERIAL. The holotype, 3 paratypes still imbedded in their matrix.

DESCRIPTION. Shell large, rather short spired, rather evolute normal to the coiling axis. Whorls increasing more in diameter than in height. Body-whorl ovate, higher than wide. Slit at the adapical, closed in young stages by an inner lamina, wide and open in adult but very narrow in senile whorls; edges coarsely crenulated, but smooth in the last whorl; abaxial edge overlapping the adaxial one in the last whorl. Base broad, very wide umbilicus.

Ornament. Growth lines as in *S. kaurna* sp. nov. and *S. altispira*. Spiral nodular cords and axial cracks.

OBSERVATIONS. *S. cadelli* sp. nov. seems to be related to the Late Eocene *S. kaurna* sp. nov. because of its distinctive body whorl and slit morphology. It also shows close affinities with the extant Bermuda *S. squamata* of Gould (1966) (*non* Blainville) from which it differs in shorter spire and straighter coiling axis.

Siliquaria s.l. sp. nov. B

FIG. 229

MATERIAL. 1 specimen (SAM P 21176)

DESCRIPTION. Shell thin, very slender, very high spired, very narrowly coiled. Whorls disjunct, increasing much more in height than in diameter. Body whorl subcircular. Slit adapical, with touching finely crenulated edges in younger and adult stages, with smooth edges in the last whorl.

Ornament. Prosocline growth lines and rugae, retroflected just at the slit.

OBSERVATIONS. Growth lines and slit morphology are close to both the extant Australian S. bernardi Mörch, and T. anguinus Linnaeus. Its coiling place it closer to S. bernardi. It differs from both the species in absence of spiral ornament and slenderness of body whorl.

The only specimen of Siliquaria s.l. sp. nov. B was found in the uncatalogued part of Tate's Collection, and was labelled only as being from Muddy Creek. It is impossible to ascertain its precise age from the matrix.

LOCALITY. Otway Basin, Tindarra Embayment, "Muddy Creek".

STRATIGRAPHIC RANGE. Undetermined. either Middle Miocene or Late Miocene/Early Pliocene (Abele et al., 1976).

SUPERFAMILY EULIMACEA

FAMILY EULIMIDAE H. & A. Adams, 1854

GENUS Niso Risso, 1826

SUBGENUS Niso s. str.

Niso (Niso) laevigata sp. nov.

FIGS. 237-241

DERIVATION OF THE NAME. From the Latin, laevigatus, smooth, because of its polished shell surface.

HOLOTYPE. GSSA M 3467A, fig. 237

PARATYPES. GSSA M 3467B, 3468-9, Figs. 238-241.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, 20.67-20.34 m. depth.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC LOCATION. Late Eocene (Early P15-middle P16).

MATERIAL 10 specimens generally well preserved; 6 specimens from Adelaide Bore and Aldinga, undifferentiated (uncatalogued Tate's material).

DESCRIPTION. Shell thick, turriculate, high spired; whorls increasing in diameter the same as in height. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the adapical-middle connection. Body whorl shape subrhomboidal. Suture flush. Margins: abaxial adapical and middle flatsubvertical undifferentiated; abaxial abapical subconvex declivous; adaxial abapical subconvex vertical; adaxial adapical declivous, flat. Margin connections: adapical adaxial-abaxial very angular; rounded the others. Base subconvex, with narrow and deep umbilicus. Peristome subrhomboidal with very broad adapical and narrow abapical gutters. Lips: abaxial adapical falciform, subconcave, with blunt edge, producing the adapical gutter. Abaxial middle and abapical subconcave with thin edge; adaxial abapical subconcave with blunt edge; adaxial adapical flat, very thin, adherent. Lip connections: adapical adaxial-abaxial angular; abaxial middle-abapical rounded; abapical adaxial-abaxial angular;

adaxial adapical-abapical subangular.

Protoconch. Few whorled (1-2), smooth, heterostrophic, with coiling axis subhorizontal, nucleus submerged; the initial whorl deformed to simulate the sharpish apical shell tip.

Ornament. Growth lines, periodically more marked, producing regular fine striae; adapical opisthocline; abapical subprosocline. Circumbilical smooth round cord, innerly bound by a step-like sulcus in the senile stages.

OBSERVATIONS. Niso laevigata differs from the Middle Eocene Anglo-Paris N. terebellata (Lamarck) (Cossmann, 1921, p.205, pl.5, fig.50-51) in having a flatter abaxial margin, narrower umbilicus, higher spire, more opisthocline growth lines, and blunter protoconch; from the Early Eocene Anglo-Paris Basin N. constricta Deshayes in much narrower umbilicus, more arched adapical growth lines, and flatter margins; and from the Pliocene ProtoAdriatic N.terebella eburnea Risso (Sacco, 1904, p.108, pl.24, fig.5) in much flatter margins, narrower umbilicus, higher spire, and in suture non-embricate.

These observations were based on specimens of the above mentioned species which are kept in the Collection of the Department of Geology, University of Adelaide.

It must be noted that there is disagreement among the authors on the taxonomic rank of the type species of Niso, N. eburnea Risso. Wenz (1940) considers it as a species; Sacco (1892, p.24; 1904, p.108) lowered it to subspecies (Sacco's'variety') of N. terebellum Chemnitz; Cossmann (1921, p.205) indicated N. terebellum as a type species of Niso.

The specimens of N. laevigata from the Tate collection are mounted on a tablet labelled Niso psila T. Woods. The other specimens on this tablet are from Muddy Creek, Schnapper Point, R. Murray, and Gellibrand River. The specimens from Muddy Creek are topotypes of N. psila. The others belong to different species. These species have in common regular axial striae, but differ in coiling, margin outline and umbilicus width. One of them shows weak spiral costellae. It is probable that these species belong to the same lineage of which N. laevigata represents the oldest known representative in Australia.

Emerson (1965) in his revision of the living Eastern Pacific species of Niso s. str. gives the following depth range: N. splendidula (Sowerby) 11-82 m; N. interrupta (Sowerby), 20-137 m; N. excolpa Bartsch, 5.5-48.5 m; N. baueri Emerson, 36.5-82 m; ?N. lomana Bartsch, 88-137 m.

Baldi (1976, p. 138) quotes the tropical Niso agenus as deep sublittoral-shallow bathyal species. Emerson's data widen the depth range of the genus to shallower waters.

OTHER LOCALITIES. Type locality, but at 24.60-24.28 m and 25.59-25.26 m; Adelaide (Kent Town) Bore; Willunga SubBasin, Aldinga.

GENUS Eulima Risso, 1826

SUBGENUS Margineulima Cossmann, 1888

Eulima (Margineulima) striata sp. nov.

FIG. 242

DERIVATION OF THE NAME. From the Latin striatus, striate, because of its ornament.

HOLOTYPE. GSSA M 3470, Fig. 242.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 23.65-23.29 m depth.

TYPE FORMATION Blanche Point Fmtn. ('Transitional Marl'Member).

STRATIGRAPHIC RANGE. Late Eocene (P16)

MATERIAL. The holotype, a juvenile adult, with last whorl damaged.

DESCRIPTION. Shell rather thick, turriculate, high spired; whorls increasing more in height than in diameter. Whorl overlapping: parallel to the coiling axis up to the middle-abapical connection; normal to it, total. Coiling axis curve in the initial teleoconch, straight in the older. Body whorl shape subtrapezoidal. Suture flush. Margins: abaxial middle and adapical undifferentiated, flat, subvertical; abaxial abapical subconcave declivous; adaxial abapical subconvex, subvertical; adaxial adapical flat, declivous. Margin connections: abapical and adapical adaxial-abaxial angular; adaxial and abaxial adapical abapical broadly angular. Base subconvex. Peristome damaged.

Protoconch. Few-whorled (2ca), smooth; initial whorl heterostrophic horizontally coiled, nucleus partly obscured. Protoconch-teleoconch transition imperceptible.

Ornament. Smooth surface. Opisthocyrt growth lines, producing regular marked axial striae.

OBSERVATIONS. Margineulima striata differs from M. danae T. Woods (Cossmann, 1921, p.195, pl. 5, fig. 40-41) in: shorter spire, smaller size in relation of whorl number, flatter abaxial margin and larger protoconch. Other differences or similarities depend upon the discovery of material in better condition than the holotype of M. striata.
The tablet bearing the topotypes of M. danae also displays specimens from Spring Creek, Cape Otway, and Gellibrand River.
The comparison of these specimens suggest the possibility of a common Australian Tertiary lineage for these forms out of which M. striata represents the oldest known representative and M. danae the youngest one.
E. danae T. Woods was instituted by Cossmann (1921) as a plesiogenotype of Margineulima Cossmann.

FAMILY ACLIDIDAE Cossmann, 1912

(*nom. correct.*, Wenz, 1940, *pro* Aclisidae Cossmann, 1912 *nom. imperf.*)

GENUS *Aclis* Loven, 1846

SUBGENUS *Graphis* Jeffreys, 1867

Aclis (Graphis) costata sp. nov.

FIGS. 243-248

DERIVATION OF THE NAME. From the Latin *costatus*, ribbed.

HOLOTYPE. SAM P 21179A, Figs. 243-245,248.

PARATYPES. SAM P 21179 B-C, Figs. 246-247.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Southern Blanche Point.

TYPE FORMATION. Blanche Point Formation (top Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (P16).

MATERIAL. 14 specimens well and badly preserved, generally with peristome damaged.

DESCRIPTION. Shell minute, thin, slender turriculate, very high spired. Whorls increasing much more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, very scarce, with whorl just tangent. Body whorl shape subelliptical, narrow and high. Suture impressed. Margins: abaxial adapical narrow subdeclivous; abaxial middle, vertical, subconvex; abaxial abapical, convex. Region connections: abaxial adapical-middle angular, subcarinated; abaxial abapical-middle imperceptible. Base concave, narrow; peristome subelliptical, high and narrow, with adapical gutter (?). Lips: abaxial damaged; abaxial abapical thin, concave; adaxial abapical subconcave, subvertical; adaxial adapical, very thin subconvex. Lip connections: adapical adaxial-abaxial very angular; adaxial adapical-abapical, imperceptible; abapical adaxial-abaxial subangular; abaxial abapical-middle subangular.

Protoconch. 2 whorls, smooth, homeostrophic, with nucleus submerged; protoconch-teleoconch transition marked by the appearance of the axial ornament; body whorl size and coiling variable: from shorter spire and larger body whorl to higher spire and slenderer body whorl. Rare spiral series of beads.

Ornament. Growth lines and axial costae prosocline, regularly interspaced. Very fine spiral costellae in the interspaces and on the costae.

OBSERVATIONS. This form appears to be very close to the Early Eocene Paris Basin Graphis gallica cossmanni De Boury (Cossmann, 1912, p. 106, pl.7, fig. 5; pl.10, fig. 34; p. 198, pl.6, fig. 26, non 27). In particular, it appears strikingly close to the specimen figured in pl.10, fig. 31, and pl.6, fig. 26. The only perceptible difference from the illustrations, is a more carinated abaxial abapical-middle connection.

Aclis (Graphis) laevigata sp. nov.

FIGS. 249-256

DERIVATION OF THE NAME. From the Latin laevigatus, smooth, because of the absence of pustulae in its senile stages.

HOLOTYPE. SAM P21180A, Figs. 249-252.

PARATYPE. SAM P21180B, Figs. 253-256.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, southern Blanche Point.

TYPE FORMATION. Blanche Point Formation (top Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (P16).

MATERIAL. 2 specimens: the holotype, with last whorl damaged; the paratype, with the early whorl damaged.

DESCRIPTION. Similar to Graphis costata sp. nov. It differs in less prosocline growth lines and nearly imperceptible axial costae, and in vermiculations grading to pustulae in older stages.

Protoconch. 2 whorls, undifferentiated from teleoconch, with high spire and less convex abaxial margins than in Graphis costata sp. nov.

and heavy chagrin-cancellate beaded riblets.

OBSERVATIONS. This form differs from *Graphis costata* sp. nov. also in protoconch morphology and absence of spiral microcostellae. It appears to be very close to the Middle Eocene Paris Basin *Graphis eocenica* (de Boury) in very faint axial ornament and margin shape (Cossmann, 1912, p. 105, pl.6, fig. 27 - as *G. gallica*; pl. 7, fig. 6-7).

SUPERFAMILY	NATICACEA
FAMILY	NATICIDAE Forbes, 1838
SUBFAMILY	POLINICINAE
GENUS	*Polinices* Montfort, 1808
SUBGENUS	*Polinices* s. str.

Polinices (Polinices) nothos sp. nov.

FIGS. 261-262, 266

DERIVATION OF THE NAME. From the Greek νονος , false, because of its erroneous initial identification as *Lunatia aldingensis* (Tate).

HOLOTYPE. SAM T 1505J, Fig. 261-262.

PARATYPE. SAM T 1505K, Fig. 266a,b.

TYPE LOCALITY. Aldinga Bay, Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (middle P16-P17).

MATERIAL. 2 types well preserved; 58 specimens from outcrops.

DESCRIPTION. Shell small; globose, conical-ovoidal, short spired; whorls increasing more in diameter than in height. Whorl overlapping: normal to the coiling axis, total; parallel to it, upt to the abaxial middle adapical connection. Abaxial margins: convex, undifferentiated, the more declivous the older the stage; narrow adsutural concave belt. Margin region connections: all imperceptible. Base convex, broad, with narrow umbilicus, nearly obscured by a thick lobe and close by a large funicle. Peristome broad, semilunar. Lips: adaxial adapical and abapical straight, very thick and smooth, producing a thick short adapical lobe, separated from the umbilical funicle by a subhorizontal wide groove; abaxial adapical and middle thin, very elliptical; abaxial abapical thick, very elliptical. Lip connections: adapical abaxial-adaxial very angular, represented by a gutter; abapical abaxial-adaxial rounded; imperceptible the others.

Protoconch. Smooth, homeostrophic, indistinct from teleoconch; nucleus very small.

Ornament. Prosocline fine growth lines and faint irregular growth rugae.

OBSERVATIONS. The tablet SAM T1505 bearing the holotype and the paratypes of *Lunatia aldingensis* (Tate) also displays specimens belonging to the other two different genera and species: *Polinices (Polinices) nothos* sp. nov. and *Tanea falsa* sp. nov. *P. nothos* is referred to *Polinices* Montfort s. str. because of its body whorl shape, narrow umbilicus, heavy funicle, thick lobe and suture.

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin; Blanche Point at Aldinga Bay ('Soft Marls' also). Murray Basin: Waikerie, Sect. 692, Hd Waikerie, Observation Bore 2, 223.10 m depth (Lower Buccleuch A Equivalents, Lindsay & Bonnett, 1973).

GENUS *Lunatia* Gray, 1847

Lunatia aldingensis (Tate, 1893)

FIGS. 257-260

1893 *Natica (Naticina) aldingensis* Tate, p. 326, pl.10, fig. 5.

1973 *Friginatica aldingensis* -Ludbrook, pl. 25, fig. 57-58.

MATERIAL. Holotype and 6 paratypes (SAM T1505 B, A, C-G); 81 specimens from outcrops (4 silicified), generally damaged.

DESCRIPTION. Shell rather thick, globose, ovoidal; whorls increasing slightly more in height than diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to just below the adapical-middle connection. Sutures adpressed, subcanaliculate. Abaxial margin regions:

adapical and middle subconvex to flattened; middle and abapical very convex. Region connections: all subangular. Base broad convex, with narrow deep umbilicus, bound by a faint rim; peristome semilunar, wide. Lips: adaxial adapical and abapical straight, thick, the latter somewhat reflected; abaxial adapical, middle and abapical very convex. Lip connections: adapical abaxial-adaxial angular, represented by a broad gutter; abapical adaxial-abaxial rounded; imperceptible the others.

Protoconch. Few-whorled, smooth, homeostrophic, with small nucleus; protoconch-teleoconch transition imperceptible.

Ornament. Prosocline growth lines and rugae; spiral faint adsutural groove; very fine spiral costellae more marked at the adapical-middle angularity.

DIMENSIONS: (mm)

Spec.	No W	Ht	Hlw	Lis	Dmx	HP	DP
T 1505	6	19.55	18.10	3.60	18.55	14.55	?9.85
T 1505 A	6	18.60	16.15	3.30	16.90	-	-
T 1505 C	5	12.25	11.60	1.75	12.20	-	-
T 1505 D	5	15.00	13.80	2.10	14.20	-	-
T 1505 E	5	12.55	10.80	1.90	12.30	-	-
T 1505 F	5	13.70	11.65	2.10	11.50	-	-
T 1505 G	4	11.20	10.65	1.30	11.15	-	-

OBSERVATIONS. Cossmann (1925, p.136) referred this form to Lunatia Gray. Darragh (1970) and Ludbrook (1973) to Friginatica Hedley. Hedley (1916) instituted Friginatica for a very smooth and featureless group of naticids, with Natica beddomei Johnston, 1894 as type species. However, as Finlay (1927, p.395) already pointed out, some of the species described as Friginatica by Hedley (1916, p.52) display quite different generic characters from Friginatica beddomei.

Later, Marwick (1924a) instituted Sulconacca for a group of naticids with canaliculate suture and a circumbilical sulcus (type: S. vaughani

Marwick). However, Finlay (1927) considered *Sulconacca* as a synonym to *Friginatica* Hedley. From the specimens and the original illustrations and diagnosis of the species unanimously referred by the authors to Friginatica, it is possible to distinguish two main groups:

- *Friginatica beddomei* Group, characterized by whorls just tangent and a broadly canaliculate suture, a wide shelf sloping to the axis, and no umbilical furrow ((*F. polita*(T. Woods), *F. marshalli* Marwick, *F. beddomei*)).
- *Sulconacca vaughani* Group. with circumbilical sulcus, narrower canaliculate suture, steeper shelf, thicker adaxial lips, shorter spire and more tangent whorls ((*S. vaughani* Marwick, *S. suturalis* (Hutton), *S. prisca* Marwick; *S. compressa* Marwick; ? *S. haasti* Marwick))(Fleming, 1966, pl.93, 99). Fleming (1966) restored *Sulconacca* to distinct genus. From the above discussion, Fleming's restoration appears to be justified.

The adaxial lip, umbilicus, and suture of *Natica aldingensis* do not match with those of *Sulconacca* or of *Friginatica*, but they do with those of *Lunatia*. Therefore, in agreement with Cossmann, the species is here referred to *Lunatia* Gray. Ludbrook's and Darragh's attribution to *Friginatica* might be due to the fact that the original series of *Lunatia aldingensis* is composite (see discussion in *Tanea falsa* and *Polinices nothos* spp. novv.)

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Blanche Point, southern side.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16), Blanche Point Formation.

FAMILY NATICINAE Forbes, 1838

GENUS *Tanea* Marwick, 1931

Tanea falsa sp. nov.

FIGS 263-265

DERIVATION OF THE NAME. From the Latin *falsus*, false, because of its erroneous initial identification as *Lunatia aldingensis* (Tate).

HOLOTYPE. SAM T 1505M, fig. 263-266

PARATYPES. SAM P 21181, fig. 265.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Blanche Point at Aldinga Bay.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. 84 specimens (26 silicified), 2 from Tate collection (SAM T 1505 M, N).

DESCRIPTION. Shell small, globose, conical-ovoidal, short spired; whorls increasing more in diameter than in height. Whorl overlapping: normal to the coiling axis, total; parallel, up to just above the abaxial-middle-adapical connection. Suture adpressed. Body whorl shape semilunate. Abaxial margins: adapical subconvex declivous; middle and abapical convex. Margin connections: adapical-middle subangular, imperceptible the others. Base wide, convex, with umbilicus partially filled by a large funicle at the middle adaxial abapical lip. Peristome semilunate. Lips: adaxial adapical and abapical thick and straight; abaxial adapical, middle, and abapical thick, very elliptical. Lip connections: adapical adaxial-abaxial broadly angular, represented by a gutter; abapical adaxial-abaxial rounded marked by a fine umbilical cord.

Protoconch. Smooth, with large nucleus. Teleoconch/protoconch transition imperceptible.

Ornament. Prosocline fine growth lines and irregular rugae.

OBSERVATIONS. Broad umbilicus, funicle, body whorl shape and suture place this form in Tanea Marwick. The specimens are generally juveniles and only one silicified represents an adult. The juveniles display an umbilical cord at the abapical adaxial-abaxial lip connection, whereas the older one does not. As soon as more material is available the meaning of this umbilical cord has to be clarified to ascertain if it has taxonomic or ontogenetic value.

The specimen SAM T 1505 L is doubtfully referred to Tanea falsa because the matrix obscures the entire base.

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Aldinga Bay. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore.

SUBFAMILY	SININAE
GENUS	Sinum Röding, 1798
SUBGENUS	Ectosinum Iredale, 1931

Sinum (Ectosinum) sp. nov.

FIGS. 485, 488

MATERIAL. One small specimen with adoral part of the last whorl damaged, and shell partly obscured by the matrix (SAM P 21229).

DESCRIPTION. Shell minute, globose, rather high spired, of three whorls. Whorls increasing far more in diameter than in height. Whorl overlapping up to the adapical region. Suture subadpressed. Abaxial margin regions: adapical narrow subconvex declivous; middle broad, convex, subvertical; abapical convex subhorizontal. Region connections all imperceptible. Base concave, Peristome subovoidal larger than high, practically obscured by the matrix.

Protoconch. homeostrophic, ?paucispiral, obscured by shell fragments.

Ornament. Prosocline growth lines; in the last whorl growth rugae more marked on the adapical.

OBSERVATIONS. Coiling, peristome and body whorl diameter, which is by far wider than in *Sinum* s. str., place this form in *Ectosinum* Iredale. This form is the oldest form known of *Ectosinum*. The only other fossil species known is the Late Oligocene-Early Miocene *E. microstira* (Tate) (Tate, 1893, p.328, pl.7, fig.10; Darragh, 1970.) *Sigaretus* Lamarck is a junior synonym of *Sinum* Röding (Wenz, 1941, p.1038).

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore.

STRATIGRAPHIC RANGE. Blanche Point Formation, Late Eocene (late P15-middle P16).

SUPERFAMILY	TONNACEA
FAMILY	CYMATIIDAE
GENUS	*Charonia* Gistel, 1848
SUBGENUS	*Austrosassia* Finlay, 1931
	Charonia (Austrosassia) cribrosa (Tate, 1888)

FIGS. 267-268

1888 *Triton cribrosus* Tate, p. 125, pl.5, fig.5.

1934 *Cymatium cribrosum*-Chapman & Crespin, p.124.

1973 *Austrosassia cribrosa* -Ludbrook, pl.25, fig. 52.

MATERIAL. Holotype and two paratypes (SAM T 503 B,A,C); 1 silicified juvenile and 1 specimen, both badly preserved.

DESCRIPTION. Shell thick, fusiform, high spired, with whorls increasing more in height than in diameter. Whorl overlapping: parallel to the coiling axis, up to the middle abapical connection, normal to the coiling axis total. Body whorl shape: ovate-clavate. Abaxial margin, convex subangular: adapical region flat, declivous; middle and abapical convex, declivous. Region connections: adapical-middle angular, carinated; imperceptible the other. Base concave, peristome broad, ovoidal, merging into a long deep broad reflected siphonal channel. Lips: adaxial adapical straight, thin, adherent; adaxial abapical elliptical, adherent, with one abapical fold; adaxial siphonal subelliptical, concave, detached; abaxial with a thick varix bearing 6 inner broad denticles; very elliptical; abaxial siphonal thin, elliptical convex. Lip connections: adaxial adapical-abapical and abaxial-siphonal imperceptible; adaxial abapical-siphonal angular; adapical adaxial-abaxial broadly angular.

Protoconch. 2 homeostrophic whorls; nucleus erect; initial whorl finely costate; the second cancellate.

Ornament. Growth lines and axial costae slightly prosocline; three prominent axial varices on the last two whorls. 5 prominent primary spiral ribs, the middle-adapical on the carina, and 3 secondary in between. In some interspaces, very fine tertiary riblets. On the abapical region dense secondary ribs. Beaded costa-rib intersections.

DIMENSIONS. (mm):

Spec.	NoW	Ht	Hlw	Lis	Dmx	HP	DP
SAM T 503B	7	33.80	23.40	6.10	15.80	20.00	-

OBSERVATIONS. Following Darragh (1970) and Lubdrook (1973) this form is referred to Austrosassia Finlay.

The silicified specimen, although badly preserved, shows cancellate ornament in the initial teleoconch whorl and similar but smaller protoconch. Wenz (1941, p.1068) ranks Austrosassia as a subgenus of Charonia Gistel.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin; Adelaide (Kent Town) Bore. Willunga SubBasin: Maslin Bay, Blanche Point, at Aldinga Bay. South Coast Norseman Basin: Albany, Plantagenet Beds (Quilty, 1974).

STRATIGRAPHIC RANGE. Blanche Point Formation, Late Eocene (P15-middle P16).

GENUS *Argobuccinum* Bruguière, 1792

SUBGENUS *Cymatiella* Iredale, 1924

Argobuccinum (Cymatiella) oligostirum (Tate,1888)

FIGS. 269-273.

1888 *Triton oligostirus* Tate, p. 126, pl.6, fig.7.

1973 *Cymatiella oligostira* -Ludbrook, pl.25, fig. 29.

MATERIAL. Holotype and paratypes (SAM T495C,A-B,D-J); 1 silicified specimen, without protoconch, 12 fragments, 9 specimens from outcrops; 4 specimens from bore material.

DESCRIPTION. Shell thick, fusiform, high spired; whorls increasing in height more than in diameter. Whorl overlapping: parallel to the coiling axis, up to the middle-abapical connection; normal to the coiling axis; total. Body whorl shape pyriform. Suture impressed, broadly ondulating, because of the varices. Abaxial margins adapical and middle convex, undifferentiated; abapical concave. Adaxial margins: abapical convex; adapical subconcave. Region connections: adapical adaxial-abaxial broadly angular; adaxial adapical-abapical subangular; abapical adaxial-abaxial, represented by the short siphonal channel; imperceptible the others. Base convex, peristome pyriform merging into short reflected siphonal channel. Lips: adaxial adapical nearly imperceptible, convex; adaxial abapical concave marked by the underlying spiral costae; abaxial very concave with inner denticulations. Lip connections: adaxial adapical-abapical angular; adapical adaxial-abaxial very angular represented by a gutter; abapical adaxial-abaxial represented by the siphonal channel.

Protoconch. 3 smooth whorls; the initial pseudo-planispiral; homeostrophic the other two, but of shorter spire.

Ornament. 2 roundish axial varices per whorl; subopisthocyrt growth lines and regular costae; very fine tertiary costellae in the interspaces. Spiral primary ribs, alternated with secondary riblets in the adapical region; in the middle and abapical region, microriblets alternated with the primary and secondary ones. Beaded costa-rib intersections.

DIMENSIONS (mm):

Spec.	NoW	Ht	Hlw	Lis	Dmx	HP	DP
1	?7	13.20	7.95	3.15	6.70	6.20	3.35

OBSERVATIONS. Cossmann (1903) referred *Triton oligostirus* Tate to *Sassia* Bellardi. Darragh (1970) and Ludbrook (1973) transferred it to *Cymatiella* Iredale. Wenz (1941) placed *Cymatiella* as a subgenus in *Argobuccinum* Bruguière.

Cymatiella quoyi (Reeve), the type species, is characteristic of shallow waters (Iredale, 1924).

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore, Adelaide Childrens Hospital Bore 5, 23.95-23.62 m, 22.64-22.31 m, 20.67-20.34 m depths. Willunga SubBasin: Maslin Bay, Blanche Point at Aldinga Bay. The other localities quoted by the authors are not considered here because of the different age, and they may be relative to different species.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16), Blanche Point Formation.

GENUS *Distorsio* Röding, 1798

SUBGENUS *Personella* Conrad, 1865.

Distorsio (Personella) maslinensis sp. nov.

FIGS. 274-277

DERIVATION OF THE NAME. From Maslin Bay, the type locality.

HOLOTYPE. SAM P 21188, Fig. 274.

PARATYPES. GSSA M 3393-94, Figs. 275-277.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Maslin Bay.

TYPE FORMATION. Blanche Point Formation ('Transitional Marl' Member).

STRATIGRAPHIC LOCATION Late Eocene (early P16).

MATERIAL. Holotype and two paratypes silicified; 5 paratypes from outcrop. 3 from bore material.

DESCRIPTION. Shell small, thick, fusiform, rather low spired; whorls increasing more in height than in diameter. Whorl overlapping: parallel to the coiling axis, up to the middle abapical connection; normal to the coiling axis, total. Suture impressed. Body whorl shape: pyriform. Abaxial margin regions: adapical middle and abapical convex, undifferentiated. Adaxial margin regions: abapical subconvex, vertical; adapical flattish. Region connections: adapical abaxial-adaxial, broadly angular; abapical adaxial-abaxial, represented by the siphonal channel; adaxial adapical-abapical rounded; imperceptible the others. Base subconcave; peristome pyriform, merging into a short squat subreflected siphonal channel. Lips: adaxial adapical convex, subimperceptible; adaxial abapical thin, flattened, detached at the siphonal channel; abaxial thick varicose, with 7 inner denticles. Lip connections: adaxial adapical-abapical broadly angular; adapical abaxial - adaxial angular.

Protoconch. Very large. 3.5 whorls: initial pseudo-planispiral; the latter two homeostrophic. Very fine spiral costellae.

Ornament. 2 round axial varices per whorl, intercalated with regular sub-orthocline costae. Spiral primary ribs, more developed in the middle region, alternated with finer secondary riblets. Rib-costa intersections beaded, particularly in the middle region.

DIMENSIONS (mm):

Spec.	NoW	Ht	HlW	Lis	Dmx	DP	HP
SAM P21188	6	9.30	6.55	1.80	6.00	2.25	5.25

OBSERVATIONS. This form is referred to *Personella* Conrad on the basis of its detached columellar lip, peristome shape, abaxial margin, and siphonal channel, and ornament . However, it differs from the type species in its lack of adaxial lip denticulations. The protoconch is unusually large. It may indicate a direct development in this species (Thorson, 1950).

A specimen from the 'Soft Marls' which was labelled '*Lampusia*, Aldinga' and referable to *P. maslinensis*, was found in the uncatalogued part of the

Tate Collection. This specimen shows a very similar protoconch, although it is smaller and smooth.

OTHER LOCALITIES. Adelaide Plains SubBasin: Adelaide Childrens Hospital, Bore 5, 25.26-24.93 m, 22.97-22.64 m, 22.31-21.98 m depths.

ORDER	NEOGASTROPODA Wenz, 1938
SUPERFAMILY	MURICACEA Fleming, 1828
FAMILY	MURICIDAE Fleming, 1828

OBSERVATIONS. Ponder (1972) revealed that the classification of this family, based essentially on shell morphology, needs further revision through anatomical control and that such studies may result in a re-shuffling of the genera and species among the various subfamilies.

Keen (1944), Vokes (1964) and Ponder (1972) revived Cossmann's 1903 subdivision of the Muricidae to include: Muricinae, Ocinebrinae, Typhinae, Trophoninae, Rapaninae, and possibly, Thaidinae. Wenz (1941) previously grouped Typhinae and Trophoninae in Muricidae and included Ocinebrinae and Thadinae in Drupinae (=Purpurinae). Trophoninae are however composite, with species possibly belonging to four different subfamilies (Ponder, 1972). Columbariidae, considered by Wenz (1941) as a subfamily of the Muricidae, are reinstated to familial rank by Darragh (1969).

SUBFAMILY	TYPHINAE Cossmann, 1903
GENUS	*Laevityphis* Cossmann, 1903
SUBGENUS	*Laevityphis* s. str.
	Laevityphis (Laevityphis) ludbrookae Keen & Campbell, 1964

FIGS. 289-290

1888 *Typhis tripterus* Tate, p.93, pl.3, fig.14 (*non* Grateloup)
1944 *Pterotyphis (Semityphis) "tripterus"* -Keen, p.67.
1964 *Laevityphis (Laevityphis) ludbrookae* Keen & Campbell, p.52,fig. 33-4,36.

1973 Laevityphis (Laevityphis) ludbrookae -Ludbrook, pl.25, fig. 46.

MATERIAL. Holotype and paratype (SAM T 453B-A). 2 silicified fragments; 1 fragmented specimen from GSSA collections (M2092).

DESCRIPTION. Shell small, fusiform, rather thin, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Body whorl shape: clavate; adapical pyriform; abapical narrow and subrectangular. Suture impressed. Abaxial margin region: adapical narrow, concave, declivous; middle subconvex, subvertical; abapical declivous, convex; siphonal straight, vertical. Region connections: adapical-middle angular carinated; middle-abapical imperceptible; abapical-siphonal rounded. Base subconcave; peristome pyriform, merging with a long narrow subreflected siphonal channel. Lips: adaxial adapical and abapical thick, elliptical, and detached; abaxial angular very thick.

Protoconch. 2 homeostrophic, smooth whorls, with nucleus slightly tilted.

Ornament. Growth lines: adapical prosocline; middle and abapical suborthocline. Three high narrow lamellose tubercules per whorl. Spiral: two carinae one adapical middle and one middle-adapical marking the end of the varices. Interspaces between varices represented by squat mounds. Tubercules hollow, roundish and orthocline, located at 2/3 of the varix interspaces; 3 on the first teleoconch whorl; four on the others.

OBSERVATIONS. L. (Laevityphis) ludbrookae is a nomen novum instituted by Keen & Campbell for "Typhis tripterus Tate", a name preoccupied by Typhis tripterus Grateloup, 1833 (Keen, 1944, p.67). The paratype T 453A, a more senile specimen, displays a less angular abaxial margin.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Adelaide Childrens Hospital Bore 5, 20.67-20.34 m depth; Wllunga SubBasin, Maslin Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation (Late Eocene, late P15-middle P16).

GENUS Typhis Montfort, 1810

SUBGENUS Talityphis Jousseaume, 1880

OBSERVATIONS. Keen (1944), Keen & Campbell (1964) and Vella (1961) restricted Talityphis Jousseaume to the American Western Tethys, and its stratigraphic range to Late Oligocene-Holocene. However, the Middle Eocene Typhis parisiensis d'Orbigny (Cossmann, 1903, pl.2, fig.19), the Middle Eocene Claibornian Typhis fragilis Conrad (Van Winkle Palmer, 1937, pl.36, figs. 1,5; pl.85, fig.12), the two Late Eocene species here described, T. tetraphyllos sp. nov. and T. waikeriensis sp. nov. and perhaps, the Late Eocene Peruvian Typhis (Laevityphis) thagus Olsson (Olsson, 1930, p.58, pl.12, fig.6) represent a homogeneous group. Their oval peristome, four retrorse tubercula per whorl, diverging siphonal fasciole and channel, and winged abaxial lip are consistent with those of the Late Oligocene Talityphis praecursor Keen & Campbell (Keen & Campbell, 1964, pl.9, figs. 14, 18, 21-22). This would extend the stratigraphic range of the genus back to the Eocene and also indicate an Atlantic Boreal origin for the two Southern Australian forms here described.

Typhis (Talityphis) tetraphyllos sp. nov.

FIGS. 283-285

DERIVATION OF THE NAME. From Tate's manuscript Greek name, composite of tetra, four and phyllon, leaf.

HOLOTYPE. SAM P 21183, Figs. 283-284

PARATYPE. SAM T 459, Fig. 285.

TYPE LOCALITY. Maslin Bay, Willunga SubBasin.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene, late P15-middle P16.

MATERIAL. The Holotype, silicified, deformed; the paratype, damaged.

DESCRIPTION. Shell thick, medium sized, high spired; whorls increasing more in height than in diameter. Whorl overlapping: parallel to the coiling axis, up to the abaxial abapical-middle connection; normal to the coiling axis, total. Body whorl shape clavate. Suture impressed. Margins: abaxial adapical narrow, concave, declivous; abaxial middle convex subvertical; adapical concave, long; adaxial abapical short, vertical; adaxial middle and adapical convex, undifferentiated. Margin connections: adapical abaxial-adaxial angular abapical adaxial-abaxial represented by the siphonal channel; adaxial middle-abapical and abaxial adapical-middle angular, the latter forming a carina, and limiting a narrow sutural ramp; undifferentiated the others. Base wide, concave. Peristome ovoidal. Siphonal channel sheathed, separated from the siphonal fasciole by a deep vertical groove; siphonal fasciole bent to the abaxial; aboral region of the neck tetragonal, with spigularities represented by the axial varices. Lips: abaxial outer varicose, alate; abaxial inner prominent, sharp, concave; adaxial prominent, sharp, detached. Lip connections: all rounded except the abapical adaxial-abaxial angular.

Protoconch. Two whorls, smooth, homeostrophic, high spired, with subdetached nucleus.

Ornament. Growth lines prosocyrt; four sharp, priminet axial varices per whorl, each with a retrorse tuberculum in a rear position at the adapical middle carina; traces of faint axial crenulations at the edge and of zig-zag striae on the lip varix of the holotype.

OBSERVATIONS. Peristome shape, retrorse tubercula, tetragonal neck, alate abaxial lip, lip ornament, and siphonal morphology place this form in Talityphis Jousseaume.

The paratype SAM T 459 is the specimen mentioned by Keen & Campbell (1964) as a possible morpha of Laevityphis ludbrookae Keen & Campbell. The matrix and the preservation of the paratype indicate the 'Soft Marl' Member as an horizon of provenance.

OTHER LOCALITIES. Aldinga Bay, Willunga SubBasin.

Typhis (Talityphis) waikeriensis sp. nov.

FIGS. 286-288

DERIVATION OF THE NAME. From Waikerie, the name of the type locality.

HOLOTYPE. GSSA M 3395, Figs. 286-288.

TYPE-LOCALITY. Waikerie Bore 2W, hd Waikerie, Sect. 692, 228.02-226.38 m depth (Murray Basin).

TYPE FORMATION. Buccleuch 'A' Beds (Lindsay & Bonnett, 1973).

STRATIGRAPHIC RANGE. Latemost Eocene, P16/P17-P17 (this study; Buonaiuto, in prep.)

MATERIAL. The holotype, only, partly damaged.

DESCRIPTION. Similar to Talityphis tetraphyllos. It differs in shorter spire, heavier shell, tubercules nearer to the varices, less prosocyrt varices, wider and heavier neck, wider siphonal fasciole-sheath groove, marked crenulation of the lip varix edge, spiral grooves and marked zig-zag striae on the lip varix.

OBSERVATIONS. Although this form is represented by only one specimen, the above described differences from T. tetraphyllos are deemed sufficient to justify a distinction at species level.

GENUS Pterynotus Swainson, 1833

SUBGENUS Pterynotus s. str.

Pterynotus (Pterynotus) bifrons Tate, 1888

FIG. 280.

1888 Murex (Pterynotus) bifrons Tate, p.97, pl.1, fig.12.

1973 Pterynotus (Pterynotus) bifrons -Ludbrook, pl.25, fig.49.

MATERIAL. Holotype and two paratypes (SAM T 439 A-C), with siphonal channel broken; 1 silicified specimen, well preserved, but with broken protoconch (SAM P 21281).

DESCRIPTION. Shell small, fusiform, high spired, whorls increasing more in height than in diameter. Whorl overlapping: parallel to the coiling axis, up to the middle abapical connection; normal to the coiling axis, total.

Suture impressed. Body whorl shape pyriform. Abaxial margins: adapical declivous subconvex; middle subconvex vertical; abapical subconvex declivous. Abaxial margin connections subangular. Base concave; peristome pyriform, merging into a long slender subreflected siphonal channel. Lips: adaxial adapical convex, thin, adherent; adaxial abapical concave, extended on the siphonal channel, thin, detached, abaxial represented by a wing-like varix. Lip connections: adapical abaxial-adaxial angular; adaxial adapical-abapical imperceptible.

Protoconch. 1 smooth whorl, short spired, slightly tilted.

Ornament. 7 wing-like axial varices per whorl, but only 5 in the last one, all of them hooked forward on the adapical. Growth lines: adapical opisthocyrt; middle and abapical suborthocline. Regular spiral ribs on the middle and abapical region. On the middle-adapical connection, faint carina produced by a rib, much stronger at carina-varix intersections.

DIMENSIONS (mm):

Spec.	Now	Ht	Hlw	Lis	Dmx	Hlw/Ht	Dmx/Ht	Dmx/hlw
SAM P21281	5	16.20	11.75	4.00	7.80	0.7253	0.4814	0.6638
T439C	3	7.15	?5.75	1.45	3.85	0.8041	0.5384	0.6695

OBSERVATIONS. Tate initially referred this form to Pteronotus Swainson, 1840 ; Cossmann (1903) transferred it to Alipurpura Bayle; Darragh (1970) and Ludbrook (1973) ascribed it to Pterynotus Swainson, 1833 .

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays. The other localities quoted by the authors are here considered doubtful because of the difference in age.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16), Blanche Point Formation ('Transitional' and 'Soft Marl' Members).

SUBGENUS Pterochelus Jousseaume, 1880

Pterynotus (Pterochelus) manubriatus (Tate, 1888)

FIGS. 278-279

1888 Murex (Pteronotus) manubriatus Tate, p.96, pl.1, fig.6.

1973 Pterynotus (Pterochelus) manubriatus -Ludbrook, pl.25, fig.41-42.

MATERIAL. Holotype and 4 paratypes (SAM T 435B, A, C-E); 1 silicified specimen deformed and accidentally damaged during description (SAM P21189).

DESCRIPTION. Shell thick, fusiform, high spired; whorls increasing slighly more in height than in diameter (spines included). Whorl overlapping: parallel to the coiling axis, up to the middle-abapical connection; normal to the coiling axis, total. Body whorl shape pyriform. Suture impressed. Abaxial margins: adapical declivous, subconvex; middle subvertical, subconvex; abapical, declivous subconvex. Abaxial margin region connections: all subangular. Base convex; peristome pyriform, merging into a long slender siphonal channel. Lips: adaxial adapical thin, adherent, straight; adaxial abapical concave, extended to the siphonal channel, detached completely at the abapical end of the peristome with a sharp inflection to form a sheath; abaxial lip thick, very elliptical, bearing a wing-like varix, with an angularity at the carina.

Protoconch. 1 heterostrophic, smooth whorl.

Ornament. Growth lines: adapical prosocline; middle and abapical orthocline. 3 wing-like varices per whorl. Varix-carina intersections bearing a short spine in juvenile stages, and a long slender digitation, bent to the apex in the senile whorls. Digitation with a slim adoral channel, in correspondence of the gutter. Spiral ribs: adapical absent; abapical and middle regular. Development of varices at regular intervals of about 120°.

OBSERVATIONS. Initially referred by Tate to Pteronotus Swainson, this form was transferred by Cossmann (1903) to Alipurpura Bayle. Wenz (1941) synonymized Alipurpura to Pterochelus Jousseaume. About the latter genus there is an inconsistency of institutional dates between Cossmann, who indicates Jousseaume as 1879, and Wenz, who gives Jousseaume as 1880. Darragh (1970) and Ludbrook (1973) maintain this species in Pterochelus.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16), Blanche Point Formation.

Pterynotus (Pterochelus) adelaidensis (Tate, 1888)

FIGS. 281-282

1888 Murex (Chicoreus) adelaidensis Tate, p. 99, pl.2, fig. 4.

1973 Pterynotus (Pterochelus) adelaidensis -Ludbrook, pl.25, fig.48.

MATERIAL. Holotype and 7 paratypes (SAM T418B, A, C-H); 1 silicified specimens, with siphonal channel damaged.

DESCRIPTION. Shell rather small, thick, fusiform, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis total; parallel to it, up to the middle-abapical connection. Suture impressed. Abaxial margins: adapical convex, declivous; middle subvertical; abapical convex declivous. Abaxial margin region connections: adapical-middle imperceptible; adapical-middle carinated. Base concave; peristome pyriform, merging into a slender reflected siphonal channel. Thick lips: adaxial adapical subelliptical; adaxial abapical subelliptical detached and, after an angularity at the peristome abapical end, extended to the siphonal channel; abaxial adapical flattened; abaxial middle and abapical elliptical. Lip connections: adaxial adapical-abapical imperceptible; adapical adaxial-abaxial angular; abaxial adapical-middle very angular, represented by a deep narrow gutter; abaxial abapical-middle imperceptible. The abaxial lip developed into a thick varix.

Protoconch. 1 whorl: heterostrophic, smooth, low spired, slightly tilted.

Ornament. Spiral primary ribs alternated with one fine secondary riblet. Two carinae at middle-adapical and middle-abapical position, alternated with two secondary riblets. Regularly interspaced axial varices, the less numerous the older the whorl; last whorl bearing 4 varices. Thin axial costellae. Varice-rib and costella-rib intersections: spiny the former, beaded the latter. At the middle-adapical carina-varix intersection the longest spine sheathing the gutter.

DIMENSIONS (mm):

Spec.	NoW	Ht	Hlw	Lis	Dmx
SAM P21185	6	10.80	-	1.85	5.45
T418A	6	13.90	9.70	2.40	6.55
T418H	6	11.45	8.00	2.30	5.45

RATIOS.

Spec.	Hlw/Ht	Dmx/Ht	Lis/Hlw	Dmx/Hlw
SAM P21185	-	.5046	-	-
T418A	.6978	.4712	.2474	.6752
T418H	.6986	.4759	.2875	.6812

OBSERVATIONS. Darragh (1970) and Ludbrook (1973) refer this species to *Pterochelus* Jousseaume. Only the most perfect specimens were measured. The holotype and 6 paratypes are glued on the adoral side, which would have made a detachment from the tablet for measurements necessary.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16), Blanche Point Formation.

SUBFAMILY TROPHONINAE Cossmann, 1903
GENUS *Trophonopsis* Bucquoy, Dautzenberg & Dollfus, 1882
SUBGENUS *Trophonopsis* s. str.

Trophonopsis (Trophonopsis) hypsellus (Tate, 1888)

FIGS. 291-292.

1888 *Trophon hypsellus* Tate, pl.111, pl.2, fig.1.
1903 *Trophon (Trophonopsis hypsellus* -Cossmann, 5^{0}, p.53-54, pl.2, fig.15.
1973 *Trophon (Zeatrophon) hypsellus* -Ludbrook, pl.25, fig.40.

MATERIAL. 13 specimens from bore material; 195 specimens (62 silicified) in different conditions of preservation; holotype and paratypes (SAM T448A -B, unnumbered).

DESCRIPTION. Shell thick, small, turriculate, high spired; whorls increasing more in height than in diameter and rather overlapping; suture impressed. Shape of abaxial margins angular, a middle adapical carina delimitating a sutural ramp. Last whorl: base convex, peristome oval with an adapical broad shallow gutter at the carina and an abapical squat, broad, reflected siphonal channel. Lips: abaxial thick angular with a protruding lamellated outer varix and an inner crenulation with five rather elongated denticles; parietal and columellar smooth and adherent. Lip connections: parietal-abaxial broadly angular, abaxial-columellar channelled; parietal-columellar imperceptible.

Protoconch. 3 smooth homeostrophic whorls with deviated apex.

Ornaments. Cancellate pattern: 6 primary spiral ribs of which two on the neck; very faint and fine secondary microriblets; axial primary costae bearing very ondulating lamellae more marked on the abaxial lip and on the neck; very fine and faint axial secondary microcostae. Occasionally, the lamellae produce scales on the carina and the varices of older outer lips still occur in younger whorls.

OBSERVATIONS. Darragh (1971) and Ludbrook (1973) refer this species to *Zeatrophon* Finlay, Cossmann (1903, 5^{0}, p.53) considers this form the plesiotype of *Trophonopsis* Bucquoy, Dautzenberg & Dollfuss.

On the basis of protoconch and the above described characteristics this form is referred to the latter subgenus. The above diagnosis is based also on Tate's typic series (SAM T448).

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin; Adelaide (Kent Town) Bore; Adelaide Childrens Hospital Bore 5, 26.25-25.83 m, 25.59-25.26 m, 24.95-24.60 m, 24.60-24.28 m, 23.29-22.97 m, 22.64-22.31 m, 22.31-21.98 m, 21.33-21.00 m, 21.00-20.67 m, 20.67-20.34 m depths. Willunga SubBasin: Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

GENUS Trophon Montfort, 1810

SUBGENUS Enantimene Iredale, 1929

Trophon (Enantimene) monotropis Tate, 1888

FIGS. 293-294

1888 Trophon monotropis Tate, p.111; pl.3, fig.4.

1973 Trophon (Enantimene) monotropis -Ludbrook, pl.25, fig.39.

MATERIAL. Holotype and 8 paratypes (SAM T 441 A-B, and unnumbered); 14 specimens in different states of preservation (11 silicified).

DESCRIPTION. Shell small, thick, fusiform, high spired; whorls increasing more in height than in diameter. Suture impressed. Body whorl shape pyriform. Abaxial margins adapical convex, declivous; middle convex, vertical; abapical subconvex declivous. Margin connections imperceptible. Base concave; peristome broad, pyriform, merging into a long slightly reflected siphonal channel. Thick lips: adaxial-adapical short adherent, flattened; adaxial abapical elliptical, detached, and, after an angularity, extended to the siphonal channel; abaxial very elliptical, extended, after an angularity, on the siphonal channel, detached.

Protoconch. 2 smooth homeostrophic whorls, with dense spiral series of pustulae.

Ornament. Round prominent regular axial costae. Fine growth lines: opisthocyrt on the adapical and middle region; prosocyrt on the abapical. Spiral primary ribs, alternated with a finer secondary riblet in the middle and abapical regions. Beaded rib- and riblet-costa intersections.

OBSERVATIONS. Cossmann (1903) referred *T.monotropis* to *Hadriania* Bucquoy, Dollfuss, & Dautzenberg. Darragh (1970) and Ludbrook (1973) refer it to *Enantimene* Iredale. The opinion of the latter is here accepted, since protoconch, siphonal channel, body whorl, and growth lines match well with *Enantimene simplex* (Hedley), the type species.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin.

STRATIGRAPHIC RANGE. Late Eocene (late P15-early P16), Blanche Point Formation.

SUPERFAMILY	BUCCINACEA
FAMILY	FASCIOLARIIDAE Chenu, 1859
SUBFAMILY	FASCIOLARIINAE Chenu, 1859
GENUS	*Latirus* Montfort, 1810
SUBGENUS	*Brocchitas* Finlay, 1927

Latirus (Brocchitas) aldingensis (Tate, 1888)

FIG. 295

1888 *Peristernia aldingensis* Tate, p.156, pl.8, fig.8a(pars.)

1973 *Brocchitas aldingensis* -Ludbrook, pl.25, fig.33.

MATERIAL. Holotype (SAM T570 B)

DESCRIPTION. Shell thick, fusiform, rather high spired; whorls increasing more in height than in diameter (Dmx/Hlw: .5). Suture flush, irregularly ondulating. Body whorl claviform. Abaxial margin regions: adapical declivous, concave; abapical convex, declivous; middle convex vertical. Region connections: adapical-middle angular, carinated; middle-abapical almost imperceptible. Base subconvex; peristome ovoidal merging into a broad rather short, somewhat reflected siphonal channel. Lips: adaxial adapical convex short, thick, detached; adaxial abapical thin with abapical fold; adaxial siphonal thin, subdetached, subconcave; abaxial thick, concave, subangular, varix bearing, with 13 broad denticles; abaxial siphonal straight adherent. Lip connections: all angular; adapical adaxial-abaxial represented by a broad gutter. Marked siphonal fasciole.

Protoconch. 3 smooth homeostrophic whorls, with submerged nucleus.

Ornament. Prosocline growth lines and varices. Spiral primary costae, intercalated by secondary costellae.

OBSERVATIONS. Tate (1888) initially referred to *Brocchitas aldingensis* an Oligocene and two Late Eocene forms, the former from Port Willunga Beds (*B. aldingensis* itself), and the latter from Blanche Point Marls (*B. altior* and *B. ?altior intermedia*). These forms differ from each other in several characteristics, other than a simple variation of spire height. The body whorl is much more slender in *B. altior* and in *B. intermedia* than in *B. aldingensis*. The varices are: orthocline in *B. altior*; prosocline in *B. aldingensis*; and in between in *B. intermedia*. Tertiary riblets are: absent in *B. aldingensis*; constant in *B. intermedia*; and restricted to the middle region in *B. altior*. Protoconch has: initial whorl pseudoplanispiral in *B. altior* and *B. intermedia*; and a homeostrophic with submerged nucleus in *B. aldingensis*. Furthermore, the last two protoconch whorls of *B. altior* are subcarinated. Therefore, *B. aldingensis* and *B. altior* represent two different species. The relationships between *B. altior* and *B. intermedia* are much closer and much more material is needed to ascertain the significance of their differences and their reciprocal stratigraphic location. Therefore, *B. intermedia* is presently considered here as a morpha of *B. altior*.

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Aldinga Bay. Noarlunga SubBasin, the cliff, 300 m north of Onkaparinga Trigonometric Point (observed in field).

STRATIGRAPHIC RANGE. Oligocene (P18-?), Port Willunga Formation. The preservation and the matrix of the holotype of B. aldingensis resembles strongly the lithology of the Ruwarung Member ('Siliceous Unit' of Lindsay, 1970). The discovery of a silicified specimen in the lower Ruwarung Member in the Noarlunga SubBasin supports such an opinion.

Latirus (Brocchitas) altior sp. nov.

FIGS. 296

1888 Peristernia aldingensis Tate, p.156, pl.8, fig.8b.(pars)

DERIVATION OF THE NAME. From the Latin altior, higher, for its spire higher than in B. aldingensis Tate.

HOLOTYPE. SAM P21191, fig. 296.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Maslin Bay, first gully south of 'Uncle Tom's Cabin'.

TYPE FORMATION. Blanche Point Formation,'Transitional Marl' Member, silicified horizon.

STRATIGRAPHIC RANGE. Late Eocene (P15-early P16)

MATERIAL. Holotype and three other silicified specimens; 2 from Tate Collection (SAM T 570 H-J).

DESCRIPTION. Similar to B. aldingensis. It differs in: a far higher spire; longer and straighter siphonal channel; an absent abaxial lirae, one columellar fold. Adaxial siphonal lip adherent, reflected on the neck. Very faint siphonal fasciole.

Protoconch. 3 smooth whorls: the first pseudoplanispiral; homeostrophic and subcarinated the other two.

Ornament. Growth lines subprosocline; orthocline axial varices. Primary spiral costae, alternated with finer secondary. Tertiary costellae in primary-secondary interspaces, in the middle region.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent

Town) Bore.

Latirus (Brocchitas) altior morpha intermedia m. nov.

FIGS. 297-299

DERIVATION OF THE NAME. From the Latin *intermedius*, transitional, because it represents a form intermediate between *B. aldingensis* (Tate) and *B. altior* sp. nov.

HOLOTYPE. GSSA M3397, Fig. 297.

PARATYPES. GSSA M 3398, SAM T 570-C, Figs. 298-299.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital Bore 5, 24.28-23.95 m depth.

TYPE FORMATION. Blanche Point Formation (late P15-middle P16).

MATERIAL. 8 paratypes (SAM T570A,C-G,K-L) and 5 from bore material.

DESCRIPTION. Shell similar to *B. altior* sp. nov. It differs in shorter spire, and siphonal channel. Peristome with narrow adapical gutter. Lips: adapical adaxial very thin; adaxial abapical with two or more folds; abaxial thin with 10-13 inner discontinuous spiral lirae.

Protoconch. 3 smooth whorls; initial pseudoplanispiral, homeostrophic the other two. Nucleus not submerged.

Ornament. Growth lines prosocline; varices from prosocline to suborthocline. Spiral primary costae intercalated by finer secondary; between secondary-primary interspaces 1 tertiary costella. In adult-senile stages, 2 tertiary costellae per interspace in the middle region.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin; Adelaide (Kent Town) Bore; the type locality, but at 20.67-20.34 m, 21.00-20.67 m and 22.64-22.31 m depths.

SUBFAMILY FUSININAE d'Orbigny, 1843

GENUS *Fusinus*, Rafinesque, 1815

SUBGENUS *Fusinus* s. str.

Fusinus (Fusinus) sculptilis (Tate, 1888)

FIG. 300-301.

1888 *Fusus sculptilis* Tate, p.137, pl.10, fig.13.

MATERIAL. Holotype and 9 paratypes (SAM T 478A-J); 4 specimens badly preserved (1 silicified).

DESCRIPTION. Shell small, fusiform, high spired; whorls increasing much more in height than in diameter. Whorl overlapping: normal to the coiling axis total; parallel to it up to the middle-abapical connection. Suture flush. Body whorl clavate. Abaxial margins: adapical declivous, convex; middle convex, vertical; abapical subconvex, declivous. Abaxial margin connections all imperceptible. Base subconcave, bound by the primary abapical costa; peristome wide, ovoidal, merging into a very narrow, long, straight siphonal channel. Lips: adaxial adapical and abapical adherent, subconcave; adaxial siphonal thin, detached; abaxial adapical, middle and abapical concave, very elliptical, varix bearing; abaxial siphonal straight. Lip connections: adaxial adapical and abapical imperceptible; angular the others.

Protoconch. 2-2.5 whorls smooth, homeostrophic with submerged nucleus; last whorl carinated.

Ornament. Growth lines: adapical and middle opisthocyrt; abapical orthocline. orthocline costae on the adapical and middle regions. Three primary spiral ribs on the middle region. Regular secondary spiral riblets on the abapical and adapical region. One secondary riblet in interspaces between primary. Interspaces narrowing to the abapical. Beaded rib-costa intersections.

OBSERVATIONS. Cossmann (1901, p.12) maintained *F. sculptilis* in *Fusus* Klein. Darragh (1970) and Ludbrook (1973) referred it to *Fusinus* Rafinesque s. str.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16). Blanche Point Formation.

SUPERFAMILY	VOLUTACEA Fleming, 1822
FAMILY	OLIVIDAE
SUBFAMILY	OLIVINAE
GENUS	Baryspira P. Fischer, 1883
SUBGENUS	Gracilispira Olson, 1956

Baryspira (Gracilispira) ligata (Tate, 1889)

FIGS. 302-306.

1889 Ancillaria ligata Tate, p.147, pl.7, fig.6.

1973 Baryspira (Gracilispira) ligata -Ludbrook, pl.25, fig.55-56.

MATERIAL. Holotype and 15 paratypes (SAM T 700C, A-B,D-R); 46 specimens in different conditions of preservation (4 silicified).

DESCRIPTION. Shell fusiform, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it up to the middle-adapical connection. Suture impressed. Body whorl lanceolate, narrow and high. Abaxial margin regions: adapical narrow, very declivous, subconvex; middle and abapical subconvex, vertical, undifferentiated. Region connections: adapical-middle angular; imperceptible the other. Base narrow, subconcave, bound at the periphery by a deep narrow groove; peristome lanceolate, high and narrow, merging into a very short broad siphonal channel. Lips: adaxial adapical subconvex, very thick, producing the enamel obscuring the adapical whorl region; adaxial abapical straight, vertical with several folds some of them merging into each other; abaxial rather thin, with rounded edges. Lip connections: adapical adaxial-abaxial very angular, represented by a narrow gutter; adaxial adapical-abapical sub-angular. Initial part and adoral part of the last whorl completely or partially obscured by the enamel. In the last whorl, the region between periphery and neck, depressed and bound by a deep groove. Two broad fascioles on the neck covered by enamel. Adapical fasciole subconvex, adapically bound by a thin rim, with very fine spiral irregular microplicae. Abapical fasciole concave, adapical bound by a flat broad subcrenulated rim with very fine irregular axial microplicae. End of the siphonal channel marked by the ends of these fascioles.

Protoconch. Two smooth whorls, the former pseudoplanispiral, the latter more helicoidal.

Ornament. Growth lines broadly sinusoidal: adapical subprosocline; abapical more prosocline.

OBSERVATIONS. Cossmann (1889, p.62) referred *Ancillaria ligata* Tate to *Sparella* Gray. Darragh (1970) and Ludbrook (1973) place it in *Gracilispira* Olson. Enamel, coiling, body whorl, and peristome agree well with the characters given by Olson (1956) for this subgenus. *Gracilispira ligata* is very closely allied with the New Zealand Bortonian-Kaiatan *G. morgani* (Allan), from which it differs in higher spire and slimmer body whorl. In Olson's 1956 revision, *Baryspira* P. Fischer is raised to genus and includes the following subgenera: *Baryspira* s. str.; *Alocospira* Cossmann; *Pinguispira* Finlay; and the new *Gracilispira*, *Gemaspira*, and *Spinaspira* Olson.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin: Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin Bay, first gully south of 'Uncle Tom's Cabin'. The other localities quoted by Dennant and Kitson (1903) are of Miocene or Pliocene age and they probably refer to species congeneric with or descendant from *G. ligata* (Tate).

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16). Blanche Point Formation.

FAMILY MITRIDAE Swainson, 1831

SUBFAMILY VEXILLINAE

GENUS *Austromitra* Finlay, 1927

Austromitra pumila (Tate, 1889)

FIGS. 307-308

1889 *Peristernia pumila* Tate, p.117, pl.4, fig.4.

1889 *Mitra citharelloides* Tate, p.143, (pars).

MATERIAL. Holotype (juvenile) and 10 paratypes (SAM T 560 B,A, C-M); 9 specimens from the tablet of *Mitra citharelloides* Tate (SAM T631 A, C, E-L ; specimen D was found destroyed); 23 specimens from outcrops (2 silicified).

DESCRIPTION. Shell small, fusiform, high spired; whorls increasing much more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it up to the middle adapical connection. Suture ondulating, adpressed. Body whorl shape subclavate. Abaxial margin regions: adapical very narrow, subdeclivous at the costae, subvertical at the interspaces; middle region subvertical; abapical declivous, from concave to subconcave. Region connections: all angular. Base concave; bound at the periphery by an angularity rather attenuated in older stages. Peristome rhomboidal in younger stages to subrhomboidal in older ones, merging into a shortish wide subreflected siphonal channel. Lips: adaxial adapical imperceptible, subconvex; adaxial abapical straight with 3 more or less prominent oblique plicae; adaxial siphonal straight and detached, or reflected and adherent; abaxial adapical short and declivous; abaxial middle vertical; abaxial abapical from subconcave to concave; abaxial siphonal convex. Lip connections: all angular. Neck with a faint pseudo-umbilicus, bound by a fasciole and generally obscured by the reflected adaxial siphonal lip.

Protoconch. Dome-like. 1-1.5 whorls, homeostrophic, with nucleus submerged, with strong axial costae and secondary spiral costellae.

Ornament. Fine suborthocline growth lines, bent forward at the suture. Axial costae suborthocline, prominent, broad, adsuturally truncated, very attenuated in senile stages. Regular flat microcostellae in the narrow interspaces.

OBSERVATIONS. Tate (1889) instituted Peristernia pumila on a series of juveniles. However, he mistook part of the juveniles and 4 seniles for specimens of Mitra citharelloides Tate in the original series. Thus, only the specimen which is the holotype is to be referred to Mitra citharelloides Tate.

M. citharelloides differs from P. pumila in having a more ovoidal body whorl, prosocline to orthocline growth lines and costae, much finer spiral costellae, more or less developed adsutural ribs, two columellar plicae and smooth protoconch. On the other hand, P. pumila shows congeneric relationships with Austromitra rubiginosa (Hutton), the type of Austromitra Finlay, and closer relationships with A. quenelli Fleming (Cernohorsky, 1970, pl.10, fig.11) in body whorl shape. Therefore, P. pumila is here referred to Austromitra. (Comparative observations directly on specimens of A. rubiginosa and A. quenelli).

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation (late P15-middle P16).

FAMILY VOLUTIDAE

SUBFAMILY SCAPHELLINAE

GENUS Notopeplum Finlay, 1927

Notopeplum protorhysum (Tate, 1889)

FIG. 309.

1889 Voluta protorhysa Tate, p.126, pl.2, fig.6a-b.

1973 Notopeplum protorhysum -Ludbrook, pl.26, fig.36.

MATERIAL. Holotype and 3 paratypes (SAM T 589 A-D); 2 badly preserved specimens (1 silicified); 1 damaged from bore material (GSSA M 2978);

DESCRIPTION. Shell thin, fusiform, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Body whorl shape semiovoidal, high and narrow. Suture flush. Abaxial margin angular in younger stages, subconvex in older. Abaxial regions: adapical declivous, flattened; abapical and middle subvertical convex. Region connections: all imperceptible. Base subconvex, wide; peristome semiovoidal, narrow and high, merging into a very short and wide siphonal channel. Lips: adaxial adapical imperceptible, subconvex; adaxial abapical straight, adherent, with 4 plicae steeper to the abapical; abaxial thin, elliptical, convex. Lip connections: adaxial adapical-abapical subangular; adapical adaxial-abaxial very angular, represented by a gutter.

Protoconch. Worn off.

Ornament. Fine growth lines; prosocline in younger stages; orthocline in older stages. Axial costae: opisthocline in the initial teleoconch whorl; prosocline in neanic and adult stages; gradually fading to disappear in senile stages. Middle-adapical spiral carina in younger stages fading completely in adult-senile stages.

DIMENSIONS (mm):

Spec.	NoW	Ht	Glw	Lis	Dmx	HP	DP
T489A	?7	39.25	28.85	7.50	14.10	22.45	6.55

OBSERVATIONS. Cossmann (1899, p.127) referred this form to Scaphella Swainson, together with Voluta mccoyi Tenison Woods, Scaphella victoriensis Cossmann (Voluta polita Tate). Finlay (1927, p.514) separated this group into a new genus Notopeplum Finlay. Wilson (1972), Darragh (1970) and Ludbrook (1973) maintain V. protorhysa in Notopeplum. Wilson (1973) transfers Notopeplum from Volutinae to Scaphellinae.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Adelaide Childrens Hospital Bore 5, 25.26-24.93 m depth. Willunga SubBasin, Maslin Bay.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16). Blanche Point Formation.

FAMILY VOLUTOMITRIDAE Gray, 1854

GENUS *Waimatea* Finlay, 1927

Waimatea subcrenularis (Tate, 1889)

FIGS. 310-313

1889 *Mitra subcrenularis* Tate, p.142, pl.5, fig.6.

1973 *Waimatea subcrenularis* -Ludbrook, pl.25; fig.25.

MATERIAL. Holotype and 3 paratypes (SAM T 647B, A, C-D); 3 silicified specimens, out of which 2 well preserved.

DESCRIPTION. Shell thin, fusiform, high spired; whorls increasing much more in height than in diameter; Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Body whorls shape semiovoidal. Suture subcanaliculate. Abaxial margin subvertical, convex, with undifferentiated regions. Base subconcave; peristome semiovoidal, high and narrow, merging into a rather long narrow siphonal channel. Lips: adaxial adapical imperceptible, convex; adaxial abapical vertical, concave, with 4 prominent plicae, the abapical one limiting the channel; abaxial concave, smooth, rather thin. Lip connections: adapical adaxial-abaxial very angular represented by a broad gutter; adaxial adapical-abapical imperceptible.

Protoconch. 2 smooth homeostrophic whorls.

Ornament. Suborthocline growth lines; orthocline axial costae, more prominent in younger stages, fading in older. Spiral costae, less marked in the middle region of the last whorl.

DIMENSIONS (mm):

Spec	NoW	Ht	Hlw	Lis	Dmx	HP	DP
SAM P 21282	7	8.65	6.05	1.40	3.20	-	-
T 647C	7	10.25	7.20	1.50	3.85	-	-

OBSERVATIONS. Cossmann (1889, *in* Tate, 1898) referred this form to *Fusimitra* *Auctorum*, *non* Conrad; Tate (1898) transferred it to *Uromitra* Bellardi; Cotton (1957), Darragh (1970) and Ludbrook (1973) again transferred it to Waimatea Finlay, and Cernohorsky (1970) to Microvoluta Angas. Here, it is maintained in Waimatea.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Adelaide Childrens Hospital,North Adelaide, hd Yatala, Town Acre 717, Bore 5, 18.90-19.20 and 22.25-23.16 m depths. Willunga SubBasin, Maslin Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation (Late Eocene) (late P15-middle P16). Cernohorsky (1970) erroneously indicates for this species a Pliocene age.

Waimatea complanata (Tate, 1889)

FIGS. 314-315

1889 Mitra complanata Tate, p.138, pl.4, fig.6.

1973 Waimatea complanata -Ludbrook, pl.25, fig.24.

MATERIAL. Holotype (SAM T643), with damaged protoconch; 4 badly preserved specimens (1 silicified); 3 specimens from the GSSA Collections.

DESCRIPTION. Shell fusiform, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle region. Body whorl shape subrhomboidal, high and narrow. Suture from adpressed to subcanaliculate. Abaxial margins: adapical and middle undifferentiated, subconvex, vertical; abapical subconcave, subvertical. Region connections: all imperceptible. Base subconcave, very narrow; peristome subrhomboidal, high and narrow, merging into a broad and rather short siphonal channel. Lips: adaxial adapical thin, subconvex, adherent; adaxial abapical thin, straight, adherent, with 4 subdeclivous plicae; adaxial siphonal straight adherent; abaxial thick, with sharp edge, subelliptical, vertical. Lip connections: adapical adaxial-abaxial very angular, represented by a rather narrow gutter; subangular all the others.

Protoconch. ?1.5 smooth homeostrophic whorls.

Ornament. Fine orthocline growth lines, subprosocline in older stages. Spiral costae on the neck. Holotype with an axial traumatic cicatrix in the last whorl.

DIMENSIONS (mm):

Spec.	NoW	Ht	Hlw	Lis	Dmx	HP	DP
GSSA M	?6	?12.15	9.10	1.95	6.00	-	-
SAM T643	6	8.30	6.0	1.30	3.45	-	-

OBSERVATIONS. Tate (1897) subsequently referred *Mitra complanata* to *Conomitra* Conrad. Cernohorsky (1970) and Darragh (1970) transferred it to *Microvoluta* Angas. Lastly Ludbrook (1973) placed it in *Waimatea*. This form and the congeneric *W. subcrenularis* Tate were not directly examined by Cernohorsky (1970). *M. complanata* falls into *Waimatea* due to its type of coiling, body whorl shape, peristome and siphonal channel, morphology and protoconch. The specimen from B.Q. Butler Bore is more inflated than the holotype, but it might represent a more senile form.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 18.90-19.20 and 21.34-21.64 m depths. Murray Basin. B.Q. Butler Bore 4, Hd Kirkpatrick, Sect. 8, 110.34-116.12 m depth.

STRATIGRAPHIC RANGE. ?Late Eocene (late P15-P17). St. Vincent Basin, Blanche Point Formation. Murray Basin: Buccleuch 'A' Beds (Ludbrook, 1969; Lindsay & Bonnett, 1973), Cernohorsky (1970) erroneously gives to *W. complanata* a Pilocene age.

FAMILY CANCELLARIIDAE H. & A. Adams, 1853

GENUS Narona H. & A. Adams, 1853

SUBGENUS Inglisella Finlay, 1924

Narona (Inglisella) turriculata (Tate, 1889)

FIGS. 316-319

1889 Cancellaria turriculata Tate, p.156, pl.10, fig.14.

1973 Inglisella turriculata -Ludbrook, pl.25, fig.28.

MATERIAL. Holotype and 3 paratypes (SAM T 724 B, A, C-D); 6 specimens (1 silicified) from outcrop; 2 specimens from Tate's uncatalogued material, labelled Aldinga.

DESCRIPTION. Shell very small, turriculate, thick, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it up to the middle-abapical connection; body whorl shape reniform. Suture flush to impressed. Abaxial margin regions: adapical declivous subconvex; middle subvertical, convergent, subconvex; abapical declivous subconvex. Region connections: adapical-middle very angular; middle-abapical subangular. Base subconcave, with a narrow pseudo-umbilical fissure: peristome subrectangular, high and narrow, merging into an abapical siphonal notch. Lips: adaxial adapical thin, adherent, subconvex; adaxial abapical thick, callous, convex, adapically detached; abaxial adapical subconvex very short; abaxial abapical and middle convex, thin, long, subinflected. Lip connections: all angular. Pseudo-umbilical fissure: produced by the rather evolute coiling, normal to the coiling axis; bound by a siphonal fasciole and partly or completely obscured by a lobe from the adaxial lip.

Protoconch. 1.5 smooth homeostrophic whorls, with rare spiral series of pustulae.

Ornament. Growth lines: suborthocline, retroflected at the carina. Prominent S-shaped axial costae. Middle adapical carina. Spiral costellae, the broadest at the carina. Beaded carina-costa intersections.

OBSERVATIONS. Cossmann (1889, fide Tate, 1898, p.389) referred this species to Narona H. & A. Adams. Darragh (1970) and Ludbrook (1973) refer it to Inglisella Finlay, which was placed by Wenz (1943, p.1364) in Narona as subgenus.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

FAMILY MARGINELLIDAE Fleming, 1828

OBSERVATIONS. This family represents one of the most difficult problems from the taxonomic viewpoint. Notwithstanding the huge number of living and fossil species attributed to this group, their anatomy and shell morphology is still poorly known. The taxonomy at generic and suprageneric level is obscure and at infrageneric level not yet fully understood. Jousseaume (1875), Cossmann (1899), Bellardi & Sacco (1890), Cotton (1949), Wenz (1938-44), and Laseron (1948, 1957) made major contributions to the taxonomy of this family, mainly at genera level.

Recently, Coan (1965) reviewed in detail the history of this family (and to it the reader is referred) and attempted a revision of its classification by recognizing three subfamilies: Marginellinae Fleming; Cystinae Stimpson; Marginelloninae Coan. Unfortunately, Coan does not offer any clue on his criteria, and his classification is just a check list of names.

Ponder (1970) stressed the extreme difficulties which still exist in grouping species into genera. The revision of the Australian Eocene Marginellidae again raised this major problem inherent to their taxonomic location. Therefore, an analysis was attempted in order to find some taxonomic markers and some diagnostic characters for this family. Laseron's approach, analogous to Schilder's for Cypraeacea, but modified, and Coan's classification were preliminarily adopted. From Marginellinae and Cystinae 43 genera and subgenera, three new genera and Leptoguana Woodring, which is considered by Coan synonym of Prunum Herrmannsen but whose morphological characters suggest otherwise, were examined.

116 morphological combinations covering 28 standard diagnostic features were tabulated by an asbence/presence method and tentatively compared in order to show differences and similarities at supraspecific level. This comparison was based on direct observations on type species or in a few cases, on species unanimously considered consubgeneric with the type species by the various authors.

As a preliminary and qualitative result only, there are the following indications. The siphonal notch and adapical gutter appeared to represent the most meaningful characters and their morphology may have subfamilial to familial significance. The different combinations observed were, however, found present in both Marginellinae and Cystinae, as arranged by Coan. Columellar plicae and lip varix may be diagnostic at generic or subgeneric level, but only in association with the above characters.

Only three types of growth lines were found: prosocline, falciform, and an intermediate type. In many species, they were obscured by the enamel. Therefore, their taxonomic value is still to be evaluated properly,

The featureless marginellid protoconch presents a similar difficulty. Two types of protoconch were observed, a small one and a larger one. They may be either high or low spired; and, in many taxa, they are obscured by the enamel. Size and spire height seem to be significant at species level, generally. Size may have supraspecific value but only in the largest forms. In some taxa, lip denticulations and varices may be of ontogenetic to specific significance only.

However, the above analysis also gave very strong indications that a further pursuit of this discussion might result in a futile exercise unless a much greater number of species for each genus is examined. Nevertheless, there is also very strong evidence that an attentive investigation on the morphology of the marginellid shell can achieve results beyond Coan's classification.

In support of this opinion, there is an unexpected discovery made during observations on the shell surface for SEM photography. A new character was found present in the marginellid shell. The surface of the basal and oral regions display minute vermiculations at about 100 magnifications. The area covered by these vermiculations and their pattern seem to vary distinctively in seven of the taxa without columellar callus here described. In the callus-bearing Marginella s.l. globosa sp. nov. vermiculations are absent (see Figs. 324-359). Notwithstanding this scanty sample, it is here believed that this new character may be of subgeneric to generic significance.

In conclusion, it is evident that thorough conchological and anatomical studies on this family are long overdue. Such investigations, however, represent major research topics which are obviously outside the scope of this thesis.

GENUS Marginella Lamarck, 1799

SUBGENUS Mioginella Laseron, 1957

Marginella (Mioginella) regula Cotton, 1949

FIGS. 353-359

1949 Marginella regula Cotton, p.213, pl.18.

1957 Mioginella regula -Laseron, p.287, fig.24.

MATERIAL. 4 syntypes (SAM P 8785); 9 specimens from Tate Collection (SAM T 656), the middle row only.

DESCRIPTION. Shell small, glossy, strombiform, rather high spired, whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the adapical middle region. Lip varix overlapping up to the carina. Body whorl shape subtrapezoidal. Suture impressed. Abaxial margin regions: adapical subconcave, narrow, declivous; middle and abapical almost straight, subvertical, convergent. Region connections: adapical-middle angular, carinated; middle-abapical nearly imperceptible. Base narrow, concave; peristome subtrapezoidal merging into a broad shallow notch. Lips: adaxial adapical convex, short, thin; adaxial abapical long, concave; abaxial adapical straight, bearing a narrow, shallow gutter; abaxial middle and abapical gently convex. Abaxial margin bearing a thick, scarcely prominent varix. Lip connections: adaxial adapical-abapical subangular; adapical adaxial-abaxial and abaxial adapical-middle angular; abaxial middle-abapical imperceptible. 5 adaxial lip plicae: 1st faint, 2nd-3rd subdeclivous, thick; 4th rather declivous; 5th very declivous. Inner large long denticulations on the abaxial lip. Callus thin, well developed.

Protoconch. Small, dome-like, paucispiral, low spired. In seniles, obscured by pustulate enamel.

Ornament. Growth lines: prosocline with the adapical part straight.

OBSERVATIONS. Laseron (1957) designated this species as the type of his Mioginella. The tablet T 656 bears three rows of specimens labelled Marginella subwentworthi. In the first row there are 4 specimens similar to M. regula, but differing in: wider peristome, more convex abaxial margin, denticles which are finer and of two orders - the former thicker and regular; the latter finer, less prominent, irregular and restricted to the middle part. Hence, the name M. subwentworthi may be restricted to this form. The second row, from Aldinga, is composed of specimens referable to M.regula. The 6 specimens of the third row are here referred to Marginella s.l. sp. nov. A.

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Aldinga Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation, 'Soft Marl' Member as suggested by the matrix and the preservation of the specimens. Late Eocene (middle P16).

SUBGENUS *Carinaginella* Laseron, 1957

Marginella (Carinaginella) elianae sp. nov.

FIGS. 341-343

DERIVATION OF THE NAME. After Dott. Eliana Garbarino (Mrs. Buonaiuto), the author's mother.

HOLOTYPE. GSSA M 3406, Figs. 341-343.

TYPE LOCALITY. Murray Basin, B.Q. Butler Bore 4, Hd Kirkpatrick, Sect. 8, 110.34-116.12 m depth.

TYPE FORMATION. Buccleuch 'A' Beds (Ludbrook, 1969; Buonaiuto, in prep.).

STRATIGRAPHIC RANGE. Latest Eocene (P16/17-P17) (Buonaiuto, in prep.).

MATERIAL. The holotype.

DESCRIPTION. Shell minute, glossy, biconical, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis total; parallel to it, up to the adapical middle region. Body whorl inner and outer shape subtrapezoidal very narrow and high. Suture adpressed. Abaxial margin regions: adapical declivous, narrow, concave; middle subconvex, subvertical, wide; abapical subvertical, convergent, subconcave. Region connections: adapical-middle angular, producing a round carina; subimperceptible the other. Base concave, wide; peristome, subrectangular, high and narrow, merging into a broad siphonal notch. Lips: adaxial adapical convex thin adherent; adaxial abapical concave, with four thick plicae; abaxial adapical declivous, thick, forming broad shallow gutter; abaxial middle and abapical subvertical, subelliptical, thick, with sharpish edge. Abaxial lip bearing a thick prominent varix. Lip connections: adapical abaxial-adaxial angular; adaxial abapical-abapical subangular; imperceptible the other. Adaxial plicae: 1st, 3rd subdeclivous, with grooved end, 4th very declivous, limiting the siphonal notch.

Protoconch. Large, dome-like, paucispiral, rather short spired, glossy.

Ornament. Very fine orthocline growth lines. Faint broadly interspaced spiral costellae.

DIMENSTIONS (mm):

Spec.	NoW	Ht	Hlw	Lis	Dmx	DP	HP
GSSA M	4	3.85	3.30	.30	2.65	.75	3.00

OBSERVATIONS. Growth lines, adapical gutter, siphonal notch, abaxial margin, peristome, lip varix, columellar plicae and body whorl place this form in *Carinaginella* Laseron. *C. elianae* differs from the type species *C. carinata* Smith in: smaller size, shorter spire, less sharp carina, heavier plicae - the most abapical less declivous, the most adapical with more grooved end, shorter neck and larger protoconch. (Comparative observations on 4 homeotypes MA C 26691, of *C. carinata*)

Laseron's 1957 illustration is misleading, since it shows a thinner abaxial lip varix and denticulations. The latter character is only present in the most senile of the homeotypes of *C. carinata*, kept in the Australian Museum Collections, therefore, it may have an ontogenetic significance only.

C. elianae sp. nov. represents the first fossil record of *Carinaginella* Smith, and extends its stratigraphic range far back to the Late Eocene. *C. carinata* has been dredged from 1450 and 1463 m depth, 56 km east of Sydney.

SUBGENUS Alaginella Laseron, 1957

Marginella (Alaginella) submicula sp. nov.

FIGS. 337-340.

DERIVATION OF THE NAME. The name 'submicula', given to this undescribed species by Tate, as indicated in the tablet SAM T 663, is here adopted

HOLOTYPE. GSSA M 3405A, Fig. 337-399.

PARATYPES. GSSA M 3405B, fig. 340.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 21.64-21.95 m depth (3 specimens).

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. 5 holotype and paratypes; 8 specimens from Tate Collection (SAM T663); 2 from outcrop material.

DESCRIPTION. Shell minute, glossy, strombiform, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis total; parallel to it up to the adapical middle region. Lip varix overlapping up to the carina. Suture adpressed. Body whorl shape subtrapezoidal. Abaxial margin regions: adapical rather broad, flat, declivous; middle vertical, convex, broad; abapical concave broad. Margin region connections: adapical-middle angular, carinated; middle-abapical rounded. Base concave, rather broad. Peristome subtrapezoidal, merging into a broad short weak notch. Lips: adaxial adapical thick, short, convex; adaxial abapical straight long; abaxial adapical declivous, producing a broad shallow gutter; abaxial middle convex, smooth, inflected. Lip connections: adaxial adapical-abapical and adapical adaxial-abaxial angular; abaxial adapical-middle angular; the abaxial abapical-middle imperceptible. Abaxial lip, bearing a thick varix. 4 thin, prominent adaxial plicae: 1st-2nd subdeclivous; 3rd declivous; 4th very declivous. Base covered by a narrow thick callus.

Protoconch. Dome-like, low spired.

Ornament. Prosocline growth lines with adapical segment orthocline.

OBSERVATIONS. This form is very close to the living *M. ochracea* Angas, the type of *Alaginella* Laseron, except in the callus, which is much thicker in the Eocene form. *A. submicula* represents the oldest fossil record of *Alaginella*.

DISTRIBUTION. Single specimens from 21.64-21.34 m and 21.03-20.73 m depths at the type locality. Willunga SubBasin, Aldinga and Maslin Bays.

GENUS *Marginella* s. l.

? *Marginella* sp. nov.

FIGS.324-327

MATERIAL. 1 specimen from GSSA Collection (GSSA M 3402); 6 specimens from Tate Collection (SAM T 656, third row).

DESCRIPTION. Shell minute, glossy, strombiform, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the adapical middle region. Lip varix overlapping, up to the carina. Body whorl shape subtrapezoidal. Abaxial margin regions: adapical very declivous, subconcave; middle and abapical subconvex, subvertical. Region connections: adapical-middle subangular; middle-abapical imperceptible. Base very narrow, concave; peristome subtrapezoidal merging into a very shallow and broad siphonal notch. Lips: adaxial adapical thin, rather long straight; adaxial abapical long, subconcave; abaxial adapical declivous, producing a broad, very shallow gutter; abaxial middle and abapical subconvex, subvertical. Lip connections: adaxial adapical-abapical subangular; adapical adaxial-abaxial and abaxial adapical-middle angular; abaxial middle-abapical imperceptible. Abaxial margin inflected, bearing a rather developed and little protruding varix. Thin, prominent adaxial plicae 1st subdeclivous; 2nd declivous; 3rd very declivous. Interior marginal lip denticulations rather thick, little protruding: adapical and abapical weak;

middle stronger, Callus thin, well developed.

Protoconch. Small, dome-like, high spired, paucispiral.

Ornament. Prosocline growth lines, with adapical part orthocline.

OBSERVATIONS. This form appears to be quite close to *Alaginella* Laseron differing from it in presence of denticulations and shallower notch and gutter, and to *Protoginella* Laseron, differing from it in internal denticulations, fainter carina and lip varix. Therefore, this form may belong to either subgenera, or to a new one. However, since the classification of Marginellidae is in the present state of chaos it is doubtfuly referred to *Marginella* s.l.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 21.64-21.95 m depth.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

GENUS *Mesoginella* Laseron, 1957

SUBGENUS *Plicaginella* Laseron, 1957

Mesoginella (Plicaginella) aldingae (Tate, 1878a)

FIGS. 344-347

1878a *Marginella aldingae* Tate, p.90 (pars).

1949 *Marginella aldingae* -Cotton, p.218, pl.17

MATERIAL. 8 syntypes well preserved (SAM T 652 A-E, L-N); 10 from Aldinga Bay; 11 from Bore material.

DESCRIPTION. Shell minute, glossy, biconical, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the adapical middle region. Body whorl shape subrectangular. Suture adpressed, ondulating. Abaxial margin regions: adapical narrow, concave; middle wide, subconvex; subvertical; abapical rather narrow, concave, declivous.

Region connections; adapical-middle very angular, represented by a carina; middle-abapical subangular. Base concave and narrow; peristome subrectangular, narrow and very high, merging into a broad siphonal notch. Lips: adaxial adapical short, convex; adaxial abapical long, concave, with 4 thick plicae; abaxial adapical steep; middle abaxial and abapical convex, undifferentiated, vertical. Lip connections: adapical abaxial-adaxial very angular, producing a shallow and narrow gutter; adaxial adapical-abapical marked by the first plica; abaxial adapical-middle very angular. Very thick varix with a round edge on the abaxial lip. Plicae: 1st-2nd subhorizontal; 3rd-4th gently declivous.

Protoconch. Dome-like, glossy, paucispiral.

Ornament. Fine orthocline growth lines. Regular prominent axial costae, fading completely on the abapical region and partly on the adapical.

OBSERVATIONS. This species was placed by Laseron (1957) in his *Plicaginella*. Coan (1965) reduced *Plicaginella* to a subgenus of *Mesoginella* Laseron.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, 23.62-23.29 m, 23.29-22.92 m, 22.64-22.31 m, 20.67-20.34 m. depts. Willunga SubBasin, Aldinga Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

GENUS *Cottonella* gen. nov.

DERIVATION OF THE NAME. After B.C. Cotton, for his studies on the South Australian Mollusca.

TYPE SPECIES. *Marginella mala* Cotton, 1949.

STRATIGRAPHIC RANGE. Late Eocene.

DESCRIPTION. Shell large, strombiform, short spired; whorl overlapping up to the middle adapical carina; peristome and body whorl shape subtrapezoidal, very narrow and high; lip varix marked but not protruding;

lip denticulations inner, thick, and long; siphonal notch rather narrow and shallow; adapical gutter wide and deep. Thick columellar plicae: five in younger, four in older stages, more and more declivous to the adapical; the most adapical one simple, bifurcated the others. Callus well developed, extended to cover the protoconch.

Protoconch. Small, dome-like, short-spired, smooth.

Ornament. Fine growth lines with adapical sinus.

OBSERVATIONS. Following Laseron's approach, the combination of callus, bifurcate columellar plicae, siphonal notch and adapical gutter places *Marginella mala* into a distinct new genus.

Cottonella mala (Cotton, 1949)

FIGS. 320-322

1949 *Marginella mala* Cotton, p.215, pl.18.

MATERIAL. 2 syntypes (SAM P 4016); 13 specimens from the uncatalogued part of Tate Collection.

DESCRIPTION. Shell rather large, strombiform, short spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis total; parallel to it, up to the middle adapical carina. Lip varix overlapping up to the preceding whorl. Suture adpressed. Abaxial margin regions: adapical gently declivous, narrow; middle subconvex, wide, subvertical; abapical concave. Region connections: adapical-middle angular with broad carina; middle-abapical subangular. Base broad, concave. Peristome subtrapezoidal very narrow and high merging into a rather narrow and shallow notch. Lips: adaxial adapical long, rather thick, concave; adaxial abapical rather thick, concave; abaxial adapical subdeclivous, forming a broad deep gutter; abaxial middle and abapical subconvex, subvertical. Well developed, yet little protruding varix on the abaxial lip. Lip connections: adaxial adapical-abapical subangular; adapical abaxial-adaxial and abaxial adapical-middle angular; abaxial middle-abapical imperceptible. Thick columellar plicae; 5 in younger stages; 4 in older stages; 1st subdeclivous, simple; 2nd-3rd subdeclivous, bifurcated; 4th rather declivous, bifurcated; 5th very declivous, bifurcated. Callus very developed, covering the base of the shell and the protoconch. Abaxial margin with inner, rather thick, long denticulations.

Protoconch and Ornament See generic diagnosis.

DISTRIBUTION. Willunga SubBasin, Aldinga Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation, Gull Rock and 'Soft Marl' Members, Late Eocene (middle P16).

GENUS *Kaurnaginella* gen. nov.

DERIVATION OF THE NAME. After the Kaurna, the tribe of the Eastern side of the St. Vincent Basin.

TYPE SPECIES. *Kaurnaginella tutugka* sp. nov.

STRATIGRAPHIC RANGE Late Eocene.

DIAGNOSIS. Shell minute, glossy, biconical, short spired. Whorl overlapping up to the abapical adapical region. Suture adpressed. Peristome and body whorl shape subtrapezoidal, high and narrow. Lip varix thick, but not prominent; abaxial lip with 9 interior long fine denticles; adaxial lip with 5 subdeclivous plicae, the thicker the more abapical. Absent siphonal notch.

Protoconch. Small, paucispiral, dome-like, very short spired.

Ornament. Fine orthocline growth lines.

OBSERVATIONS. This genus differs from *Kogomea* Habe, *Dentiginella* Laseron, and *Vetaginella* Laseron in the absence of a notch and the presence of adaxial enamel. It differs from *Euliginella* Laseron in its interiorly denticulate margin and presence of enamel. It is close to *Topaginella* Laseron, from which it differs in the presence of enamel, smaller size, less plicae (5 vs 8) and finer abaxial lip denticulations. The type of coiling is similar to that of *Lataginella* Laseron.

Kaurnaginella tutugka sp. nov.

FIGS. 328-332

DERIVATION OF THE NAME. From the Kaurna tutugka, very small, because of its size.

HOLOTYPE. GSSA M 3403A , Figs. 328, 332.

PARATYPES. GSSA M 3403 B, C, Figs. 329-331.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717 Bore 5, 23.62-23.29 m depth.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene.

MATERIAL. 15 paratypes from bore material, 5 from outcrop.

DESCRIPTION. See generic diagnosis.

OBSERVATIONS. This species was found also in the outcrops of the Willunga SubBasin. However, because of their better preservation, the holotype was chosen from the subsurface material.

DISTRIBUTION. Also, at depths of 25.26-24.93 m, 23.62-23.29 m, 23.29-22.97 m, 22.97-22.64 m, 22.64-22.31 m, 21.98-21.65 m, 21.33-21.00 m, 21.00-20.67 m and 20.67-20.34 m at the type locality. Willunga SubBasin, Maslin Bay. Blanche Point at Aldinga Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

GENUS Cassoginella Laseron, 1957

Cassoginella palla (Cotton, 1949)

FIGS. 348-352

1878a Marginella aldingae Tate, p.90 (pars).

1949 Marginella palla Cotton, p.215, pl.18.

1957 Cassoginella palla -Laseron, p.287, fig.25.

MATERIAL. Holotype and 5 paratypes (SAM T 652 H, F-G, I-K); 5 specimens from bore material, all very well preserved; 3 from outcrop material.

DESCRIPTION. Shell minute, glossy, biconical, rather high spired, whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, normal; parallel to it, up to the adapical middle region. Body whorl shape subrectangular. Suture adpressed, ondulating. Abaxial margin regions: adapical narrow concave, adsuturally subvertical, absuturally subdeclivous; middle subconvex, vertical; abapical concave, very declivous, convergent. Region connections: adapical-middle very angular, carinated; abapical-middle subangular. Base narrow and concave; peristome subrectangular, merging into a broad siphonal notch. Lips: adaxial adapical subconvex; adaxial abapical subconcave, with 4 thick plicae; abaxial adapical subdeclivous, forming a broad deep gutter; abaxial abapical and middle subconvex, subvertical. Lip connections: adapical adaxial-abaxial very angular; abaxial adapical-middle angular; adaxial adapical-abapical subimperceptible; abaxial abapical-middle imperceptible. Abaxial lip bearing a thick varix with a sharpish and finely denticulate edge. Adaxial plicae: 1st-2nd subhorizontal, with bifurcated ends; 3rd-4th gently declivous.

Protoconch. As in *P. aldingae* (Tate), but smaller and higher spired.

Ornament. Fine orthocline growth lines; prominent axial costae, as in *P. aldingae*. A short, blunt abaxial spine on the adapical lip varix.

OBSERVATIONS. Tate (1878) initially mistook this form for *Plicaginella aldingae* and included some specimens of this species in the original series of *P. aldingae*. Cotton (1949) separated such specimens as a distinct species under the name of *Marginella palla* Cotton. Finally, Laseron (1957) chose *M. palla* as the type of his *Cassoginella*.

DISTRIBUTION. St. Vincent Basin: Willunga SubBasin, Blanche Point, at Aldinga Bay. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore

5, 23.26-24.93 m, 23.29-22.97 m and 22.31-21.98 m depths. Willunga SubBasin, Maslin Bay. Murray Basin, B.Q. Butler, Hd Kirkpatrick, Section 8, Bore 4, 110.34-116.12 m depth.

STRATIGRAPHIC RANGE. St. Vincent Basin: Blanche Point Formation. Murray Basin: Buccleuch 'A' Beds. Late Eocene (late P15-P17).

GENUS *Conuginella* Laseron, 1957

Conuginella muna sp. nov.

FIG. 323

DERIVATION OF THE NAME. From the Kaurna *muna*, ancestor.

HOLOTYPE. GSSA M 3417, Fig. 323.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide,Hd Yatala, Town Acre 717, Bore 1, 21.95-22.25 m depth.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. The holotype with damaged last whorl.

DESCRIPTION. Shell rather small, glossy, biconical, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-adapical carina. Body whorl shape subrectangular, high and narrow. Suture adpressed. Abaxial margin regions: adapical declivous, subconvex; middle and abapical subconvex, subvertical. Region connections: adapical-middle angular forming a round carina; middle-abapical imperceptible. Base subconvex, narrow, bound at the periphery by a faint sulcus. Peristome subrectangular. Lips: adaxial adapical long, subconvex; adaxial abapical concave, with 5 thick prominent plicae; abaxial adapical declivous; abaxial middle and abapical subconvex; subvertical. Lip connections: adapical adaxial abaxial narrowly angular; abaxial adapical-middle rounded, abaxial middle-abapical imperceptible; adaxial adapical-abapical angular. Adaxial plicae: 1st-2nd subdeclivous; 3rd-4th declivous; 5th very declivous.

Protoconch. Large, dome-like, short spired.

Ornament. Growth lines: adapical opisthocyrt; middle and abapical orthocline.

OBSERVATIONS. Growth lines, body whorl, columellar plicae, whorl overlapping, and traces of a thickened abaxial lip place this form in *Conuginella* Laseron. *Conuginella inermis* (Tate), the type species, may represent a composite species. The syntypes and paratypes from Muddy Creek match well with the specimen from Balcombe Bay, but the two specimens from Table Cape display a broader adapical gutter and a lip varix, thicker and more developed in the adapical part. The discovery of further specimens referable to this genus. in the uncatalogued Tate Collection labelled as '*Marginella obconica* aff. *inermis*' confirms these differences.

The synoptic table below suggests that lip varix morphology, denticulations and protoconch may represent specific characters. Spire and whorl overlapping show variability and may be a bit doubtful as to specific significance. These 4 species might represent a phylogenetic lineage, but much more material is needed to clarify this problem.

(264 A)

Synoptic Table

Species	Spire	Whorl over-lapping	Varix	Varix	denticles	adapical gutter	Columellar plicae	Protoconch	Age & Locality
Conuginella inermis (Tate)	short but slightly variable	adapical-middle to at carina	overlapping	medium thick	interior-marginal middle, and denser abapical	broad, with angularity at adapical-middle connection	the same	small, short spire	Middle Miocene Balcombe Bay, Muddy Creek.
Conuginella sp.	"	"	"	somewhat thicker	"	broader, imperceptible connection		large, short spire	early Early Miocene, Table Cape
"*M. obconica* Tate"	very short but somewhat variable	at the carina	total	thick	as above, heavier more interspaced	shallower imperceptible connection		large, very short spire	Oligocene/ Miocene "Spring Creek"
Conuginella muna sp.nov.	short, but highest of the four	at the carina	-	-	-	-		large, short spire	St. Vincent Basin, Late Eocene

GENUS *Marginella* s.l.

Marginella s.l. *globosa* sp. nov.

FIGS. 333-336

DERIVATION OF THE NAME. From the Latin *globosus*, globose, because of its shell shape.

HOLOTYPE. GSSA M 3404A, Fig. 333.

PARATYPES. GSSA M 3404B-G, Figs. 334-336.

TYPE LOCALITY. B.Q. BUtler Bore 4, Hd Kirkpatrick, Sect. 8, 110.34-116.12 m depth, Murray Basin.

TYPE FORMATION. Buccleuch 'A' Beds (Buonaiuto, in prep.; Ludbrook, 1969).

STRATIGRAPHIC RANGE. Eocene (P16/17-P17) (Buonaiuto, this study; in prep.)

MATERIAL. 6 well preserved specimens.

DESCRIPTION. Shell, minute, glossy, globose, biconical, rather high spired; whorls increasing slightly more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to just below the carina. Lip varix overlapping just up to the carina. Body whorl shape subtrapezoidal. Suture adpressed. Abaxial margin regions: adapical narrow, flattened, declivous; middle wide, convex, subvertical; abapical concave, narrower, very declivous. Base concave covered by a thick extended callus. Peristome subtrapezoidal, merging into a wide shallow siphonal notch. Lips: adaxial adapical broad, subconvex; adaxial abapical broad, concave, with 4 plicae; abaxial adapical concave, forming a broad gutter; abaxial middle and abapical convex, inflected and smooth. Lip connections: adaxial adapical-abapical subangular; adapical adaxial-abaxial and abaxial adapical-middle angular; abaxial middle-abapical imperceptible. Rather thick, protruding varix on the abaxial lip. Adaxial plicae: 1st-2nd subdeclivous, bifurcated; 3rd bifurcated and 4th simple rather declivous.

Protoconch. Dome-like, small, low spired.

Ornament. Growth lines: prosocline, but with shallow adapical sinus.

OBSERVATIONS. This form might represent a new genus, but for the moment it is referred to Marginella s.l.

SUBORDER	TOXOGLOSSA
SUPERFAMILY	CONACEA
FAMILY	TURRIDAE
SUBFAMILY	TURRICULINAE
GENUS	Comitas Finlay, 1926
SUBGENUS	Comitas s. str.

Comitas (Comitas) aldingensis Powell, 1944

FIGS. 364-365

Carinacomitas
1944 Comitas (h) aldingensis Powell, p.18, pl.1, fig.7.

1969 Comitas (Comitas) aldingensis -Powell, p.292, pl.222, fig.5.

MATERIAL. 3 silicified specimens; 9 from bore material (GSSA) 1 from the uncatalogued Tate Collection (SAM P21195).

DESCRIPTION. Shell small, rather thin, fusiform, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Suture flush. Body whorl shape clavate. Abaxial margin regions: adapical subconvex, declivous; middle and abapical subconvex, subvertical, convergent. Region connections: adapical-middle very angular, carinated; middle-abapical imperceptible. Base subconvex; peristome semiovoidal, broad, merging into a wide, subreflected, curved, and rather short siphonal channel. Lips: adaxial adapical thin, subconvex, nearly imperceptible; adaxial abapical straight from very thin to imperceptible; adaxial adapical and middle lirate, convex; abaxial siphonal concave. Lip connections: adaxial adapical-abapical subangular; adapical adaxial-abaxial very angular, forming a semicircular gutter.

Protoconch. 2 angular whorls: the initial smooth pseudo-planispiral; the latter homeostrophic, with two spiral costae, one adsutural and one on the carina; In the terminal part of the last whorl two secondary microcostae on both flanks of the carina.

Ornament. Sinusoidal growth lines: adapical opisthocyrt; abapical and middle prosocyrt. Prosocline axial costae, faded on the adapical region. Spiral ribs: primary alternated with finer secondary; on the adapical region 3 secondary between the adsutural and the adcarinal primary. The costa-rib intersections somewhat beaded at the primary costae in the carina region. On the neck, closer primary and obsolete secondary.

OBSERVATIONS. Initially, Powell (1944) referred this species to Carinacomitas Powell, a subgenus of Comitas Finlay. Subsequent observations on protoconch by Vella (1954, p.548) and Marwick (1965, p.42) revealed that the carinated protoconch, a diagnostic feature for Carinacomitas, falls within the variability of the species of Comitas. Thus, Powell (1969) synonymized Carinacomitas to Comitas s. str.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 23.16-22.86, 21.95-21.64, 19.81-19.51, 19.20-18.90 m depths; Bore 1, 22.25-21.95 m depth. Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

Comitas sp. nov.

MATERIAL. 2 silicified specimens, badly preserved; 1 well preserved.

DESCRIPTION. Shell fusiform, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle abapical connection. Body whorl shape clavate. Suture flush, ondulating. Abaxial margin regions: adapical declivous, from subconcave to flat; middle and abapical subconvex subvertical. Region connections: adapical-middle angular, carinated;

middle-abapical imperceptible. Base subconvex; peristome ovoidal merging into a long subreflected siphonal channel. Lips: adaxial adapical subconcave, thin, adherent; adaxial abapical straight, adherent; both depressed and bound by a rim; abaxial damaged. Lip connections: adaxial adapical abapical subangular; adapical adaxial-abapical very angular. On the neck a faint abapical fasciole.

Protoconch. 3 homeostrophic pustular whorls, with submerged nucleus. Protoconch-teleoconch transition marked by relict peristome, shaped as the growth lines.

Ornament. Sinusoidal growth lines: adapical very opisthocyrt; middle and abapical prosocyrt. Opisthocline varices,fainter on the adapical. Flat primary spiral ribs, irregularly alternated with finer secondary. Carina rib more marked.

OBSERVATIONS. This form is very close to the Janjukian Comitas pseudoclarae Powell (Powell, 1944, p.18, pl.1, fig.6). It differs from it in spiral ornament pattern and somewhat in varix shape.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5. 24.93-24.61 m depth. Willunga SubBasin, Maslin Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation, Late Eocene (late P15-middle P16).

GENUS Knefastia Dall, 1919

Knefastia sp. nov.

MATERIAL. 19 specimens (silicified), mainly juveniles.

DESCRIPTION. Shell fusiform, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Body whorl shape clavate. Suture flush. Abaxial margin regions: adapical declivous, subconvex; middle and abapical very declivous, subconvex. Region connections: adapical-middle angular, carinated; middle-abapical imperceptible. Base subconvex; peristome very narrow, subovoidal, merging into a broad, rather short siphonal channel. Thick lips: adaxial adapical adherent, subconvex; adaxial abapical convex; abaxial adapical subconvex narrow, declivous with a semicircular broad sinus; abaxial abapical and middle subconvex, very declivous. Lip connections: adaxial adapical-abapical imperceptible; adapical adaxial-abaxial and abaxial adapical-middle angular.

Protoconch. Conical, 3 homeostrophic whorls, with small nucleus. Opisthocyrt costellae on the last whorl.

Ornament. Growth lines: adapical opisthocyrt; middle and abapical prosocline. Subprosocline axial costae. Spiral primary costellae, alternated with secondary ones.

OBSERVATIONS. Growth lines, peristome, and ornament pattern place this form in *Knefastia* Dall (Powell, 1942, p.41, fig.E-21; 1969, p.390). The protoconch, however, is similar to *Insolentia* Finlay. Powell (1969) raised *Knefastia*, considered by Wenz (1943) as subgenus of *Turricula* Schumacher, to full generic status.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 22.86-22.56 depth. Willunga SubBasin, Maslin Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation, 'Transitional Marl' Member. Late Eocene (late P15-early P16).

SUBFAMILY MITROMORPHINAE

GENUS *Vexithara* Finlay, 1926

Vexithara citharelloides (Tate, 1889)

FIGS. 360-363

1889 *Mitra citharelloides* Tate, p.143, pl.5, fig.11 (*pars*).

1973 *Austromitra citharelloides* -Ludbrook, pl.25, fig. 26.

MATERIAL. The holotype (SAM T 631B); 11 specimens (1 silicified) from outcrop material.

DESCRIPTION. Shell fusiform, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Body whorl shape subclavate. Suture adpressed, slightly ondulating. Abaxial margin regions: adapical narrow, very declivous; middle wide, subconvex, subvertical; abapical very declivous; wide, subconcave. Region connections: both subangular, adapical-middle with a rather marked carina. Base wide, convex; peristome ovate, very high and narrow, merging into a rather short, deep, convergent siphonal channel. Lips: adaxial adapical thin, from adherent to depressed and bound by a rim; adaxial abapical from straight to subconvex, with three plicae; adaxial siphonal straight and subvertical; abaxial thin, convex, abaxial siphonal subconvex. Lip connections: adapical abaxial-adaxial very angular, producing a narrow gutter; adaxial adapical-abapical from angular to imperceptible; angular all the others. Adaxial plicae, not always present in adult senile stages. Siphonal fasciole from faint to marked, partially or entirely obscured by an adherent callosity, produced by the adaxial siphonal lip.

Protoconch. 2 smooth whorls, the second homeostrophic.

Ornament. Fine growth lines and prominent axial costae, both from prosocline to orthocline, with the adsutural end bent forward. Fine spiral costellae separated by narrower interspaces, the fainter the older the stage.

DIMENSIONS: (mm);

Spec	NoW	Ht	Hlw	Lis	Dmx	DP	HP
SAM P 21208	7	11.90	8.00	2.30	4.30	-	-
T631B	6	9.90	6.85	1.85	3.85	-	-

OBSERVATIONS. Tate (1889) initially mentioned a close resemblance of this form to Cithara Bruguière. Subsequently, Cossmann (1889, in Tate, 1897) referred M. citharelloides to Uromitra Bellardi, and later (1899, p.165) to Costellaria Swainson. Darragh (1970) and Ludbrook (1973) placed this species in Austromitra Finlay (Vexillinae). Cernohorsky (1972, p.209; pers. comm., 1975) refers it to Vexithara Finlay (Mitromorphinae). The cause of the disagreement among the authors may be found in the fact that all of Tate's types of M. citharelloides, except the holotype, belong to Austromitra pumila (Tate) (q.v.).

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (early to middle P16).

SUBFAMILY DAPHNELLINAE

GENUS Rugobela Finlay, 1924

Rugobela sp. nov.

FIGS. 370-371

MATERIAL. 2 badly preserved silicified specimens; 3 specimens from bore material, with damaged last whorl.

DESCRIPTION. Shell very small, fusiform, rather short spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle abapical connection. Body whorl shape clavate. Suture adpressed. Abaxial margin regions: adapical concave declivous; middle and abapical subconvex, subvertical. Region connections: adapical-middle angular, carinate; middle-abapical imperceptible. Base concave; peristome subovoidal, narrow and high, merging into a rather short and broad siphonal channel. Lips: adaxial adapical and abapical thick, adherent, convex; abaxial elliptical. Lip connections: adaxial adapical-abapical subangular; adapical adaxial-abaxial, very angular, producing a gutter.

Protoconch. Four homeostrophic smooth whorls.

Ornament. Sinusoidal growth lines: adapical opisthocyrt; middle and abapical prosocyrt. Axial costae prosocyrt, very attenuated on the adapical region; the weaker the costae the older the stage. Very large adsutural spiral costa; between it and the carina, finer and finer costellae, absent on the middle region, again present on the abapical, alternated with finer secondary ones.

OBSERVATIONS. Growth lines, protoconch, and sutural costa place this form in *Rugobela* Finlay. *Rugobela* sp. nov. is very close to the Janjukian *R. exculpta* Powell (Powell, 1944, p.63, pl.6, fig.5), from which it differs in adapical costae and secondary abapical costellae. Powell (*ibid*) reports a worn specimen of *Rugobela* sp. from Aldinga Bay. The lack of illustration makes any comparison impossible. The younger silicified specimen from Maslin Bay differs from the Adelaide Plains specimen in having a slenderer body whorl.

DISTRIBUTION. St. Vincent Basin: Willunga SubBasin, Maslin Bay. Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, 20.67-20.34 m, 21.34-21.03, 22.86-22.55, 22.25-21.95 m depths.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

SUBCLASS EUTHYNEURA Spengel, 1881

ORDER ENTOMOTAENIATA Cossmann, 1896

REMARKS ON NOMENCLATURE. Taylor and Sohl (1962) restored Entomotaeniata Cossmann to include Nerineacea and Pyramidellacea in order to obviate a new name for a new order as proposed by Morton (1958, p.177).

The Entomotaeniata was originally erected by Cossmann (1896, p.5) as a suborder of Tectibranchia (Opisthobranchia) to include Nerineiidae Zittel, Tubiferidae Cossmann, and Itieridae Cossmann. Later Cossmann (1921, p. 209-10) supported the descent of the Pyramidellidae from the Itieridae. Wenz (1939, p.64) postulated instead an ancestor common to Nerineacea and Pyramidellacea, although he doubted their relationships with the Opisthobranchia. A few years later, Fretter & Graham (1949) demonstrated that the Pyramidellacea belong to the Opisthobranchia. Later, Morton (1958) suggested the institution of a new order for these Pyramidellacea distinct from bullomorphs and showing some likenesses to Prosobranchia. Cox & Knight (1960) considered Pyramidellacea "incertae sedis" at order level. Ptchelintsev & Korobkov (1960) included Pyramidellacea together with Nerineacea and Itieracea in the Archaeogastropoda. Subsequently, Ptchelintsev (1968) instituted a new order Murchisoniata to include Itieracea, Tubiferacea, and Nerineacea and other Mesogastropod superfamilies, and in the same paper she considered Entomotaeniata Cossmann invalid. But earlier Cox & Knight (1960) had already instituted Murchisonina as a doubtful suborder of Archaeogastropoda to include Murchisoniacea. Therefore, Ptchelintsev's name is a junior synonym (ex eodem typo) of Cox & Knight's. Furthermore, Ptchelintsev's order could be composite, since some of its superfamilies are referred by various authors to different orders (Climo, 1975, Kosuge, 1964). Pending clarification, Taylor & Sohl's and Climo's classifications are followed here.

SUPERFAMILY PYRAMIDELLACEA d'Orbigny, 1840
(nom. transl., Wenz, 1940, ex Pyramidellidae d'Orbigny, 1840)

FAMILY PYRAMIDELLIDAE d'Orbigny, 1840
(syn. Pyramidellidae Gray, 1847)

In this family Cossmann (1921, p.210, footnote) recognized three informal groups: 'pyramidelliformes, odontostomiformes, et turbonilliformes", transitional into each other. Earlier, Tryon (1883) distinguished a new family of Turbonillidae from Pyramidellidae on the basis of absence or presence and number of columellar plicae. It is to be remarked that he transferred Chenitzia d'Orbigny,1839 to Eulimidae, but he was clearly affected by the then existing confusion about this genus. Wenz (1940), following the general opinion, lumped these groups into Pyramidellidae. As already mentioned, Fretter & Graham (1949) transferred the superfamily to Euthyneura (Opisthobranchia). Laseron (1959) instituted three subfamilies from the only three genera recognized by Dall & Bartsch (1904, 1909) in Pyramidellidae. Practically, he formalized Cossmann's 1921 groups. Laseron's subfamilies are here revised: -

Pyramidellinae d'Orbigny, 1840
(nom. transl. Laseron, 1959, ex Pyramidellidae d'Orbigny, 1840)
(syn: 'pyramidelliformes' Cossmann, 1921)

Key: shells with 2-3 columellar plicae (Laseron, 1959)

Odontostomiinae Laseron, 1959
(syn: 'odontostomiformes' Cossmann, 1921;
Turbonillidae Tryon, 1883, pro parte)

Key: one columellar plica

Turbonillinae Tryon, 1883
(nom. transl. herein, ex Turbonillidae Tryon, 1883)
(syn: 'Turbonilliformes' Cossmann, 1921;
Turbonillidae Laseron, 1959, ex eodem typo)

Key: shells with no columellar plica

Laseron (1959) also increased the number of the genera and elevated all the subgenera represented in Australia to genera, as Laws previously did for the New Zealand ones. In this study the classification of this family is not critically reviewed and Laws's classification is followed in general because of the intricate problems still existing both in taxonomy and in nomenclature. It is hoped that in future someone will undertake a thorough study of this family.

GENUS *Chemnitzia* d'Orbigny, 1839
(*non* d'Orbigny, 1843; *non* d'Orbigny, 1850)
Type species: *Melania campanellae* Philippi

The name *Chemnitzia*, after the initial 1839 institution, was often misused by d'Orbigny himself and by successive authors for Mesozoic forms (see for details Cossmann, 1909, p.12-13.) Nevertheless, *Chemnitzia* d'Orbigny, 1839, today is generally accepted with *Melania campanellae* Philippi as the type species. But Sacco (1892, p.72) attributed *M. campanellae* to *T. lactea* (Linné) as a subspecies/morpha quite different from the typical *T. lactea*.

He also remarked that the authors were divided in this point. Philippi himself and other malacologists considered *M. campanellae* and *T. lactea* as belonging to the same species, whereas other authors split them into two different species. Dall & Bartsch (1904, 1906), on the other hand, considered *Chemnitzia* d'Orbigny, 1839 as a distinct and valid taxon and referred it to *Turbonilla* (Leach) Risso, as a subgenus. Sacco (1904, p.109), unconvinced, quoted Dall & Bartsch's revision only as information, and warned of the problems raised by it. Cossmann (1917, 1921) twice established generic identity between *T. lactea* and *M. campanellae* and, therefore, synonymized *Chemnitzia* d'Orbigny to *Turbonilla* (Leach) Risso. Laws (1937a), Wenz (1940), and Laseron (1959) roughly followed Dall & Bartsch. Pchelintsev & Korobkov (1960), on the contrary, followed Cossmann's viewpoint.

The diagnosis by the different authors, derived from Dall & Bartsch (1909), gives as a distinctive character between *Turbonilla* and *Chemnitzia* the presence in the former and absence in the latter of axial costae on the base, and as a common character absence of spiral ornaments. Laws (1937a) also distinguished two groups in Turbonilla: A with polygyrate helicoid protoconch; B, with planorboid paucispiral protoconch. In Chemnitzia, he (1937b) again distinguished two groups: A with heterostrophic helicoid 2-whorled protoconch; B with a) protoconch fairly obliquely tilted and tip of the nucleus more or less evenly convex, b) protoconch upright and exert and nucleus tip subangled.

Laws, following the Australasian tradition, placed more emphasis on the protoconch than Dall and Bartsch. Laws (1937b) and Laseron (1959) elevated Chemnitzia to generic rank.

GENUS Chemnitzia d'Orbigny, 1839

Chemnitzia sp.

FIGS. 382-384

MATERIAL. 1 juvenile specimen preserved.

DESCRIPTION. Shell turriculate, high spired; scarcely overlapping whorls increasing more in height than in diameter; suture slightly grooved; abaxial margins subconvex. Base subconvex; broad semilunar peristome, damaged. Parietal lip thin adherent; abaxial and abapical lips convex and thick; columellar lip straight. Lip connections: parietal-abaxial angular producing a gutter; abaxial-abapical imperceptible; abapical-columellar markedly angular; columellar-parietal slightly angular.

Protoconch. Strongly heterostrophic, sinistral helicoid, with the former two whorls very overlapping; the third whorl displays the inversion in the coiling direction from sinistral to dextral.

Ornament. Orthocline round broad ribs with narrower interspaces, fading completely on the base. Protoconch smooth.

OBSERVATIONS. The specimen represents a new undescribed and the oldest form of this family in this area. It may or may not represent a new species in this province. The protoconch places this form in Laws' *Chemnitzia* Group B, in the same group of *Chemnitzia* sp. nov. B.

LOCALITY. Noarlunga Township, Onkaparinga River, left bank, behind the Oval.

STRATIGRAPHIC LOCATION. Detritus from the 'Transitional Marl' Member. Late Eocene, possibly late P15-early P16.

Chemnitzia sp. nov. B

FIGS. 385-387

MATERIAL. 1 specimen with damaged last whorl; 1 fragment of last whorl.

DESCRIPTION. Shell minute, thick, turriculate, short spired; whorls increasing much more in height than in diameter. Whorl overlapping: normal to the coiling axis; total; parallel to it up to the middle-abapical connection; Suture flush, subadpressed. Abaxial margin regions: middle and adapical undifferentiated, subconvex, vertical.

Protoconch. 3 smooth heterostrophic whorls: initial whorls sinistral, horizontally coiled; last whorl destral and homeostrophic, after a twist; protoconch-teleoconch transition marked by the appearance of axial ornaments.

Ornament. Growth lines and axial costae; orthocline in the first teleoconch whorl, opisthocline on the others. Axial costae flat, with narrower flat, interspaces. Smooth abapical region.

OBSERVATIONS. The protoconch places this form in Laws' *Chemnitzia* Group B, and in the subgroup characterized by horizontally coiled protoconch (Laws, 1937b, p.64).

Chemnitzia sp. nov. B differs from *Chemnitzia* sp. nov. A in shape of the costae and of interspaces.

Due to the very bad preservation of the specimens, no name is proposed for this undescribed form.

DISTRIBUTION. Willunga SubBasin, Blanche Point at Aldinga Bay.

STRATIGRAPHIC RANGE. Gull Rock Member, Blanche Point Formation. Late Eocene (middle P16).

GENUS *Turbonilla* (Leach) Risso, 1826

Type species: *Turbo lacteus* Linné, 1776 (ed. 12th, p.1258, *fide* Sacco, 1892); subsequent designation, Woodward, 1880.

((*syn*: *Chemnitzia elegantissima* (Montagu), Woodward, 1880, p.239 (*Turbonilla* syn. to *Chemnitzia* d'Orbigny))

The major authors either indicated different species as the type of this genus or called by different names the type species as follows:

Chemnitzia elegantissima (Montagu) --- Woodward, 1880, p.239. (*Turbonilla* is here synonym of *Chemnitzia*).

Turbonilla lactea (Linné) --- Bucquoy, Dautzenberg & Dollfus, 1883 (*non vidi*, *fide* Cossmann & Peyrot, 1917, p.141).

Turbonilla lactea (Linné) --- Sacco, 1892, p.72.

Turbonilla typica Dall & Bartsch --- Dall & Bartsch, 1904, p.4 (*nom. nov. pro* *T. plicatula* Risso, non Scacchi).

Turbonilla typica Dall & Bartsch ---- Dall & Bartsch, 1909, p.29 (*nom. nov. pro.* *T. plicata* Risso, 1826, *non* Brocchi, 1814).

Turbonilla lactea (Linné) --- Cossmann & Peyrot, 1917, p.141.

Turbonilla lactea (Linné) --- Cossmann, 1921, p.278.

Turbonilla lactea (Linné) --- Wenz, 1940, p. 869.

Turbonilla plicatula Risso --- Laseron, 1959, p.232 (= *T. typica* Dall & Bartsch, 1904, *non* Scacchi).

Turbonilla lactea (Linné) --- Pchelintsev & Korobkov, 1960, p.134.

Although the concept and definition of *Turbonilla* (Leach) Risso is quite clear and consistent among the authors, the identity of the type species is still confused. The main causes are:

- No initial institution of a type species by Risso (1826, *non vidi*);
- Quotations by successive authors of different species as an example, i.e. *T. scalaris* Philippi and *T. lactea* (Linné) by H. & A. Adams (1857) and *T. elegantissima* (Montagu) by Fischer, (1885).
- Mistakes of taxonomic and nomenclatural nature as in Dall & Bartsch (1904, 1909) and still extant in successive authors (Laseron, 1959)
- Conspecificity of the two species more frequently indicated as type-species: *T. elegantissima* and *T. lactea* (Sacco, 1892, p.72).

In this matter, there are other points contributing to the confusion. About the conspecificity of *T. elegantissima* and *T. lactea* Sacco (1892) wrote:

> 'This species was variously interpreted by malacologists and, therefore, a sure reference for comparison is still lacking because the illustrations of this species given by Montagu, Brown, Philippi, Jeffrey, Bucquoy, Dautzenberg & Dollfus, etc. etc. differ from each other. In such an uncertainty, Jeffreys's illustration (British Conch., v. 5, pl. 76, fig. 3) could be chosen as provisional type because of Jeffreys's particular competence, because it is clear and well drafted, and also because Monterosato and the other malacologists consider it one of the best ones. Yet, I verified that the fossil forms were rather similar to *T. campanellae* (Philippi), to which I therefore thought opportune to parallel them, generally. I attribute the name of *gallica* Sacco to the form figured by Bucquoy, Dautzenberg & Dollfus (1883, Moll. Roussillon, pl.21, fig.7) and of *parvogallica* Sacco to the form referred to the same species and illustrated on the same plate in fig.6, since they appear to me quite distinct from Linneus's typical form.'
>
> (Translation from Italian by M.F. Buonaiuto)

The names '*gallica*' and '*parvogallica*' designate Sacco's 'varieties' which could refer to either subspecies or morphae (Sacco, 1892, p.83).

Dall & Bartsch (1904, p.4) instituted as the type of *Turbonilla* (Leach) Risso *Turbonilla typica* Dall & Bartsch which is a new name for *Turbonilla plicatula* Risso, non Scacchi. Later, the same authors (1909, p.29) again indicated as type species *T. typica* but *T. typica* was given as *nomen novum* this time *pro* *T. plicata* Risso *non* *Turbo plicatus* Brocchi, 1814. *Turbonilla plicata* Risso and *Turbo plicatus* Brocchi are wrongly spelt for Turbonilla plicatula Risso and Turbo plicatulus Brocchi. Furthermore, no T. plicatus was ever instituted by Brocchi (see Rossi Ronchetti, 1956, p.5-6). Turbo plicatulus Scacchi belongs to a different genus (fide Laseron, 1959, p.232). T. plicatula Risso is junior name of Turbo plicatulus Brocchi according to Sacco (1904, p.109).

Turbo plicatulus Brocchi, 1814, raises by itself another problem. The specimen figured by Brocchi is among the lost types of the Brocchi's Collection (Sacco, 1892, p.85; Rossi Ronchetti, 1952, p.5). Sacco (ibid) referring T. plicatulus doubtfully to Pyrgolampros Sacco, remarked that:

> 'the seven specimens still kept in the vial labelled 'Turbo plicatulus', belong to Pyrgostylus, Pyrgostelus, Turbonilla, etc. and they are a half size smaller and they clearly do not match with Brocchi's figure. Also, although Brocchi's description states the absence of spiral striae, in the original figure there are signs of fine spiral striae which would rather indicate a Strioturbonilla.'
>
> (Translation from Italian M.F. Buonaiuto)

Therefore, beside the tantamount point of priority of T. lactea (Linné) as type species because of Woodward's 1880 designation, not only would T. plicatulus Brocchi, 1814 (=T. typica Dall & Bartsch, 1904 = T. plicatula Risso, 1826 - see Sacco, 1904) not even be referable to Turbonilla s. str. because of its possible striation, but also it was known in literature that the holotype was lost, that no neotype was instituted, and that the specimens of the original series belong to different genera.

HABITAT. The living species of Turbonilla are ectoparasitic on coelenterates and sedentary polychaete worms. T. lactea (Linné) is recorded under stones and crevices on muddy rocky shores and down to 18.3 m depth (Fretter, 1951, Fretter & Graham, 1949, 1962).

T. fenestrata (Forbes) has a recorded depth range of 13-22 in muddy bottoms. T. delicata Monterosato was found at 22 m depth; T. crenata Brown at 5.50-73 m (sandy muds); T. fulvocincta (Thompson) at 33.04-165.2 (sandy muds); T. innovata Monterosato, under stones and rock crevices, in low tide; T. jeffreysi (Forbes & Hanley) at 5.50-91.50 (muddy gravel); T. rufescens (Forbes) at 36.5-110 m.

Turbonilla kaurna sp. nov.

FIG. 391

DERIVATION OF THE NAME. After the Kaurna, the Aboriginal tribe of the Eastern Gulf St. Vincent.

HOLOTYPE. SAM P 21200, Fig. 391.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Blanche Point, Aldinga Bay side.

TYPE FORMATION. Blanche Point Formation. Top of Gull Rock Member.

STRATIGRAPHIC LOCATION. Late Eocene (middle P16).

MATERIAL. Holotype with protoconch and last whorl damaged; 1 squashed and badly damaged specimen (doubtful).

DESCRIPTION. Shell very minute, thin, turriculate, high spired, whorls increasing in height about the same as in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to just above the middle-abapical connection. Suture subadpressed; body whorl shape trapezoidal. Margins: abaxial adapical narrow, subconvex, declivous; abaxial middle broad, subconvex, vertical; abaxial abapical subhorizontal, flat, broad; adaxial abapical subconvex, vertical; adaxial adapical subconcave, very wide, declivous. Margin connections: all angular. Base convex; peristome subtrapezoidal. Lips damaged. Protoconch damaged.

Ornament. Growth lines and axial costae: adapical and middle subopisthocyrt; abapical subprosocyrt. Axial costae present, weak on the base.

OBSERVATIONS. T. kaurna sp. nov. shows close relationships with the Holocene New Zealand T. suteri Powell, T. moorei Laws, T. haroldi Laws (Laws, 1937a, pp. 419-420, Figs. 16, 14, 13), in body whorl and margin shape, overlapping, growth lines and axial costae. These New Zealand species are characterized by paucispiral 'planorboid' protoconch (Turbonilla Group B; Laws, 1937a, p.406-7). Unfortunately, the poor preservation of the specimens does not allow for clarification of the relationships between T. kaurna and Laws's Turbonilla Group B.

Turbonillae rossiae sp.nov.

FIGS. 388-390

DERIVATION OF THE NAME. After Professor C. Rossi Ronchetti, Istituto di Paleontologia, Milano.

HOLOTYPE, SAM P 21199, Figs. 388-390.

TYPE LOCALITY. Blanche Point (Aldinga Bay), Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. The holotype only.

DESCRIPTION. Shell minute, turriculate, rather high spired; whorls increasing about the same in diameter as in height. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to just above the middle-abapical connection. Abaxial margin regions: adapical and middle undifferentiated, subconvex, subvertical; abapical convex. Region connections: adapical-middle imperceptible; middle-abapical rounded.

Protoconch. 2-3 heterostrophic smooth whorls: initial whorls sinistral tilted, with partially submerged nucleus; after a twist, dextral last whorl. Protoconch-teleoconch transition marked by the appearance of axial costae.

Ornament. Growth lines: adapical and middle very fine and opisthocyrt; abapical developed into fine prosocyrt growth rugae. Axial costae: adapical and middle to opisthocyrt to orthocline; abapical faded prosocyrt.

OBSERVATIONS. T. rossiae differs from T. kaurna in shorter spire, larger body whorl and costae. The initial protoconch whorls of T. rossiae and T. lactea (Linné) (Cox in Moore, 1960, p.I, 113; fig. 69-M) are similar. Their pseudoplanispiral coiling places them in Laws's 1937 Turbonilla Group B.

Turbonilla sp. nov.

FIG. 392

MATERIAL. 1 specimen, with last one and a half whorl preserved and with damaged peristome.

DESCRIPTION. Shell minute, thick, turriculate acicular, high spired, whorls increasing much more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Suture flush. Body whorl shape: outer subtrapezoidal; inner ovate. Abaxial margin: abaxial middle and adapical undifferentiated, flat, vertical; abaxial abapical subconvex, declivous. Region connections: adapical-middle subangular; middle-abapical subangular.

Ornament. Regular fine prominent axial costae, with wider interspaces, and fading on the base.

OBSERVATIONS. This form is referred to Turbonilla Risso because of the presence of faded costae on the base.

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Blanche Point, Aldinga Bay side.

STRATIGRAPHIC RANGE. Blanche Point Formation, Gull Rock Member (top). Late Eocene (middle P16).

GENUS Syrnola A. Adams, 1860

Syrnola s. l. sp. nov.

FIGS. 398-399

MATERIAL. 1 specimen with protoconch and last whorl damaged.

DESCRIPTION. Shell minute, turriculate, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle abapical connection. Body whorl ? subrhomboidal. Suture flush, Margins: abaxial adapical and middle undifferentiated, convex, very declivous; abaxial abapical subconvex; adaxial adapical subconvex; adaxial adapical subconcave.

Margin connections: abapical and adapical adaxial-abaxial angular; subangular the others. Base broad, subconvex, with narrow umbilicus. Peristome and lips damaged. Adaxial abapical detached, with a plica.

Protoconch. Damaged, but of syrnolid type.

Ornament. Smooth surface, growth lines imperceptible. Traumatic cicatrix on the initial part of the last whorl.

OBSERVATIONS. This form is placed by its protoconch within the syrnolid genera. The poor preservation of the specimen does not allow a more precise determination. The shallow umbilicus is similar to the one of *Pachysyrnola* Cossmann. The body whorl and the peristome place it close to *Colsyrnola* Iredale. Laseron (1959) figures species of *Colsyrnola* which during ontogenesis change their type of suture from flush to subgrooved to deepley grooved, i.e. : *C. margarita* Laseron (fig. 34-35) and *C. canaria* Hedley (Laseron, 1959, fig. 37). These two species resemble in the juvenile stages *Syrnola* s.l. sp. nov.

DISTRIBUTION. Murray Basin, Waikerie Observation Bore 2, Hd Waikerie, Sect. 692, 3 km south-south-west of Waikerie Township, 210.31-211.83 depth.

STRATIGRAPHIC RANGE. 'Lower Buccleuch A equivalent'. Late Eocene (Lindsay & Bonnett, 1973) (P16/17-P17, Buonaiuto, this study).

SUBGENUS *Pachysyrnola* Cossmann, 1907

Syrnola (Pachysyrnola) habei sp. nov.

FIGS. 393-397

DERIVATION OF THE NAME. After Professor T. Habe, National Science Museum Tokyo, for his studies on Japanese Mollusca.

HOLOTYPE. GSSA M 3413, Figs. 393-394.

PARATYPE. SAM P 21202B, Figs. 395-397.

TYPE FORMATION. Blanche Point Formation, Gull Rock Member.

TYPE LOCALITY. Adelaide Plains SubBasin, Adelaide Childrens Hospital, Hd Yatala, Town Acre 717, Bore 5, 21.33-21.00 m depth.

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. 3 specimens, slightly damaged.

DESCRIPTION. Shell minute, thin, turriculate, rather high spired; whorls increasing in height about the same as in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Suture adpressed in early stages, flush in the last whorl. Body whorl shape subrhomboidal. Abaxial margin regions: adapical and middle undifferentiated, flat, very declivous; abaxial abapical subconvex, declivous; adaxial abapical straight vertical; adaxial adapical subconcave declivous. Region connections: adapical and abapical adaxial-abaxial angular; adaxial adapical-abapical and abaxial middle-abapical broadly angular to subangular. Base broad, subconvex, narrowly umbilicate. Subrhomboidal peristome and lips damaged. Adaxial abapical lip thin, detached, with one thick, prominent, subdeclivous plica.

Protoconch Sinistral heterostrophic: 1 smooth whorl, subhorizontally coiled; nucleus submerged; undifferentiated from the teleoconch.

Ornament. Growth lines: adapical and middle opisthocline; adsutural falciform; abapical orthocline. Very fine spiral microstriae in one specimen.

OBSERVATIONS. Narrow umbilicus, thin plica-bearing adaxial abapical lip, syrnolid protoconch, and suture place this form very close to the Eocene Paris Basin P. carinulata Cossmann (Cossmann, 1921, p.230, pl.5, fig. 52-3). Pachysyrnola is doubtfully maintained by Wenz (1940) as subgenus of Syrnola A. Adams.

OTHER LOCALITIES. Blanche Point (Aldinga Bay side), Willunga SubBasin, St. Vincent Basin.

GENUS Odostomia Fleming, 1817

SUBGENUS Auristomia Monterosato, 1884

Odostomia (Auristomia) sulcata sp. nov.

FIGS. 406-410

DERIVATION OF THE NAME. From the Latin sulcatus, grooved, because of its suture.

HOLOTYPE. SAM P 21205A, Figs. 406-407

PARATYPES. SAM P 21205B-C, Figs. 408-410.

TYPE LOCALITY. Blanche Point (Aldinga Bay side), Willunga Sub-Basin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. 5 specimens rather well preserved.

DESCRIPTION. Shell very minute, rather thick, turriculate, rather high spired; whorls increasing more in height than in diameter. Whorl overlapping normal to the coiling axis, total; parallel to it up to just below the middle-abapical connection. Body whorl shape ovate, very narrow at the adapical. Suture grooved. Margin regions: abaxial middle and adapical undifferentiated, flat, very declivous; abaxial abapical very convex; adaxial abapical convex; adaxial adapical subconcave. Region connections: all subangular except the adapical adaxial-abaxial, very angular. Base convex, rather broad, with a reduced umbilical depression, partially or entirely obscured by the adaxial callus. Peristome ovate with a narrow adapical gutter. Lips: abaxial adapical and middle subconcave and sharp; abaxial abapical very concave and sharp; adaxial abapical concave, thick, adherent, producing a narrow callus; adaxial adapical adherent, concave, thin. Lip connections: all subangular, except the adapical adaxial-abapical very angular. 1 very faint columellar plica.

Protoconch. 2 whorls: smooth, heterostrophic, coiled around a very oblique axis, undifferentiated from the teleoconch.

Ornament. Straight prosocline growth lines.

OBSERVATIONS. Odostomiid protoconch, body whorl shape, suture, very faint adaxial lip plica, callus, and peristome place this form in *Auristomia* Monterosato (Cossmann, 1921, p.246). *A. sulcata* represents the first record of the subgenus in Australasia.

GENUS *Tiberia* Monterosato, 1875

SUBGENUS *Cossmannica* Dall & Bartsch, 1904

Tiberia (Cossmannica) maxwelli sp. nov.

FIGS. 400-405.

DERIVATION OF THE NAME. After P.A. Maxwell, New Zealand Geological Survey, for his studies of New Zealand Eocene Mollusca.

HOLOTYPE. SAM P 21203A, Fig. 400.

PARATYPES. SAM P 21203B, 21204A-C, Figs. 401-405.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Blanche Point, Aldinga Bay side.

TYPE FORMATION. Blanche Point Formation, Gull Rock Member.

STRATIGRAPHIC LOCATION. Late Eocene (middle P16).

MATERIAL. 11 specimens in various condition of preservation.

DESCRIPTION. Shell minute, thin, subcyrtoconoid; whorls increasing slightly more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it, up to the middle-abapical connection. Suture flush. Body whorl shape subrhomboidal. Abaxial margin regions: middle and adapical undifferentiated, flat, subvertical; abapical convex. Region connections: adapical-middle imperceptible; middle-abapical subangular. Base convex. Peristome damaged. Lips: adaxial abapical straight, vertical, detached with two plicae - the adapical well developed, subhorizontal; the abapical faint very declivous; adaxial adapical very thin, flat.

Protoconch. 1 whorl: smooth, heterostrophic, submerged, horizontally coiled.

Ornament. Growth lines: middle and adapical opisthocline; abapical prosocyrt.

OBSERVATIONS. The two adaxial lip plicae, body whorl shape, growth lines and protoconch place this form in *Cossmannica* Dall & Bartsch. Direct comparison with specimens of the Early Eocene Paris Basin, *Pyramidella clandestina* Deshayes, the type of *Cossmannica*, revealed that this species differs from *C. maxwelli.* in higher spire and smaller protoconch.

Dall & Bartsch (1904) instituted *Cossmannica* as a section of *Eulimella* Forbes, subgenus of *Pyramidella* Lamarck. Cossmann (1921) elevated *Cossmannica* to a genus, because he considered it a junior synonym of *Diptychus* Cossmann, 1888, a name preoccupied by *Diptychus* Milne Edwards, 1880. Wenz (1940) classed *Cossmannica* as a subgenus of *Tiberia* Monterosato.

ORDER HETEROGASTROPODA Kosuge, 1966

In this suborder Kosuge (1966, p.32) includes the Triphoracea, (= Triphoroidea) Architectonicacea, Epitoniacea, and Mathildidae. He places the Heterogastropoda in intermediate yet distinct position between the Tenioglossa (Mesogastropoda) and Stenoglossa (Neogastropoda). Climo (1975) elevates Heterogastropoda to ordinal rank and transfers it to Euthyneura.

SUPERFAMILY TRIPHORACEA Kosuge, 1964

(*nom. correct.*, Buonaiuto, herein, *pro Triphoroidea* Kosuge, 1964, *nom. perf.*)

From the taxonomic and anatomical viewpoint this group was always overlooked by researchers. Only recently, Laseron (1954, 1958) B.A. Marshall (1977a, b) and Kosuge (1961-67) gave something more than a simple description of the species. Laseron (1958) discussed in some detail shell morphology and ornament and their role in taxonomy. He observed also that the types of protoconch in the fossil species differ from the living ones. Marshall (1977 a,b) revised the dextral genera Triforis Deshayes and Metaxia Monterosato. Kosuge revised this group in a series of contributions on the Triphoridae of Japan, after Laseron's approach. As a result of his anatomical observations, he instituted the new superfamily Triphoroidea (1964) because of distinctive anatomical features of the digestive organs, such as acrembolic proboscis, oesophageal pouch, ptenoglossan type of radula and because of shell features such as multispiral mamillated or ornamented protoconchs and spiral operculum. These characteristics not only separate the Triphoridae from the Cerithiopsidae, hitherto considered very close to them, but also from the Stenoglossa, because of the non-lamellate operculum and the type of acrembolic proboscis never found in the Stenoglossa. On the other hand, these features place Triphoracea close to: the Epitoniacea for the type of radula and digestive tract; the Architectonicacea for the similar acrembolic proboscis and radula; the Mathildidae, which are allied to Architectonicacea, for shell morphology. These observations support earlier opinions by Risbec (1955, p.68-69) and Taylor & Sohl (1962, p.15, no.18).

Kosuge established the name Triphoroidea after the recommendation of the I.C.Z.N. (art. 29a) (nomen perfectum) but, in order to maintain homogeneity with the ending of all the other superfamilies, this name is here revised in Triphoracea (nomen correctum).

The Australasian Eocene Triphoridae are practically unknown. In New Zealand only a Bortonian-Kaiatan species, Triphora aoteaensis Marshall & Murdoch, 1920, p. 129, pl.6, fig. 3) has been described. The other known species range from the Early Miocene to Holocene.

In Australia, the Tertiary Triphoridae are entirely undescribed except for two Pliocene forms from the Adelaide Plains SubBasin, Triphora praegranifera Ludbrook and Isotriphora salisburyensis Ludbrook (Ludbrook, 1957, p.35, pl.2, fig.16; pl.2, fig.15), and for three Middle

Miocene forms from Muddy Creek, 'Triphora' planata, 'T'. wilkinsoni, 'T'. sulcata Tenison Woods (Tenison Woods, 1879, p.6, pl.1, fig.12; 1979a, p.233, pl.20, fig.9; pl.20, fig.12). Laseron (1958, p.576) quotes the occurrence in Balcombe Bay (Middle Miocene) of at least 15-16 species of which he figures some protoconchs and ornaments (ibid., figs. 247-255), but no further description is given. The classification here adopted is that of Wenz (1940) as revised by Kosuge (1966). Wenz's subgeneric classification of Triphora Blainville is maintained.

The Possible Role of Triphoracea in Palaeogeographic and Stratigraphic Correlations

Judged from observations by Scheltema (1971a, 1971b) the living Triphoridae are characterized by teleplanic (far-wandering) eurythermal larvae, that is they have 'a pelagic development of long duration, and can tolerate extreme temperature ranges. Therefore, they are easily dispersed over long distances by oceanic currents. Hence, their very widespread distribution (Scheltema, 1971b, pp. 21-22). This behaviour in the living species would open a new approach to taxonomy and distribution of the fossil Triphoridae. If their past behaviour were analogous to that of the present they would validly contribute to palaeogeographical and stratigraphical correlations.

The electral Triforis Deshayes deserves particular mention. This very little known genus, when not confused with Triphora Blainville by authors, was recognized as an extinct group until recently (Cossmann, 1906; Kosuge, 1967; Marshall, 1977a). Kosuge (1967) described three living representatives of Triforis: T. (Trituba) dexia (Verco) and T. (Granulotriforis) epallaxa (Verco) in Australia, and Granulotriforis tanseiae Kosuge in Japan. Therefore, he assumed that these living species are the survivors of tropical-subtropical stocks which once populated the Early Tertiary Tethys and Indo-Pacific. Meanwhile they gradually disappeared from the Central and Western Tethys with the deterioration of the climate, but still survived in the tropical-subtropical belt of the Indo- and South-West Pacific and gradually adapted to cooler conditions (Kosuge, 1967) and to deeper waters (Marshall, 1977a).

The oldest records of Australasian Triforis were the Early Miocene (Opoitian), T. (Triforis) zecollatus (Laws) and T. (Granulotriforis) neozelanicus (Laws) (Kosuge, 1967, p.127, pl.1, fig.8; p.129, pl.1, fig.4). With the discovery of a Late Eocene Granulotriforis from the St. Vincent Basin, the colonization of Australia by Triforis is shown to be much older and at least coinciding with the Late Eocene climatic optimum. Hence the arrival of the group in New Zealand and in the Indo-Pacific is also shown to be a successive event. The record of Trituba Jousseaume and Granulotriforis Kosuge from the Eocene to the Holocene, though poor and desultory, gives evidence that these subgenera had representatives which are still to be described throughout the Tertiary and the Quaternary.

FAMILY TRIPHORIDAE Jousseaume, 1884

Kosuge (1966, p.309-11) supplied rather detailed information on shell morphology and to this paper the reader is referred. At p. 314-17 he distinguished three subfamilies: Iniforinae, Mastoniirae and Triphorinae. In the Iniforinae the shell is sinistral, cyrtoconoid, the abapical and adapical channels close and tubular (p. 314); In the Mastoniinae the shell is sinistral, cyrtoconoid; the abapical adapical channels reduced to narrow grooves; there are 2 to 3 spiral cords on the abaxial margin; the operculum is paucispiral. The subfamily Triphorinae s. str. is monogeneric, the shell is elongate, very high spired, cyrtoconoid; the adapical channel a narrow slit, the abapical channel a narrow groove; there are three spiral beaded cords.

The affinities of Triforis Deshayes with its three subgenera Triforis s. str., Trituba Jousseaume, and Granulotriforis Kosuge are uncertain.

The shell is dextral, high spired, cyrtoconoid, the adapical and abapical channels tubular; there are two or three spiral cords, axial costae can be present, growth lines are opisthocline sinusoidal; the base is concave. (Kosuge, 1967; this study, figs. 26-31).

SUBFAMILY MASTONIINAE Kosuge, 1966

GENUS *Kosugeia* gen. nov.

DERIVATION OF THE NAME. Dedicated to S. Kosuge, National Science Museum, Tokyo, for his studies on Triphoridae.

TYPE SPECIES. *Kosugeia costatosulcata* sp. nov.

STRATIGRAPHIC RANGE. ?-Late Eocene-?

DIAGNOSIS Shell minute turriculate, sinistral, high spired, whorls increasing much more in height than in diameter; whorl overlapping up to the periphery; suture flush, pseudogrooved; body whorl shape rhomboidal; abaxial margin flattened with undifferentiated regions: base subconvex; peristome rhomboidal, merging into a wide short reflected siphonal channel. Lips: parietal very thin, long subconvex, gently declivous; columellar short, straight; abaxial long, straight; abapical subconcave, gently declivous, inflected. Lip connections: parietal-abaxial angular, probably producing a shallow gutter; abaxial-abapical, parietal-columellar rounded angular; abapical-columellar angular.

Protoconch. Three homeostrophic carinated whorls, with axial costae; smooth nucleus tilted and partly submerged.

Ornament. Axial orthocline costae intersected by two spiral sulci at adapical-middle and at the periphery; straight opisthocline growth lines; base smooth.

OBSERVATIONS. This new genus is instituted for a very unusual triforid form. The protoconch is similar to that in *Litharium* Dall because of its submerged nucleus and the presence of axial costellae similar to that of the teleoconch, but it differs from *Litharium* because the latter has a less submerged nucleus. It is one of the few Triphorids without cyrtoconoid shell. The body whorl shape is close to those of *Viriola* Jousseaume and *Cautor* Finlay. The abapical lip is inflected, the siphonal channel is reflected and strongly deviated from the axis, The growth lines indicate a very reduced adapical channel (cf. fig. 412 and 437, 439). But the striking difference is in the ornament pattern which consists of orthocline axial costae interrupted by spiral sulci; the base is smooth with only some irregular growth rugae on the siphonal channel. The above characteristics place this genus in Mastoniinae Kosuge.

Kosugeia costatosulcata sp. nov.

Figs. 411-414

DERIVATION OF THE NAME. From the combination of the Latin *costatus*, ribbed, and *sulcatus*, grooved, because of its ornament.

HOLOTYPE. SAM P 21209, fig. 414.

PARATYPE. GSSA M 3148, Figs. 411-413.

TYPE LOCALITY. Maslin Bay, Willunga SubBasin.

TYPE FORMATION. Blanche Point Formation ('Transitional Marl' Member).

STRATIGRAPHIC RANGE. Late Eocene (late P15-early P16).

MATERIAL. The holotype with peristome damaged; shell silicified. The paratype with peristome damaged.

DESCRIPTION. As for genus, above. Suture flush, but appears grooved because of the adjacent abapical groove separating the costae from the thin sharp peripheral carina. To complete the description of the ornament: growth lines subopisthocline on the abaxial margin, opisthocyrt on the abapical. Peripheral carina at abaxial-abapical connection; faint spiral microsulci: 2 adapical and 3 abapical to the adapical sulcus; 2 faint spiral micro costellae limiting the adapical sulcus.

OTHER LOCALITIES. Adelaide Childrens Hospital, Bore 5, Hd Yatala TA 717, 22.64-22.31 m depth.

Kosugeia sp. nov.

MATERIAL. 1 specimen damaged during observation.

DESCRIPTION. Like *Kosugeia costatosulcata*. It differs in having thicker axial costellae and wider adapical sulcus.

OBSERVATIONS. This form is very close to *K. costatosulcata* and is its probable descendant. Unfortunately, in the attempt to free it from the encrusting matrix, the only specimen available was completely damaged and only an internal mould remains.

LOCALITY. Blanche Point at Aldinga Bay, Willunga SubBasin.

STRATIGRAPHIC LOCATION. Blanche Point Formation (top of Gull Rock Member). Late Eocene (middle P16).

GENUS *Inella* Bayle, 1878

Inella maxwelli sp. nov.

FIGS. 415-420.

DERIVATION OF THE NAME. From P.A. Maxwell, New Zealand Geological Survey, Lower Hutt, for his studies on the Kaiatan molluscan faunas from MacCullough's Bridge (Late Eocene).

HOLOTYPE. SAM P 21210, Figs. 415-417.

PARATYPES. SAM P 21210 A-B, Figs. 418-410.

TYPE LOCALITY. Blanche Point at Aldinga Bay, Willunga SubBasin.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. The holotype, juvenile, well preserved; two paratypes rather damaged.

DESCRIPTION. Shell minute, thin, turriculate, sinistral, high spired; whorls increasing more in height than in diameter; whorl overlapping up to the middle-abapical connection; suture flush, pseudogrooved. Body whorl shape subrectangular, higher than wide. Abaxial margin regions:

adapical flat, very declivous in younger stages, subvertical in senile; middle vertical and convex, the convexity decreasing gradually with the whorl number; region connections subangular. Base flat, peristome subrectangular merging into a short reflected siphonal channel.

Protoconch. 2 whorls, the initial heterostrophic pseudoplanispiral, the latter homeostrophic, both very convex subcarinated; nucleus smooth, submerged; axial costae with two middle spiral costae developed on the latter whorl.

Ornament. Growth lines and axial costae subopisthocline. Four spiral ribs on the abaxial margin: 1st adsutural; 2nd to 3rd middle; 4th at the middle-abapical connection; a weaker fifth on the last whorl in the interspace. Spirally elongated beads at medial rib-costa intersections. Base smooth.

OBSERVATIONS. Growth lines, ornament pattern, neck and body whorl shape place this form closer to Inella Bayle to which it is referred. The holotype, though juvenile, was chosen because it is the best preserved specimen. The decreasing convexity of the abaxial margin with whorl number is to be noted.

GENUS Viriola Jousseaume, 1884

Viriola sp. nov.

FIGS. 421-422

MATERIAL. 1 specimen with the last 2.5 whorls preserved. (GSSA M 3419)

DESCRIPTION. Shell small, sinistral, turriculate, very high spired; whorls increasing in height much more than in diameter; whorl overlapping up to just below the periphery. Suture flush, pseudogrooved. Body whorl shape subtrapezoidal. Abaxial margin subconvex with undifferentiated regions. Abapical margin convex. Abapical-abaxial margin connection angular. Base convex; peristome subtrapezoidal merging into a very short reflected siphonal channel. Lips: abaxial and abapical broken, probably both subconvex; parietal subconcave, thin;

columellar straight very thick, subdetached. Lip connections: all rounded, the parietal abaxial producing a rounded narrow gutter.

Ornament. Growth lines and axial costae opisthocline sinusoidal. 5 spiral cords: adsutural broad triangular in section; 2nd-to 3rd flattened; 4th triangular rostrum-like, peripheric; 5th faint, step-like, basal, near the periphery. Spiral interspaces: 1st-2nd very wide, V-shaped; 2nd-3rd a simple fine stria; 3rd-4th U-shaped, wide and deep; 4th-5th wide and flat. Fine subquadrate beads at cord-costa intersections.

OBSERVATIONS. This form was compared with specimens of *Viriola bayani* Jousseaume, type species of *Viriola* Jousseaume, kept in the S.A. Museum. Close affinities in growth lines, columella, and siphonal channel, coiling, body whorl shape, adapical gutter place this form in *Viriola*. As other species described in the present study this form displays only one peripheral basal cord against the two or more of the coeval Paris Basin or Holocene ones.

LOCALITY. Adelaide Childrens Hospital Bore 1, Hd Yatala, TA 717, 23.95-23.62 m depth.

STRATIGRAPHIC RANGE. Lower Blanche Point Formation, Late Eocene.

SUBFAMILY	TRIPHORINAE (*nom. transl.*, Kosuge, 1966, from *Triphoridae* Jousseaume, 1884)
GENUS	*Triphora* Blainville, 1828
SUBGENUS	*Ogivia* Harris & Burrows, 1891

Triphora (Ogivia) trirostrata sp. nov.

FIGS. 424-427

DERIVATION OF THE NAME. (from the) Composite Latin words *tres*, three, and *rostratus*, beaked, because of the number of its cords and the shape of its beads.

HOLOTYPE. GSSA M 3420, Figs. 424-426.

PARATYPE. GSSA M 3421, Fig. 427.

TYPE LOCALITY. Adelaide Childrens Hospital Bore 5, 21.00-20.34 m depth.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (late P15-middle P16).

MATERIAL. The holotype, and the paratype; 2 badly preserved silicified specimens from outcrop material.

DESCRIPTION. Shell, minute, sinistral, turriculate, high spired, whorl increasing more in height than in diameter, whorl overlapping up to the periphery, suture flush. Body whorl shape: inner ovoidal, outer subquadrate. Abaxial margin flat, with undifferentiated regions. Base subconvex; peristome ?subquadrate merging into a short narrow transversal comma-shaped siphonal channel. Lips damaged. Columellar callus narrow, subdetached.

Protoconch. Three whorls, homeostrophic, smooth, carinated, with tilted submerged nucleus. The abaxial margin of the 1st whorl is convex, gradually becoming carinated with a concave adapical region and a flat to concave middle region. In the last two whorls 2 adapical spiral costae appear and develop into the adsutural and middle costae of the teleoconch. The carina migrate to the abapical and develop into the abapical cord of the teleoconch.

Ornament. Growth lines opisthocyrt on the base and opisthocline straight on the abaxial round costae. 5 spiral cords: 1st adsutural flat broad, 2nd narrower flat, 3rd middle abapical broad sharp, 4th peripheral, thinner, sharp, 5th peripheral basal thin step-like. Spiral interspaces: 1st-2nd very narrow, 2nd-3rd broad, 3rd-4th very narrow, 4th-5th very broad, flat. Rostrum-shaped beads at costa-cord intersections.

OBSERVATIONS. This species is placed in Ogivia Harris & Burrows. The direct comparison of this form with Triphora (Ogivia) singularis (Deshayes) from the Middle Eocene of the Paris Basin, type specis of Ogivia, (Cossmann, 1906, p.171, pl.12, figs. 48-49) showed close affinities. O. singularis differs from O. trirostrata in much finer adapical middle cord, and consequently, wider interspaces; on the other hand, it displays similar shape in body whorl, siphonal channel and beads. The peripheral basal cord is similar also. The protoconch is similarly smooth, and has a tilted subglobose nucleus; the specimens of <u>O. singularis</u> here examined have damaged protoconchs but they show traces of carina. Kosuge (1966) synonymized <u>Notosinister</u> Finlay with <u>Triphora</u> Blainville on anatomical grounds.

<u>OTHER LOCALITIES.</u> The type locality, at 23.95-23.62 m depth. Willunga SubBasin, Maslin Bay.

<u>Triphora</u> s.l. <u>muna</u> sp. nov.

FIGS. 429-430,432-435

<u>DERIVATION OF THE NAME.</u> From the Aboriginal Kaurna word <u>muna</u>, old.

<u>HOLOTYPE.</u> SAM P 21213, Figs. 432-434.

<u>PARATYPES.</u> SAM P 21213A, Figs. 429-430; GSSA M 3422, Fig. 435.

<u>TYPE LOCALITY.</u> Blanche Point at Aldinga Bay, Willunga SubBasin.

<u>TYPE FORMATION.</u> Blanche Point Formation.

<u>STRATIGRAPHIC RANGE.</u> Late Eocene (late P15-P17)

<u>MATERIAL.</u> 2 juveniles from bore material; 2 juveniles, 2 adults, 2 seniles differently preserved, from outcrop material.

<u>DESCRIPTION.</u> Shell rather small, thick, sinistral, cyrtoconoid, whorls increasing slightly more in height than in diameter; whorl overlapping up to the periphery; suture flush, Body whorl shape: outer subquadrate in juvenile stages, more ?rounded in senile ones. Abaxial margin with undifferentiated regions from flat juvenile to subconvex in adult-senile stages. Abapical margin flat in juvenile, convex in adult-senile stages. Margin connections from angular in juvenile to rounded in adult-senile stages. Base flat in juvenile stages, convex in adult-senile ones. Peristome merging into a short siphonal channel (too damaged for detailed description).

<u>Protoconch.</u> About 2 whorls, smooth, homeostrophic, with smooth

submerged tilted nucleus, three spiral carinae which develop into the main cords of the teloconch.

Ornament. Opisthocline straight growth lines and axial costae; opisthocyrt growth lines on the base. Three heavy cords on the abaxial margin, one smooth rib at the periphery; 1 step-like weak peripheral basal riblet.

OBSERVATIONS. This form shows convergence with the Middle Eocene Parisian Triforis (Epetrium) inversus Lamarck (Deshayes, 1866, p.238, pl.81, figs. 22-23), placed by Cossmann in Triphora s. str. (Cossmann, 1906, p.170) or in Epetrium Harris & Burrows (= Stylia Jousseaume) (Cossmann, 1889, p.56).

From direct comparison, they show a similar protoconch, though that of T. inversus is smaller, and similar ornament and growth lines. T. inversus differs in having a much more slender shell, and a very well developed peripheral basal costa. Both the species show straight opisthocline growth lines on the abaxial margin. This character excludes them from Epetrium which displays an adsutural sinus (Cossmann, 1906, p.167). Therefore, T. muna is referred to Triphora s.l., the subgeneric location being rather uncertain.

OTHER LOCALITIES. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital, Bore 5, 24.60-24.28 m depth. Murray Basin, Waikerie Bore 2W, sect. 692, Hd Waikerie, 228.02-226.38 m depth.

STRATIGRAPHIC RANGE. St. Vincent Basin, Blanche Point Formation. Murray Basin, Buccleuch 'B' Beds (Lindsay & Bonnett, 1973). Late Eocene (late P15-P17).

SUBGENUS Isotriphora Cotton & Godfrey, 1931

Triphora (Isotriphora) sp. nov.

FIGS. 423

MATERIAL. 1 specimen with only one and a half whorls preserved (SAM P 21211).

DESCRIPTION. Abaxial and abapical margins flat. Margin connection angular. Base flat, peristome subtrapezoidal, higher than wide, merging into a short transverse siphonal channel, partly closed by the abapical lip. Whorl overlapping just below the periphery; suture flush, subgrooved.

Ornament. Opisthocline growth lines and costae. 3 adapical-middle large spiral cords and one smooth peripheral basal costella. Two other spiral smooth basal costellae, the inner one fainter. At the costa-cord intersections there are subquadrate, pseudo-imbricate beads.

OBSERVATIONS. Suture, peristome, siphonal channel, and ornament place this form close to the Holocene *Isotriphora tasmanica* Tenison Woods, type species of *Isotriphora* Cotton & Godfrey (Cotton & Godfrey, 1931, p.52, pl. 1, fig.3). The new species therefore represents the oldest record of this subgenus.

LOCALITY. Willunga SubBasin, Aldinga Bay at Blanche Point.

STRATIGRAPHIC RANGE. Blanche Point Formation (Top of Gull Rock Member), Late Eocene (middle P16).

INCERTAE SEDIS

Triphora s.l. sp. nov. A

FIG. 428

MATERIAL. 1 neanic specimen broken in two pieces during observation (SAM P 21212).

DESCRIPTION. 3-whorled protoconch and the initial whorl of the teleoconch. Initial whorl of the protoconch smooth globose, heterostrophic, with horizontal coiling axis and submerged nucleus: 2nd whorl smooth, helicospiral, carinated; 3rd-4th, homeostrophic with the 2nd, carinated, bearing axial costellae and a spiral costella on the carina.

OBSERVATIONS. The protoconch of this form is close to that of *Mesophora* Laseron in having the initial whorl globose and horizontally coiled; it resembles *Coriophora* Laseron in the ornament of the initial teleoconch (Laseron, 1958). Furthermore, in the teleoconch the body whorl shape is subquadrate and the growth lines and axial costae are opisthocline straight. Therefore, this form is placed in Triphora s.l.

LOCALITY. Willunga SubBasin, Blanche Point at Aldinga Bay.

STRATIGRAPHIC RANGE. Blanche Point Formation (Top of Gull Rock Member), Late Eocene (middle P16).

Triphora s.l. ?sp. nov. B

FIG. 431

MATERIAL. 1 very worn specimen (GSSA M 3423).

DESCRIPTION. This specimen is too worn for a good diagnosis. The shell is rather large, thick, sinistral, high spired, turriculate; suture probably flush; whorl overlapping up to the periphery. It bears traces of three primary cords with large beads and of opisthocline axial costae.

OBSERVATIONS. This form bears some resemblance to Triphora muna sp. nov. but it could represent a new form.

LOCALITY. B.Q. Butler Bore, Hd Kirkpatrick, Sect. 4, 125-118.77 m depth.

STRATIGRAPHIC RANGE. Buccleuch 'A' Beds, Latest Eocene (P16/17-P17) (Buonaiuto, this study).

FAMILY	TRIFORIDAE Jousseaume, 1884
SUBFAMILY	TRIFORINAE Jousseaume, 1884
GENUS	Triforis Deshayes, 1834

Kosuge (1967) revised this genus, extending its stratigraphic range to the Holocene. He referred to it three subgenera: Triforis s. str. (Eocene-Miocene); Trituba Jousseaume (Eocene-Holocene); and Granulotriforis Kosuge (Eocene-Holocene, Kosuge, 1967, this study).

But except for a brief quotation in a previous paper (Kosuge, 1966) he did not discuss the taxonomic position of Epetrium Harris & Burrows (Paleocene-Pliocene), considered by Cossmann (1906) and Wenz (1940) a sinistral subgenus of *T. Triforis.* Kosuge (1966, 1967) does not locate this genus in any subfamily and therefore it is here considered as *incertae sedis* within the Triphoridae, though it is characterized by adapical and abapical tubular channels as in the Iniforinae Kosuge. The only certain diagnostic character for both sinistral and dextral forms appears to be the adsutural sinus in the growth lines, produced by the adapical channel (Cossmann, 1906, p.167; this study, figs. 437-439).

SUBGENUS *Granulotriforis* Kosuge, 1967

Triforis (Granulotriforis) sp. nov.

FIGS. 436-437

MATERIAL. 1 specimen with 5 whorls preserved (GSSA M 3424).

DESCRIPTION. Shell minute, thin, turriculate, dextral, whorls increasing in diameter about the same as in height, whorl overlapping up to the periphery, suture flush, body whorl shape subtrapexoidal. Margins: abaxial flat, vertical; abapical subhorizontal, flat.

Ornament. Opisthocline, sinusoidal growth lines and faint axial costae; two spiral cords, one adsutural, the other more markedly peripheral; both bearing prominent beads, the adsutural ones twisted.

OBSERVATIONS. Growth lines, beads, spiral cords, suture, body whorl shape, and smooth flat base are close to the New Zealand Miocene *Granulotriforis neozelanicus* (Laws) (Kosuge, 1967, p.129, pl.1, fig.4) and to the Miocene Tethyan *G. dujardini* (Mayer) (Kosuge, 1967, p.128, pl.1, fig.6) and to the Holocene *G. tanseiae* Kosuge, the type species (Kosuge 1967, p.126, pl.1, figs. 5, 7). In direct comparison, much closer similarities in ornament were found between this Late Eocene form and *Granulotriforis epallaxa* (Verco) (Verco, 1909, p.279, pl.22, fig. 1; this study, figs. 438-441). *Granulotriforis tanseiae* differs from *G. epallaxa* in its rounder aperture, more compressed adapical channel, steeper base, and protoconch with shorter spire and fewer whorls.

Another species which should be referred to *Granulotriforis* is *Triforis* *tauroturrita* Sacco (Sacco, 1895, p.62, pl.3, figs. 58-9) from the Proto-Adriatic Ligurian-Piedmont Basin (Early Miocene, *Helvetien Auct*.). Marshall (1977a) recently added three extant new species to this subgenus: *G. antepallaxa* Marshall, *G. blacki* Marshall, and *G. tui* Marshall, from Three Kings Islands (New Zealand). *Granulotriforis* sp. nov. represents the oldest record of the subgenus. Therefore, the stratigraphic range of *Granulotriforis* is extended far back to the Late Eocene.

LOCALITY. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore, N.E. Parklands, Hd Adelaide.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

FAMILY ARCHITECTONICIDAE
GENUS *Pseudomalaxis* Fischer, 1885
SUBGENUS *Pseudomalaxis* s. str.

Pseudomalaxis (Pseudomalxis) ludbrookae sp. nov.

1975 *Pseudomalaxis (Pseudomalaxis) asculpturatus* -Buonaiuto, p.25, fig. 3 a-c (pars).

DERIVATION OF THE NAME. After N.H. Ludbrook, for her contributions to Australian palaeontology.

HOLOTYPE. GSSA M 3299, figured in Buonaiuto, 1975, fig. 3a-c.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 21.64-21.95 m depth.

TYPE FORMATION. Blanche Point Formation ('Transitional Marl' Member)

STRATIGRAPHIC RANGE. Late Eocene, at the Hantkenina zone (P15/16), (J.M. Lindsay *in* Buonaiuto, 1975).

OBSERVATIONS. The subsequent discovery of specimens referable to the typical New Zealand *Pseudomalaxis asculpturatus* Maxwell (Buonaiuto, 1975, figs. 1-2a-c) in the upper Gull Rock Member of Blanche Point Formation revealed the differences between the'Transitional Marl'form and the New Zealand and Gull Rock forms. The former differs from the latter in: slenderer body whorl, greater number of whorls, thicker shell, shorter spire, more prominent carinae and subconvex adapical and abaxial margins. Therefore, on the basis of these differences the 'Transitional Marl' form is here referred to a new species, P. ludbrookae.

Direct comparison of the types of P. ludbrookae with senile and juvenile specimens of the Anglo-Paris Middle Eocene P. dixoni Vasseur revealed significant affinities in whorl coiling, margins outline and, in particular, ornament . These similarities suggest a possible Boreal Atlantic origin for P. ludbrookae.

Pseudomalaxis (Pseudomalaxis) asculpturatus Maxwell,1966

1966 Pseudomalaxis asculpturatus Maxwell, p. 444, figs. 11-13.

1976 Pseudomalaxis asculpturatus -Buonaiuto, p.25, figs 1-2a-c (pars).

OBSERVATIONS. After the publication of the paper by Buonaiuto (1975), four more specimens of this rare species were found in the upper Gull Rock Member from Willunga SubBasin. These specimens well match with the topotypes of P. asculpturatus Maxwell, but are quite distinctive from the older P. ludbrookae, previously described.

This finding is of significant importance since it may supply a useful indication in the correlation between the New Zealand and Australian Late Eocene events, because it is one of the few species undoubtedly common to these regions. From its stratigraphic range, P. asculpturatus seems to belong to a stock probably developed in the Australasian region, but of more ancient Boreal Atlantic ancestry than P. ludbrookae.

DISTRIBUTION. New Zealand, McCullough's Bridge. St. Vincent Basin, Willunga SubBasin: Blanche Point (3 specimens); Willunga Bore WLG 37, 66.47-66.41 m depth (1 spec.), 81.70-82.00 m (1 spec.).

STRATIGRAPHIC RANGE. New Zealand, Upper Waihao Greensand, Kaiatan, late Middle to early Late Eocene. St. Vincent Basin, Top Gull Rock Member, Late Eocene (middle P16).

FAMILY MATHILDIDAE

GENUS *Acrocoelum* Cossmann, 1888

Acrocoelum margaritatum sp. nov.

FIGS. 376-378

DERIVATION OF THE NAME. From the Latin *margaritatum*, beaded, because of its beaded cords.

HOLOTYPE. SAM P 21196, Figs. 376-378.

TYPE LOCALITY. Willunga SubBasin, Maslin Bay.

TYPE FORMATION. Blanche Point Formation ('Transitional Marl' Member).

STRATIGRAPHIC LOCATION. Late Eocene (early P16).

MATERIAL. The holotype well preserved, but with the protoconch damaged.

DESCRIPTION. Shell small, turriculate, high spired; whorls increasing more in height than in diameter. Whorl overlapping: normal to the coiling axis, total; parallel to it just below the middle abapical connection. Body whorl shape ovoidal. Suture abutted. Abaxial margin convex, with undifferentiated regions. Base subconvex, bound by a slight subangularity, with narrow and shallow umbilicus. Peristome subovoidal. Lips: adaxial adapical straight, thin, imperceptible; adaxial abapical thin, elliptical, concave, somewhat reflected; abapical concave, subelliptical; abaxial elliptical concave. Lip connections: adaxial adapical-abapical imperceptible; abapical adaxial-abaxial subangular; abaxial abapical-middle and adapical adaxial-abaxial broadly angular.

Protoconch. Damaged.

Ornament. Prosocline growth lines and rugae. Spiral primary cords alternated with finer secondary cords, in the abaxial middle and adapical regions. Beaded ruga-cord intersection.

OBSERVATIONS. This form could be easily attributed to either Matildon Iredale or Tubena Marwick, or Acrocoelum Cossmann. However, its umbili is too wide in comparison with Mathildona euglypta Iredale (Iredale, 1929 p.186, pl.40, fig.6) and too narrow in comparison with Tubena viola Marwick (Marwick, 1943, p.188, pl.26, fig.14; pl.27, fig.30), but it is similar to Acrocoelum bouryi Cossmann. The body whorl is as slender as M. euglypta and A. bouryi, but more than in T. viola. Sutures, are abutte as in both A. bouryi and M. euglypta, but flush in T. viola.

The suture in T. viola is not parallel to the spiral cords as in A. bouryi and in M. euglypta and in this form. Finally, M. euglypta diff from A. bouryi and this form in the presence of a thicker adaxial adapica lip. In conclusion, there is enough similarity in characters to ascribe this form to Acrocoelum Cossmann.

SUPERFAMILY	EPITONIACEA
FAMILY	EPITONIIDAE
GENUS	Cirsotrema Mörch, 1852
SUBGENUS	Cirsotrema s. str.

Cirsotrema (Cirsotrema) mariae (Tate, 1885)

FIGS. 329-381

1885 Caloscala mariae Tate, p.3.

1890 Scalaria (Cirsotrema) mariae-Tate, p.230

1892 Scalaria mariae-Tate, pl.12, fig. 2.

1973 Cirsotrema mariae -Ludbrook, pl.25, fig.30.

MATERIAL. 81juvenile specimens, generally badly preserved.

DESCRIPTION. Shell thin, small, turriculate, high spired, nearly advolute; whorls increasing more in height than in diameter; whorls tangent; suture line impressed. Whorl body shape ovoidal: outer abaxial margins, adaxial straight, adapical flattened and declivous to the axis, abaxial and abapical rounded; adaxial-abapical and adapical connections very angular abaxial-abapical imperceptible. Base flattened. Peristome ovoidal, abaxial lip very varicose, adaxial abapical lip smooth, producing a thin callus not adherent to the base, faint gutters at the adapical and abapical ends.

Ornament. Cancellate pattern. In the abaxial region about 20 spiral prominent ribs, increasing abapically in diameter; the last one, the biggest bounding the base; very faint secondary riblets in interspaces. On the abapical region spiral ribs very faint, nearly imperceptible. Rather prominent axial ribs. Frequent irregularly occurring varices as remnants of old outer lips.

OBSERVATIONS. C. mariae, according to De Boury (1887), p.40), Cossmann (1912, 9^{0}, p.51), and Tate himself (1892, ibid), is the type of the subgenus Caloscala Tate, synonym of Cirsotrema Mörch s. str. The Tortachilla Limestone specimens seem to be characterized by thicker axial costae than those from Blanche Point Formation.

DISTRIBUTION. St. Vincent Basin: Willunga SubBasin, Maslin and Aldinga Bays. Murray Basin: Padthaway Ridge, B.Q. Butler Bore 4, Hd Kirkpatrick, Sect. 8, 125-118.77 m depth.

STRATIGRAPHIC RANGE. St. Vincent Basin: Tortachilla Limestone-Blanche Point Formation. Murray Basin: Buccleuch Beds. Late Eocene (P15-P17).

ORDER CEPHALASPIDEA Fischer, 1883

The Australian Late Eocene Cephalaspidea, herein described, are characterized by minute shells except for the Scaphandridae and Pteropoda. Therefore, their size makes them very difficult to collect with common hand-picking methods and their fragile preservation increases the difficulty of freeing them from the host rock and of observing satisfactorily their morphology. The latter factor is a constant problem in all the micromollusca from the Blanche Point Marls in Aldinga and Maslin Bays, because they are also slightly compressed.

In this revision, another unexpected problem augmented the difficulties: the disappearance of nearly all Cossmann's paratypes (about 200 specimens) which, according to Tate (*in* Cossmann, 1897), were placed in the Museum of the University of Adelaide. Riedel's 1949 Catalogue of Tate's Collection still records their presence at that time. Searches in the South Australian Museum and Adelaide University Geology Department were unsuccessful, except for the rediscovery of the syntypes of *Triploca ligata* Tate. Sometime earlier, when dealing with the Cancellariidae, it was revealed that the middle Miocene *incertae sedis*, *Cancellaria alveolata* Tate, an (Darragh, 1971), should have been referred to *Obrussena* Iredale, Acteonidae. This species is therefore included in the present study and the stratigraphic range of the living genus *Obrussena* is extended back to the Miocene. Furthermore, during the searches in the collections of the Geology Department of the University of Adelaide, an undescribed specimen of *Ectosinum* Iredale (Naticidae) from Adelaide (Kent Town) Bore was found and in its matrix was unexpectedly found a well preserved Pteropod, referable to *Bovicornu* Meyer, a genus hitherto unknown outside the North American Eocene Tethys.

Finally, a brief description of the shell structure of *Praehyalocylis annulata* (Tate) and *Bovicornu robbai* sp. nov. is given with a comparative reference to the shell structure of the Palaeozoic Cricoconarida

(=Tentaculitoidea) and Hyolitha, which past authors considered ancestors or allied forms of Pteropoda, because of their striking shell convergence.

FAMILY ACTEONIDAE

SUBFAMILY ACTEONINAE

GENUS *Acteon* Montfort, 1810

SUBGENUS *Acteon* s. str.

Acteon (Acteon) subscalatus Cossmann, 1897

FIGS. 442-444

1897 *Actaeon subscalatus* Cossmann, p.2, pl.1, fig.8-9.

MATERIAL. 38 silicified adult and juvenile specimens in various states of preservation. 1 adult non-silicified.

DESCRIPTION. Shell minute, globose, rather high spired; whorls increasing more in height than in diameter; whorl overlapping up to the abapical half of the middle region. Suture subimpressed. Abaxial margin regions: adapical very narrow and declivous; middle wide, subvertical, subconvex; abapical narrow, convex. Region connections: middle-adapical angular; middle-abapical subangular. Last whorl: peristome holostomatous, lanceolate; base subconvex. Lips: parietal, convex, very thin; columellar straight, reflected, adherent, with a plica; abaxial subconcave; abapical very concave. Lip connections: abaxial-abapical subangular; all the others angular.

Protoconch. 1 smooth, heterostrophic whorl with submerged nucleus.

Ornament. Heavy spiral flat costae with punctate interspaces.

OBSERVATIONS. The paratypes have not been found in the Tate collection so a direct comparison is as yet impossible. Nevertheless, the silicified specimens well match with Cossmann's original figure and diagnosis.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Aldinga and Maslin Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

GENUS ?Kleinacteon Vokes, 1939

?Kleinacteon dubius sp. nov.

FIGS. 448-451

DERIVATION OF THE NAME. From the Latin dubius, doubtful, because of its uncertain taxonomic position.

HOLOTYPE. SAM P 21219, Figs.449-451.

PARATYPE. GSSA M 3425, Fig. 448.

TYPE LOCALITY. Aldinga Bay, Blanche Point.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Gull Rock-'Soft Marl' Members, Late Eocene (middle P16).

MATERIAL. 99 specimens generally slightly squashed and damaged.

DESCRIPTION. Shell minute, thin, rather high spired, whorls increasing more in height than in diameter; whorl overlapping up just above the middle-abapical connection. Suture adpressed. Abaxial margin regions: all subconvex, adapical and middle very declivous. Region connections: adapical-middle imperceptible; middle-abapical angular. Last whorl: base broad, subconvex, with shallow umbilicus; peristome holostomatous, lanceolate. Lips: parietal, thin convex, long; columellar rather long, concave, detached; abapical concave; abaxial subconcave, long.

Lip connections: parietal-abaxial narrow, angular; parietal-columellar angular; columellar-abapical subangular; abaxial-abapical rounded.

Protoconch. Dome-like, 2-2½ whorls homeostrophic smooth.

Ornament. Broad, flat spiral costae with very narrow punctate interspaces; growth lines prosocline.

OBSERVATIONS. This form is referred to Kleinacteon Vokes on the basis of its homeostrophic protoconch, absence of columellar plicae, and shape of the peristome. The general shell shape is closer to Semiacteon Cossmann, but a direct comparison with specimens of the type S. sphaericulus (Deshayes) revealed in the latter species heterostrophic protoconch with submerged nucleus and a weak columellar plica. ?Kleinacteon dubius differs from K. moodyi (Dickerson), type of Kleinacteon, in having a higher spire and angular periphery and much more minute dimensions.

The spiral costae are similar to those of Metacteon Thiele and Semiacteon Cossmann. In coiling it is close to Tornatellaea Conrad. ?K. dubius could represent a new genus or subgenus probably closer to Kleinacteon.

OTHER LOCALITIES. Adelaide Plains SubBasin, Bore CH3, (DDH), 20.1 m depth.

GENUS Kaurnacteon gen. nov.

DERIVATION OF THE NAME. Composition of the name of the Kaurna, the Aboriginal people of the Eastern St. Vincent Gulf, and of Acteon Montfort.

TYPE SPECIES. Kaurnacteon elevatus sp. nov.

STRATIGRAPHIC RANGE. Late Eocene

DIAGNOSIS. Shell minute, turriculate, high spired; whorl overlapping up to the middle-abapical connection. Peristome and body whorl lanceolate, but shorter and broader than in Acteon Montfort. Columellar lip with two plicae.

Protoconch. Large, heterostrophic and submerged like in Acteon.

OBSERVATIONS. The new genus Kaurnacteon is instituted for the Late Eocene K. elevatus sp. nov., which displays the above described characters referable to no supraspecific taxon known in Acteonidae.

Kaurnacteon elevatus sp. nov.

FIGS. 445-447, 452-454

DERIVATION OF THE NAME. From the Latin elevatus, high.

HOLOTYPE. SAM P21220, Fig. 452-454.

PARATYPES. SAM P 21218A-C, Figs. 445-447.

TYPE LOCALITY. Blanche Point at Aldinga Bay.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member)

STRATIGRAPHIC RANGE. Gull Rock-'Soft Marl' Members, Late Eocene (middle P16).

MATERIAL. 31 specimens generally well preserved.

DESCRIPTION. Shell minute, turriculate, rather high spired; whorl increasing more in height than in diameter; whorl overlapping up to the middle-abapical connection. Suture subimpressed. Abaxial margin regions: adapical and middle subconvex, subvertical; abapical convex. Region connections: middle-adapical imperceptible; middle-abapical angular. Last whorl: base broad, concave, with narrow umbilicus. Peristome holostomatous, lanceolate, rather wide. Lips: parietal thin, straight; columellar straight vertical, with two plicae; abapical concave; abaxial subvertical, subconcave. Lip connections: abapical-abaxial rounded; all the others angular. From the columellar lip a reflected and detached lobe partially covering the umbilicus.

Protoconch. 1 large, smooth, heterostrophic whorl with nucleus tilted and submerged.

Ornament. Prosocline growth lines; flat broad spiral costae, with very narrow punctate interspaces.

GENUS *Tornatellaea* Conrad, 1860

SUBGENUS *Tornatellaea* s. str.

Tornatellaea (Tornatellaea) minutissima sp. nov.

FIGS. 455-458

DERIVATION OF THE NAME. From the Latin *minutissimus*, very minute.

HOLOTYPE. GSSA M 3427, Figs. 457-458.

PARATYPE. GSSA M 3426, Figs. 455-456.

TYPE LOCALITY. Murray Basin, Waikerie Bore 2, Hd Waikerie, sect. 692, 223.10 m depth.

TYPE FORMATION. Beccleuch Beds (lower Buccleuch 'A' equivalent of Lindsay & Bonnett, 1973).

STRATIGRAPHIC RANGE. Late Eocene (P16/17-P17).

MATERIAL. 17 specimens, the major part of them damaged.

DESCRIPTION. Shell minute, globose, rather high spired; whorls increasing more in height than in diameter; whorl expansion rather slow; whorl translation rather high; whorl overlapping up to part of the adapical middle region. Suture subcanaliculate. Abaxial margin regions: adapical and middle subconvex; abapical narrow concave. Region connections: adapical-middle imperceptible; abapical-middle angular. Last whorl: peristome lanceolate; base convex. Lips: parietal very thin, convex, long; columellar shorter, straight with two protruding declivous plicae; abapical convex, narrow; abaxial subconvex. Lip connections: abaxial-parietal very angular; parietal-columellar, columellar-abapical, abapical-abaxial angular. Columella with a thin narrow callus. Abapical plica and narrow peristome shape the abapical margin in a marked sinus. Interior smooth.

Protoconch. heterostrophic, with submerged nucleus.

Ornament. Orthocline growth lines; spiral flat costae with narrow smooth interspaces.

OBSERVATIONS. This form is referred to *Tornatellaea* Conrad s. str. because of its peristome shape, two columellar plicae, and protoconch. Direct comparison with *T. simulata* (Solander) confirms that the two species belong to the same genus *T. minutissima* displays a marked abapical sinus similar to *Triploca* Tate. The sinus is broad and faint in *T. simulata* and *T. bella* Conrad.

DISTRIBUTION. The type locality, but at 228.02-226.38 m depth.

SUBGENUS Triploca Tate, 1893

Tornatellaea (Triploca) ligata Tate, 1893

FIGS. 459-461

1893 Triploca ligata Tate, p. 186, pl.11, fig. 7

1895 Tornatellaea (Triploca) ligata -Cossmann, p.50, pl.7, fig.19.

1897 Triploca ligata-Cossmann, p.6, pl.1, fig. 16-17.

1959 Tornatellaea (Triploca) ligata -Zilch, p.8, fig.11.

MATERIAL. Lectotype and paralectotype (SAM T 1758 A-B) the former very well preserved, the latter damaged.

DESCRIPTION. Shell very small, thick, fusiform, globose, high spired; whorls increasing more in height than in diameter; whorl expansion rather low; whorl translation rather high; whorl overlapping up to just above the middle-abapical connection. Suture subcanaliculate. Abaxial margin region: very narrow, flat, horizontal sutural shelf, middle and abapical subconvex, abapical very narrow and straight. Region connections: middle-adapical imperceptible: shelf-adapical sharply angular; abapical-middle broadly angular. Last whorl: base subconvex, with very narrow vertical pseudoumbilicus produced by the reflected columellar lip; peristome lanceolate rather wide. Lips: parietal very thin, convex, long; columellar straight with three thick protruding sub-declivous plicae; abapical straight very narrow; abaxial long, subconcave. Lip connections: parietal-abaxial narrowly angular producing an adapical gutter; parietal-columellar, columellar-abapical, abapical-abaxial broadly angular. The abaxial lip bears an inner aboral thickening. The abapical plica and the abaxial lip shape the abapical margin in a weak sinus.

Protoconch. 1 smooth heterostrophic whorl with submerged nucleus.

Ornament: growth lines orthocline; flat spiral costae with very narrow interspaces, the adsutural one very wide; a very fine stria in the middle of each spiral costa displayed on the last whorl of the oldest specimen (T 1758 A).

OBSERVATIONS. These two specimens were rediscovered in the Tate material still kept in the Department of Geology of the University of Adelaide.

As noted by Riedel (1948), the specimen T 1758 A corresponds exactly to Tate's original figure. Riedel (1948) quoted these two specimens as syntypes. There is no original designation of holotype by Tate, but Cossmann (1897) quoted a neotype from his Collection, presumably on the mistaken assumption that the types were lost. But, on the contrary, they are still in the Tate Collection. It is therefore deemed that Cossmann's institution of a neotype from topotypic material (Cossmann, 1897) is invalid (I.C.Z.N., Art. 75, 75b-c). The figured syntype SAM T 1758 A is here designated as Lectotype and the syntype SAM T 1758 B as paralectotype. of *Triploca ligata* Tate, 1893. *T. ligata* is the type and the oldest known species of *Triploca* Tate. Instituted as genus, *Triploca* was subsequently classified by Cossmann (1895) as subgenus of *Tornatellaea* Conrad, because of similar peristome outline. Zilch (1959) still follows Cossmann's classification.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Otway Basin: Brown's Creek (lower Brown's Creek Formation).

STRATIGRAPHIC RANGE. Late Eocene.

GENUS *Tenuiacteon* Aldrich, 1921

Tenuiacteon acicularis sp.nov.

FIGS. 462-464

DERIVATION OF THE NAME. From the Latin *acicularis*, needle-like because of its shape.

HOLOTYPE. SAM P 21221, Figs. 462-464.

TYPE LOCALITY. St. Vincent Basin, Willunga SubBasin, Blanche Point at Aldinga Bay.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene.

MATERIAL. 3 specimens, 1 adult with peristome damaged, and 2 juveniles.

DESCRIPTION. Shell very minute, turriculate, very high spired; whorl increasing rapidly in height than in diameter; whorl expansion very low; whorl translation very high; whorl overlapping up to the middle abapical connection. Suture impressed. Abaxial margin regions: adapical and middle subvertical, abapical subhorizontal. Region connections: middle-abapical subangular; middle-adapical imperceptible. Last whorl: base broad, subconvex; peristome lanceolate, holostomatous, rather wide. Lips: parietal convex; columellar subvertical straight with a plica; abaxial subvertical subconcave; abapical concave, subhorizontal. Lip connections: parietal-abaxial narrow and angular; parietal-columellar, abaxial-abapical, and columellar-abapical broadly angular.

Protoconch. Large, high spired, heterostrophic, paucispiral, with tilted nucleus.

Ornaments. Flat broad spiral costae with very narrow interspaces with very narrow punctate interspaces; growth lines prosocline.

OBSERVATIONS. This form is referred to Tenuiacteon Aldrich on the similarity of protoconch and peristome, and slender high spired shell.

DISTRIBUTION. Murray Basin: Waikerie Bore 2, 228.02-226.38 m depth.

Obrussena alveolata (Tate, 1889)

FIGS. 480-483

1889 Cancellaria alveolata Tate, p.154, pl.10, fig. 7a, b.

MATERIAL. The holotype SAM T 713, very well preserved.

DESCRIPTION. Shell minute, globose, rather high spired; whorls increasing more in height than in diameter; whorl overlapping covering the abapical half of the middle region. Suture subcanaliculate. Abaxial margin: all the regions subconvex. Region connections: all imperceptible. Last whorl: peristome holostomatous, lanceolate, wide and high, with wide adapical gutter; base broad, convex, with narrow deep umbilicus. Lips:

parietal long thin, adherent, convex; columellar concave with weak adapical plica; abapical subconvex, short; abaxial long, subconvex, sharp, bearing a marked aboral varix. Lip connections: parietal-abaxial, columellar-abapical very angular; columellar-parietal angular; abaxial-abapical imperceptible. The adapical gutter is represented by a long semilunate sinus gradually shallower to abapical.

Protoconch. Anastrophic, 1 whorl smooth, low spired, with submerged nucleus, distinct from the teleoconch.

Ornament. Prosocyrt growth lines and fine axial costellae; regular spiral riblets, out of which two on the inner margin of the umbilicus. Costella-riblet intersections producing an alveolate surface in the interspaces.

OBSERVATIONS. Initially this form was doubtfully referred by Tate to Cancellaria Lamarck. Darragh (1970, p.154) still considered it 'incertae sedis'. The comparison of the holotype of C. alveolata Tate with Obrussena bracteata (Iredale), type of Obrussena Iredale, revealed striking congeneric affinities. C. alveolata differs from O. bracteata in shallower adapical gutter and suture, smoother inner whorl surface, and presence of spiral costellae on the entire inner surface of the umbilicus.

Obrussena Iredale is placed oubtfully in the Acteonidae by both Iredale (1925) and Zilch (1959). Obrussena is nomen novum for Obrussa Iredale, 1925, a name preoccupied by Braun (1925) for a Microlepidopterous genus (Iredale, 1930, p.175).

O. bracteata was dredged at depth range of 119-156 m.

DISTRIBUTION. Otway Basin: Muddy Creek.

STRATIGRAPHIC RANGE. Tate's 'Lower Beds', Muddy Creek Marls, Balcombian or Bairnsdalian (early Middle Miocene) (Ludbrook, 1973).

SUPERFAMILY PHILINACEA

FAMILY SCAPHANDRIDAE

GENUS *Acteocina* Gray, 1847

Acteocina scalarum sp. nov.

FIGS. 465-469

DERIVATION OF THE NAME. From the Latin, *scalae*, staircase, because of its step-like sutural shelf.

HOLOTYPE. SAM P 21222, Figs. 467-468.

PARATYPE. SAM P 21222 A, Figs. 465-466.

TYPE LOCALITY. Blanche Point at Aldinga Bay.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Gull Rock-'Soft Marl' Members. Late Eocene (middle P16).

MATERIAL. 5 specimens badly preserved.

DESCRIPTION. Shell minute, thin, cylindrical, low spired; whorls increasing in height than in diameter; whorl expansion very high, parallel to the axis, very little normal to the axis; whorl translation very low with increments ranging from negative to positive values; whorl overlapping up to the adapical middle region. Suture subcanaliculate. Abaxial margin regions: adapical very narrow subconcave subdeclivous to the axis; middle straight, vertical; abapical convex, narrow. Region connections: adapical-middle rectangular, producing a round carina; middle-abapical imperceptible. Last whorl: base narrow subconvex; peristome holostomatous, narrow, inverted-comma-like. Lips: parietal straight, vertical; columellar concave adherent and covering the umbillicus; abapical very concave, abaxial-abapical subconvex; abaxial-middle vertical straight. Lip connections: parietal-abaxial, adapical-/middle-abaxial angular; parietal-columellar broadly angular; rounded the others.

Protoconch. Protruding, papillate, heterostrophic, with nucleus coiled around a horizontal axis.

Ornament. Growth lines prosocyrt, producing fine opisthocline microrugae on the sutural shelf. Flat wide spiral costae with very narrow punctuate interspaces.

OBSERVATIONS. This form is referred to *Acteocina* Gray on the basis of the protruding, papillate and coiled on a horizontal axis nucleus of the protoconch, and of the adherent columellar lip, and of its coiling. *Acteocina scalarum* differs from the Eocene Claibornian *A. commita* (De Gregorio) (Palmer, 1937, p.490, pl.75, figs. 1-3) and *A. leai* (Aldrich) (*ibidem*, p.491, pl.75, fig.19) in having a much lower spire and a wider peristome and ornamented surface.

GENUS *Cylichna* Loven, 1846

SUBGENUS *Cylichna* s. str.

Cylichna (Cylichna) cf. *angustata* (Tate & Cossmann,1897)

FIGS. 473-474

1897 *Bullinella angustata* Tate & Cossmann, *in* Cossmann, p.11, pl.2, fig.1-2.

MATERIAL. 6 very badly preserved silicified specimens.

DESCRIPTION. Like *Cylichnania callosa* (Tate & Cossmann), differing mainly in narrower peristome, deep umbilicus, and more slender shell. Ornament not preserved.

OBSERVATIONS. It is possible to refer this form to *C. angustata* from the original illustrations and diagnosis. Unfortunately the 30 homeotypes quoted by Riedel in the Tate Collection are missing and so direct comparison is impossible. The state of preservation of the specimens is such that some uncertainty in determining them is still felt.

Following Darragh (1971), *Bullinella angustata* is referred to *Cylichna* Loven s. str.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays. Murray Basin: Waikerie Project Bore 2, Hd Waikerie, section 692, 228.02-226.38 m depth.

STRATIGRAPHIC RANGE. St. Vincent Basin, Blanche Point Formation. Murray Basin, Buccleuch Beds. Late Eocene (late P16-P17).

SUBGENUS Cylichnania Marwick, 1931

Cylichna (Cylichnania) callosa (Tate & Cossmann, in Cossmann, 1897)

FIGS. 470-472

1897 Cylichnella callosa Tate & Cossmann, in Cossmann, p.17, pl.2, fig.19-20.

MATERIAL. 13 specimens generally badly preserved (7 silicified).

DESCRIPTION. Shell minute, cylindrical, very involute; whorl height smaller than the height of the body whorl; whorl expansion very high parallel to the axis, very small normal to the axis; whorl translation very low; whorl overlapping total. Suture impressed. Abaxial margin regions: adapical narrow, convex, declivous to the axis; middle very wide, subvertical, subconvex; abapical very convex. Region connections: adapical-middle very angular; middle-abapical subangular. Last whorl: base narrow subconvex ; peristome very narrow holostomatous subrhomboidal. Lips: parietal imperceptible, very long, subconvex; columellar straight, thick; abaxial adapical very narrow, thick, subconcave; abaxial-middle thin, very long, subconcave; abapical narrow, very concave. Lip connections: parietal-abaxial and parietal columellar angular; abaxial adapical-middle very angular producing a narrow deep gutter; abapical columellar and abapical-abaxial imperceptible. Two columellar plicae and thick narrow detached columellar callus.

Protoconch. Totally submerged.

Ornament. Faint spiral striations more marked in juvenile stages.

OBSERVATIONS. The 50 paratypes recorded by Riedel are missing from the Tate Collection. Following Darragh (1970), this species is referred to Cylichnania Marwick.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Aldinga and Maslin Bays. Dennant & Kitson (1903) quoted it also in Ninety Mile Desert, here considered doubtful.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

FAMILY RETUSIDAE

GENUS *Retusa* T. Brown, 1827

SUBGENUS *Decorifer* Iredale, 1937

Retusa (Decorifer) crassa sp. nov.

FIGS. 475-477

DERIVATION OF THE NAME. From the Latin word *crassus*, stout.

HOLOTYPE. SAM P 21227, fig. 475.

PARATYPES. SAM P 21227A-B, Figs. 476-477.

TYPE LOCALITY. Willunga SubBasin, St. Vincent Basin, Blanche Point at Aldinga Bay.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. 80 specimens generally slightly squashed.

DESCRIPTION. Shell minute, thin, cylindrical, very low spired; whorl height smaller than peristome height; whorl expansion very high parallel to the axis, very low normal to it; whorl translation very low. Suture flush. Abaxial margin regions: adapical subconvex, narrow, producing a sutural shelf; middle very broad, vertical, subconvex, adapical convex. Region connections: adapical-middle sharply angular, bearing a thin sharp carina; middle-abapical imperceptible. Last whorl: base narrow concave with very shallow pseudo-umbilicus; peristome inverted-comma-shaped holostomatous, very narrow, and high. Lips: parietal subconvex, long; columellar concave, abapically detached; adapical abaxial subhorizontal; middle abaxial subconcave, subvertical; abapical very concave. Lip connections: parietal-abaxial, adapical-/ Middle abaxial very angular; abaxial-abapical imperceptible; rounded the others.

Protoconch. Partly submerged.

Ornament. Growth lines prosocyrt, with deep opistocyrt sinus on the sutural shelf, where they form marked costellae; faint spiral costellae on the adapical region.

OBSERVATIONS. This form is referred to *Decorifer* Iredale.
Its general features refer it to *Retusa* Brown, but the peristome shape and growth lines are typical of *Decorifer* Iredale. Beside its shorter and larger shell it differs from *D. elisa* Iredale, the type species, in the presence of a carina instead of a groove at the adapical-middle abaxial connection.
The stratigraphic range of *Decorifer* Iredale is therefore extended back from Holoce to Late Eocene.

Concerning *Retusa* T. Brown, 1827 a discrepancy exists between Cossmann (1895, p.821) and Zilch (1959, p.45). The former gave as type species the living *Retusa truncatula* (Bruguière), the latter the living *Retusa obtusa* (Montagu). The protoconch of *Retusa (Decorifer) crassa* is similar to the one of *Retusa truncatula* (Bruguière) (Rodriguez Babio & Thiriot-Quiévereux, 1975, p.91, pl.4, figs. D-F) although the latter is more submerged, and that of *Retusa mamillata* (Philippi) (p. 90, pl.4, figs. A-C) which is much more protruding.

Retusa (Decorifer) gracilis sp. nov.

FIGS. 478-479

DERIVATION OF THE NAME. From the Latin *gracilis*, slender because of its shell shape.

HOLOTYPE. SAM P 21228, figs. 478-479.

TYPE LOCALITY. Blanche Point at Aldinga Bay, Willunga SubBasin, St.

Vincent Basin.

TYPE FORMATION. Blanche Point Formation (Gull Rock Member).

STRATIGRAPHIC RANGE. Late Eocene (middle P16).

MATERIAL. The holotype.

DESCRIPTION. Like *Decorifer crassa* but much higher and more slender. Protoconch more submerged. Deep semicircular adapical gutter.

Ornament. Only prosocyrt growth lines, developed into rugae on the sutural shelf.

ORDER PTEROPODA Cuvier, 1804
(*syn*: THECOSOMATA Blainville, 1824)

OBSERVATIONS ON THE CLASSIFICATION OF PTEROPODA

The morphology, the anatomy, the taxonomy and the geographical distribution of the living Pteropoda were thoroughly described by Van der Spoel (1967) . McGowan (1963),Herman (1971), Herman & Rosenberg (1969), Boltovskoy (1971), Chin Chen & Be (1964), Chin Chen (1966-71) and others studied their geographical and vertical distributions in the present oceans. In particular Herman and Chen investigated them as possible bathymetric and climatological indicators.

The fossil species and assemblages were systematically studied by Collins (1934) from the North American Tertiary and recently by Robba (1971, 1972) from the Chattian-Serravallian of the Liguria-Piedmont Basin and Curry (1965) from the Paleogene of Great Britain. Robba, in particular, gave a detailed picture of the stratigraphic distribution of their assemblages and demonstrated their utility as biostratigraphic tools.

The oldest name in literature for this order is the vernacular 'Pteropodes' Cuvier, 1804, later Latinized by Dumeril (1806) into Pteropoda (Cox *in*

Moore, 1960, p.1153). Both the names have priority over Thecosomata Blainville, 1824. Zilch (1959) and Van der Spoel (1967) adopted the name Thecostomata, but neither of them discusses or quotes Cuvier's or Dumeril's names. Therefore, for the time being the better known and older name Pteropoda Cuvier, after Cox (_in_ Moore, 1960) is preferred.

Van der Spoel recognizes in this order two suborders:

PSEUDOTHECOSTOMATA (= PERACLIDACEA of Wenz & Zilch, 1959):

> 'Wings fused to a swimming-plate, on which the mouth protrudes with proboscis in the frontal margin; shell either absent or represented by pseudoconch- of cartilagous-like material; when the shell is represented by a calcareous shell, a distinct rostrum and clear sculpture is present. ...'
>
> (Van der Spoel, p. 33)

EUTHECOSOMATA (= SPIRATELLACEA of Zilch, 1959):

as further defined.

Cox (_in_ Moore, 1960, p.1153) quotes Thecosomata Blainville as a suborder of Pteropoda.

Van der Spoel's classification is here followed and an attempt is made to extend it also to the fossil genera.

SUBORDER EUTHECOSOMATA Meisenheimer, 1905

Key diagnosis: shell calcareous, proboscis and distinct rostrum absent, mouth and wings at the same level (Van der Spoel, p.33).

In this Suborder Van der Spoel recognizes two families:

LIMACINIDAE GRAY, 1847 (syn.: SPIRATELLIDAE Dall, 1921): shell with pseudosinistral coiling (hyperstrophic dextral, p.10); with operculum; mantle cavity at the dorsal side (Van der Spoel, p.35).

In this family only three genera are generally recognized, _Limacina_ Bosc, with which is also synonymized _Thielea_ Strebel (= Thilea), the genus recognized in Zilch's classification and the recently instituted _Skapotion_ Curry, 1965 (Eocene).

CAVOLINIIDAE Gray, 1850; as below described.

FAMILY CAVOLINIIDAE Gray, 1850

Key diagnosis: shell uncoiled, straight, curved or twisted, mostly with differentiated ventral and dorsal sides, without operculum; mantle cavity and mantle gland at the ventral side; anus on the left; bilaterally symmetrical (Van der Spoel, p.35, 105); three ontogentic morpha defined as 'skinny', minute and aberrant (Van der Spoel, p.164). The common spelling and name CAVOLINIDAE d'Orbigny, 1842, was amended in CAVOLINIIDAE Gray, 1950, by the I.C.Z.N. (Op. 883, 1969), at Lemche's(1964)request. For details, the reader is referred to these papers. Van der Spoel recognizes in CAVOLINIIDAE three subfamilies:

CAVOLIINAE s. str.: shell flattened, neither conical nor cylindrical, with differentiated ventral and dorsal sides, well separated by dorsoventral compression, the dorsal sides more flattened; slit-like aperture; maximum diameter in the adapical (caudal) region: embryonic shell thrown off during life (p.53, 105).

Genera: *Diacria* Gray, 1847 (Miocene-Holocene); *Cavolinia* Abildgaard, 1791 with two subgenera, *Cavolinia* s. str. (Miocene-Holocene) and *Gamopleura* Bellardi 1872 (Miocene).

CUVIERININAE Van der Spoel, 1967: shell bottle-shaped or cylindrical, round aperture, maximum diameter at the aperture; embryonic shell thrown off during life.

To this subfamily Van der Spoel referred only *Cuvierina* Boas, 1886, with which he synonymized a *Vaginella* Hedley, 1917. But Hedley, in his 1917 checklist of New South Wales marine fauna referred only *Cuvieria urceolaris* Mörch 1850 (=*Cuvierina columnella* Brazier, 1892) to *Vaginella* Daudin, 1800.

CLIOINAE Van der Spoel, 1967: as follows:

SUBFAMILY CLIOINAE Van der Spoel, 1967

(*nom. correct.*, herein, *pro* Clionae Van der Spoel, 1967
nom. imperf.)

Key diagnosis: conical or subcylindrical shell; round, oval, or subtriangular cross section, with no or poor differentiation between dorsal and ventral sides; maximum diameter at the aperture; embryonic part always preserved except in *Hyalocylis* Fol.

Van der Spoel's original spelling of this subfamily is Clionae (*nomen imperfectum*) from the type genus *Clio* Linné, from the Latin form *Clio*. Consequently, the correct spelling is Clioinae (*nomen correctum*).

Genera: *Creseis* Rang (Eocene-Recent); *Styliola* Blainville (?Eocene, Miocene-Recent); *Hyalocylis* Fol (?Neogene-Recent), *Praehyalocylis* (Korobkov) Korobkov & Makarova (Late Eocene-Miocene); *Clio* Linnaeus (*Syn*: *Proclio* Hubendick) (?Paleocene-Holocene - see Avnimelech, 1945), *Euchilotheca* P. Fischer (Eocene), *Bovicornu* O. Meyer (Eocene), ?*Tibiella* O. Meyer (Eocene), *Vaginella* Daudin (Paleocene-Miocene, - see Avnimelech, 1945), *Bowdenatheca* Collins (Miocene).

Curry (1965) transferred *Thecopsella* Cossmann to Caecidae because its shell grows beyond the stage of the thickened lip, as in that Family. He also included *Camptoceratops* Wenz - type: *C. prisca* (Godwin-Austen), Early Eocene - previously and doubtfully referred to Planorbinae (Wenz & Zilch, 1959, p.108). Curry also considers *Bovicornu* O. Meyer and *Camptoceratops* Wenz as closely related, possibly synonyms. The features of *Bovicornu robbai* sp. nov. exclude the latter hypothesis. But it is quite possible that *Bovicornu* is a more evolute descendant of *Camptoceratops*.

When the stratigraphic ranges of the Cavoliniidae have been revised properly and when *Camptoceratops* has commonly been accepted as a pteropod, this genus, *Bovicornu*, and *Euchilotheca* Cossmann, the other allied genus, may turn out to be the probable keys to cavoliniid phylogeny. Van der Spoel's attempt to establish a pteropod phylogeny is unsatisfactory because no fossil record was taken into account.

NOTES ON PTEROPOD SHELL STRUCTURE

As late as the early 1960s Pteropoda were regarded by several authors as descendants of the Paleozoic Cricoconarida (=Tentaculitoidea), Hyolitha, and other cone-shaped forms because of their striking shell convergence (Lyashenkova, 1959; Korobkov & Makarova, 1962; D.W. Fisher, 1962, p. W99-101; Runnegar et al., 1975, p.188). But the studies by Fisher (ibidem) and Runnegar et al. (ibidem) exclude any relationship between these forms and Mollusca though Cricoconarida are still yet doubtfully considered an extinct class of Mollusca (Fisher, 1962, p. W101). Nevertheless, the comparison of the shell structures in Pteropoda (Figs. 57-60), Cricoconarida (Lyashenkova 1959, p. 56-72, textfigs. 1-11), and Hyolitha (Runnegar et al., 1975, p. 186-7, figs. 5-6) reveals clear-cut differences among them. As reported by Horowitz & Potter (1971, p.66-7), the pteropod shell structure is ill known: according to Bøggild (1930, p.319) the shell structure is aragonitic and has homogeneous microstructure. Earlier,Cayeux (1931, p. 489, pl. 54, fig. 2) observed a three layered shell in a Tertiary pteropod. S.E.M. photographs of a shell fragment of Praehyalocylis annulata (Tate) (Figs.) and of a broken edge of Bovicornu robbai sp. nov. (Fig.) showed a quite unusual structure, supporting Cayeux's observations. In shell fragments of P. annulata it would appear a two layered structure, though it is quite probable that the inner layer had been decorticated, remaining adherent to the matrix filling. B. robbai (Fig. 60) displays a three layered shell with the inner and outer layers very reduced (the poor quality of the photograph is caused by the high charging of the surrounding matrix, see Figs. 44, 51). The middle complex-crossed layer is very developed and it is composed of cone-in-cone lamellae (figs. 57, 60) with concavity to the growth direction. P. annulata (Tate) also displays in the middle layer transversal tubular cavities of irregular length and distribution (figs. 58-59). The diameter of these cavities is just smaller than the thickness of the middle layer. Again in the middle layer, several specimens referable to two nannofossil species were observed as inclusions.

of *Praehyalocylis* and *Bovicornu* The shell structure, shows some convergence with that of the serpulids , but the latter is two layered and has an outer cone-in-cone layer . with concavity facing to the growth direction (Horowitz & Potter, 1971, p.61, fig. 23).

GENUS *Praehyalocylis* (Korobkov) Korobkov & Makarova, 1962
(type species: *P. chivensis* Korobkov & Makarova, 1962)

DIAGNOSIS. Shell relatively small (length up to 23 mm), high conical, straight to slightly arched dorsally, without deviation of the apex; cross section round; neanic part of the shell very narrow, elongated, smooth or annulated; embryonic part papillate and separated from the teleoconch by a constriction; absence of septa both in the neanic and older parts of the teleoconch. Surface covered by ring-like costae, the number of which is variable within the same species. Shell wall very thin, homogeneous, with no channels (after Korobkov & Makarova).

STRATIGRAPHIC RANGE. Late Eocene (*P. chivensis*, *P. annulata* (Tate)); Middle Oligocene (*P. maxima* Ludwig); Miocene (*P. cretacea* Blanckenhorn), *P. euphratensis* (Avnimelech)). Blanckenhorn's Cretaceous species were shown to be of Miocene age by Avnimelech (1945, p.643-44). So the range of *Prehyalocylis* is to be restricted to Eocene-Miocene.

OBSERVATIONS. KOROBKOV (1962) specified for *Prehyalocylis* a straight shell cone. Observations on unsquashed specimens of *P. annulata* (Tate) showed a slight dorsal arching of the shell. There is a very close affinity of *P. chivensis* with *P. annulata* even in their variability of the number of costae. Their conspecificity is suspected but only a direct comparison would reveal their actual relationships (Korobkov & Makarova, 1962, pl.3, figs. 1-8; Tate, 1887, pl.20, fig.1, this study, figs 489-500). As a matter of fact, if the diffusion of Pteropoda in the Paleogene were similar to the one in the Holocene, then it should not be difficult to accept conspecific or infraspecific relationships between these species.

Hyalocylis Fol differs from *Praehyalocylis* in (Korobkov & Makarova, 1962) in the following respects: it has a more arched shell; smaller size (up to 8 mm); oval cross section, somewhat compressed on the dorsal side; embryonic nucleus drop-like separated from the teleoconch by a septum and not preserved throughout life.

Hyalocylis is a probable descendant of *Praehyalocylis*, as inferred by Korobkov & Makarova. Its stratigraphic range should be restricted to ?Neogene-Holocene.

The probable palaeo-environment of *Praehyalocylis* could be suggested only by *H. striata* Rang, the type and the only known species of *Hyalocylis*. *H. striata* is tropical-subtropical, world-wide spread, between North and South 40° parallels, but rare occurrences are known between 40° and 65° South parallels in connection with warm currents. Temperature range: 17.5-27.8°C. Salinity oscillating around an average of 36.2% (Van der Spoel, 1967; Robba, 1971; Herman, 1971).

Praehyalocylis annulata (Tate, 1887)

FIGS. 489-500

1887 *Styliola annulata* Tate, p. 195, pl.20, fig. 1.

1899 *Styliola annulata* -Tate, p.260.

MATERIAL. 23 specimens in various state of preservation, 4 of them silicified; only one perfectly preserved; 3 syntypes and 4 paratypes (SAM T 214).

DESCRIPTION. Shell thin, transparent, orthoconical, with apex slightly arched and pointed. Peristome and body whorl subcircular.

Ornament. Regular annular outer costae, corresponding to inner annular sulci. Frequency of costae variable individual by individual.

OBSERVATIONS. Conical shell, arched apex, and round cross-section place this form into Praehyalocylis. Tate initially referred this species to Styliola Lesuer, 1825 (non Blainville, 1927); Darragh (1970, p.154) referred it to Clio Linné. Robba (1973, correspondence), unaware of Korobkov & Makarova's paper, ascribes S. annulata to Hyalocylis.

In the original series it is not indicated what specimen is the holotype. The figured specimen is from Aldinga and is either a composition from the various specimens or is the larger of the two squashed syntypes, now damaged. The specimens from Adelaide (Kent Town) Bore, although with damaged shell, show a very good preservation of the shell. One of the silicified specimens is a perfect reproduction of the shell of this species.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Aldinga and Maslin Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation, Late Eocene (late P15-middle P16).

GENUS Bovicornu O. Meyer, 1886

Bovicornu robbai sp. nov.

FIGS. 484-487,501

DERIVATION OF THE NAME. From Dott. Elio Robba, Istituto di Paleontologia in Milano, Italia, for his studies on the fossil Pteropods from the Liguria-Piedmont Basin (ProtoAdriatic).

HOLOTYPE. SAM P 21229, Figs. 484-487, 501.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent

Town) Bore.

TYPE FORMATION. Blanche Point Formation.

STRATIGRAPHIC RANGE. Late Eocene (Late P15-middle P16)

MATERIAL. The holotype only, well preserved but with damaged adapical part and aperture.

DESCRIPTION. Shell minute, very thin, hyaline, suborthoconic slightly sinusoidal. Body whorl shape subcircular. Ogival nucleus, bearing an adapical short spine, separated from the teleoconch by a constriction.

Ornament. Smooth, with only very fine growth lines.

OBSERVATIONS. This undescribed form was found embedded in a sandy glauconitic matrix filling a specimen of *Sinum (Ectosinum)* sp. nov. from Adelaide (Kent Town) Bore and preserved in the Tate Museum, University of Adelaide. Nucleus, sinusoidal shell and body whorl shape place this form in *Bovicornu* O. Meyer. It differs from the Late Eocene *B. eocenense* O. Meyer (Collins, 1934, p. 212, pl.9, fig. 3; pl. 13, fig. 5) in its shorter, wider, and less sinusoidal shell, much larger protoconch and in its apical spine. *B. gracile* O. Meyer (*ibidem*, p. 213, pl.9, fig.8; pl.13, fig.4), the other known species, is geniculate and more slender, and its protoconch bears no apical spine. It should be noted that both the types of *B. eocenense* and of *B. gracile* might have broken apical spines as well as apertures. All the three species have similar constriction between protoconch and teleoconch. Collins (1934, p.166-7) suspected possible infrageneric relationships or synonymity between *Euchilotheca* Cossmann and *Bovicornu* Meyer because of their similar shape. The aperture of *B. robbai* is sharp and not reflected and rounded like that of *Euchilotheca*. Therefore, the two genera have to be kept distinct. *Euchilotheca* is *incertae sedis* placed by authors either in Pteropoda or in Caecidae, though Zilch (1959) keeps it in Pteropoda. *Bovicornu* Meyer has hitherto been recorded only in the North American Eocene Tethys.

CLASS	BIVALVIA (Buonanni) Linnaeus, 1758
SUBCLASS	PALEOTAXODONTA Korobkov, 1954
ORDER	NUCULOIDA Dall, 1899
SUPERFAMILY	NUCULACEA Gray, 1824
FAMILY	NUCULIDAE Gray, 1824
GENUS	*Pronucula* Hedley, 1902
SUBGENUS	*Pronucula* s. str.
	Pronucula (Pronucula) tatei (Finlay, 1924)

FIG. 502

1886 *Nucula semistriata* Tate, p.128, pl.4, fig.5a-b (*non* Wood, 1840)

1924c *Nucula tatei* Finlay, p.107 (nom. nov.).

1961 *Pronucula tatei* -Ludbrook, p.56, pl.1, fig.5-6.

MATERIAL. 38 specimens (13 LV, 13 RV, 7 BV, 5 vv) generally badly preserved, 9 silicified; the holotype and 9 non-numbered paratypes (SAM T 1045).

DESCRIPTION. Shell small, thick, subtrigonal, rather inflated, umbones with opisthogyrate beaks. Margins: posterodorsal very short, subelliptical; posterior short, subelliptical; antero dorsal and anterior undifferentiated; ventral elliptical. Margin connections: posterodorsal -posterior subangular; anterodorsal-anterior imperceptible; posterior-ventral angular;anterior-ventral rounded.

Shell longitudinal outline rather convex. Regions: anterior narrow subconvex; posterior narrower, flattened; dorsoventral broad subconvex. Region connections: faint anterior and posterior ridges. Maximum convexity at the anterior ridge. Cardinal area with very small, long and narrow resilifer, iso-orientated with the anterior ridge. Hinge with 11 anterior and 6 posterior straight teeth. Ovoidal adductor scars; smaller the anterior; both just below the hinge. Interior nacreous, faintly striated, commissure region crenulated.

Ornament. Regular concentric costae, more marked toward the commissure.

OBSERVATIONS. Following Ludbrook (1961) and Darragh (1970), this form is maintained in Pronucula Hedley s. str.. The original name of Nucula semistriata Tate was changed by Finlay (1924c) into Nucula tatei because it is preoccupied by N. semistriata Wood, 1840.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Aldinga and Maslin Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation, Late Eocene (late P15-middle P16).

SUPERFAMILY	NUCULANACEA H. Adams & A. Adams, 1958
FAMILY	NUCULANIDAE H. Adams & A. Admas, 1858
GENUS	Nuculana Link, 1807
SUBGENUS	Saccella Woodring, 1925

Nuculana (Saccella) chapmani Finlay, 1924

FIGS. 503-508

1886 Leda apiculata Tate, p.131, pl.9, figs.4a,b.

1924 Nuculana chapmani Finlay, p.107.

1927a Nuculana chapmani -Finlay, p.523.

1961 Nuculana (Saccella) chapmani -Ludbrook, p.57, pl.2, fig.1-2.

MATERIAL. 49 specimens (16 LV, 18 RV, 4 BV, 11 vv) generally badly preserved (2 silicified); holotype and 24 paratypes (SAM T 1036).

DESCRIPTION. Shell small, nuculaniform, inflated, equivalve, very inequilateral; umbos opisthogyrate with small acute beaks. Margins: anterodorsal short and subelliptical; posterodorsal very long straight, concave at the end; posterior, ventral and anterior very elliptical. Margin connections: anterior-anterodorsal round; posterior-posterodorsal very angular, producing a sharp long rostrum; anterior-ventral and posterior-ventral imperceptible.

Shell longitudinal outline very convex with maximum in the dorsal region. Regions: anterodorsal narrow and steep; posterodorsal very steep and narrow; anterior, posterior, ventral, and dorsal regularly convex. Taxondont hinge with 13 anterior and 13 posterior chevron shaped teeth; resilifer triangular and deep; Pallial line imperceptible; adductor scars imperceptible; commissure region smooth and narrow, broadened at the rostrum.

Ornament. Concentric costae with somewhat narrower interspaces, slightly fading on the antero- and posterodorsal regions.

OBSERVATIONS. Finlay (1924c, p.107) referred this species to *Nuculana* Link and instituted the new name '*chapmani*' for it because of the homonymy of Tate's name '*apiculata*' with the congeneric *Nucula apiculata* Sowerby, 1836. Later, following a discussion on a possible restoration of *N. apiculata* Sowerby to *Nucula* Lamarck, he (1927a, p.523) maintained his 1924 name as valid, because of the priority of *Nucula apiculata* Reuss, 1844, which is also referable to *Nuculana*.

The original series of this species is represented by specimens from different localities and ages: the Late Eocene Aldinga and Adelaide Bore; the Late Oligocene-Early Miocene 'Spring Creek'; the Early Miocene Table Cape and Gellibrand River; the Miocene 'Camperdown'. The holotype is of Late Eocene age and from the '*Turritella* Clays, Blanche Point, Aldinga', (see Finlay, 1927a) that is from the 'Soft Marl' Member, as indicated by its preservation.

No distinctive difference was found between the Late Eocene and the younger forms (see also Ludbrook, 1961). However, the material available is too scanty for any definitive conclusion. Therefore, the name '*N. chapmani* Finlay' is restricted to the Late Eocene form temporarily. *Nuculana (Saccella) chapmani* belongs to the West Tethyan *N. striata* group of Glibert & Van der Poel (1965).

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin and Aldinga Bays. The other localities mentioned by Kitson & Dennant (1903) and Ludbrook (1961) are purposefully omitted, pending a future revision of the species.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16). The actual stratigraphic range of the species has to be revised and depends upon the revision of the species.

SUBGENUS *Ledella* Verrill & Bush, 1897

Nuculana (Ledella) leptorhyncha (Tate, 1886)

FIGS. 509-513)

1886 *Leda leptorhyncha* Tate, p.131, pl.10, figs. 5a-b.

1961 *Ledella leptorhyncha* -Ludbrook, p. 61, pl.1, figs.3-4.

MATERIAL. 593 specimens (116 LV, 103 RV, 176 BV, 198 vv), 24 silicified specimens, differently preserved (13 LV, 5 RV, 6 BV); Lectotype and 11 paratypes (9 BV, 2 LV, 1 vv) (SAM T 1041 A-M, specimen K practically destroyed); 3 specimens (2 BV, 1 RV) from bore material.

DESCRIPTION. Shell small, rather thin, nuculaniform, rather inflated; umbones with small opisthogyrate beaks. Margins: anterodorsal and anterior subelliptical, undifferentiated; posterior and posterodorsal straight, undifferentiated; ventral very elliptical. Margin connections: anterior-ventral very angular; posterior-ventral very angular, rostrate. Shell longitudinal outline very convex. Regions: anterior and dorso-ventral convex; posterior concave; posterodorsal flat, steep; Region connections: posterior-dorsoventral and anterior dorsoventral imperceptible; posterior-posterodorsal angular, represented by a ridge. Resilifer deep, triangular. Hinge with chevron-shaped teeth, the number of which is directly related to the age. Pallial line and adductor scars nearly imperceptible.

Ornament. Strong concentric costae.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Adelaide Metropolitan Subway, Bore CH3, 20.1 m depth. Willunga SubBasin, Maslin and Aldinga Bays. Murray Basin, Waikerie Bore 2, Hd Waikerie, Sect.692, 228.02-226.38 m and 223.10 m depth.B.Q. Butler Bore 4, Hd Kirkpatrick, Sect. 8, 125-118.77 m depth.

STRATIGRAPHIC RANGE. St. Vincent Basin, Blanche Point Formation. Murray Basin, Buccleuch Beds. Late Eocene (late P15-P17).

SUBGENUS Poroleda Tate, 1893

Nuculana (Poroleda) sp. nov.

FIG. 514

1886 Poroleda huttoni -Tate, p.130, pl.6, fig.4 (pars).

1961 Poroleda huttoni -Ludbrook, p.63 (pars).

MATERIAL. 30 specimens (12 LV, 5 RV, 13 BV) generally badly preserved (1 silicified); 6 specimens from Tate Collection (SAM T 1037-1a; T 1037-2).

DESCRIPTION. Shell small, thin, nuculaniform, subinflated; umbones with very small opisthogyrate beaks. Margins: anterodorsal very short, subelliptical posterodorsal, very long, subelliptical, concave; posterior very short, straight; ventral very long, elliptical. Margin connections: anterior-anterodorsal and anterior-ventral subangular; posterior-posterodorsal and posterior-ventral sharply angular.

Shell longitudinal outline, weakly convex. Regions: anterior and dorsoventral regularly convex; posterior subconcave; posterodorsal flat, steep. Region connections: anterior-dorsoventral imperceptible; dorsoventral~~-~~/ and posteroventral-posterior angular, represented by ridges. Hinge; embricated chevron-shaped teeth, the posterior ones more elongated. Interior smooth; pallial line and scars subimperceptible; inner ridge corresponding to the outer dorsoventral-posterior one.

Ornament. Concentric costae and faint radial ornaments on the dorsoventral region.

OBSERVATIONS. This form was hitherto referred to Poroleda huttoni T. Woods, although Tate (1886) and Ludbrook (1961) already pointed out differences between the Late Eocene forms and the Neogene ones. Due to the scarcity of of material, the only possible difference between them appears to be the radial ornament in the Late Eocene form. Therefore, the latter is referred to *Poroleda* sp. nov., whereas the Neogene forms are temporarily still referred to *Poroleda huttoni* s.l. More and better material is needed: a) to define more precisely the Late Eocene form, b) to revise the Neogene forms of *P. huttoni* s.l. Unfortunately, Tate's only specimen from outcrop (T 1037 A-1) is damaged.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

SUBCLASS	PTERIOMORPHIA Beurlen, 1944
ORDER	ARCOIDA Stoliczka, 1871
SUPERFAMILY	ARCACEA Lamarck, 1807

Although the Late Eocene Arcacea of the St. Vincent Basin were recently described by Ludbrook (1965), the availability of new material which is stratigraphically well located and the re-examination of the types revealed a number of taxonomic problems at generic, subgeneric and specific level.

Notogrammatodon cainozoicus (Tate) was shown to include at least two species, one of which has been separated as (Late Eocene) *N. inexpectatus* Maxwell. The name *N. cainozoicus* has been restricted to the Neogene forms, *in sensu lato*. *N. inexpectatus* also represents one of the few known species in common with New Zealand. *Arca equidens* Tate, referred by Ludbrook to *Plagiarca* Conrad (Arcinae), is referred to a new genus *Allasinazella* gen. nov. (Striarcinae). The discussion of this new genus provoked a revision of the Striarcinae, and, in particular, the clarification of the relationships between *Striarca* Conrad and *Arcopsis* Koenen. Finally, a new subgenus of *Porterius* Clark, *Ludbrookella*, is here instituted for the Late Eocene L. spinosa sp. nov. and the Neogene Barbatia celleporacea Tate.

Newell's classification (in Moore, 1969) is basically followed here. The terminology is after Noda (1966).

FAMILY ARCIDAE Lamarck, 1809
SUBFAMILY ARCINAE Lamarck, 1809
GENUS Arca (Rumphius, 1711) Linné, 1758
SUBGENUS Arca s. str.

Arca (Arca) pseudonavicularis Tate, 1886

FIGS. 521-522

1886 Arca pseudonavicularis Tate, p.139, pl.11, fig.8.
1965 Arca pseudonavicularis -Ludbrook, p.94, pl.3, figs.30-31.

MATERIAL. Holotype and 2 paratypes (SAM T 1057A-C) (2 RV, 1 LV).

DESCRIPTION. Shell subtrapezoidal, inequilateral, very inflated. Umbones with very recurved acuminate orthogyrate beaks. Margins: anterodorsal short, subelliptical; posterodorsal long, subelliptical; anterior short, very elliptical; posterior short, straight; ventral very long subelliptical. Margin connections: all very angular, except the anterior-ventral rounded.

Longitudinal shell outline very convex, subtrapezoidal. Regions: anterior very narrow, declivous; posterior subconcave, broader, less declivous; dorsoventral very broad, subconvex, more and more declivous to the margin. Region connections: anterior-dorsoventral nearly imperceptible; posterior-dorsoventral represented by a sharp posterior ridge. Median sulcus wide and shallow. Hinge straight with numerous transverse teeth. Tooth surface with parallel striations. Cardinal area very broad, flat, with chevron-shaped grooves. Scars ovoidal, subtriangular, elongated, subdepressed, with no ridges. Interior finely striated. Pallial line perceptible. Commissure region smooth. Narrow byssal gape.

Ornament. Radial costae, frequently dichotomous in adult and senile stages. Radial interspaces slightly narrower. On the posterior region, less numerous costae and broader interspaces. Concentric ribs. Beaded costa-rib intersections.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

GENUS Barbatia Gray, 1842

SUBGENUS Barbatia s. str.

Barbatia (Barbatia) limatella Tate, 1886

FIGS. 523-527

1886 Barbatia limatella Tate, p.141, pl.10, fig.2.

1965 Barbatia (Barbatia) limatella -Ludbrook, p.97, pl.3, fig.21-23.

MATERIAL. Holotype and 10 paratypes (SAM T 1048 B,A, C-L ; 1 specimen from Bore Material; 31 specimens from outcrop (1 silicified); 22 LV, 21 RV).

DESCRIPTION. Shell thick, subtrapezoidal, inflated, strongly inequilateral, equivalve. Umbones with prosogyrate beaks. Margins: posterodorsal very long, subelliptical; anterodorsal short, straight; anterior short, very elliptical; posterior short elliptical; ventral very long, subelliptical with a broad faint middle concavity. Margin connections: anterior-anterodorsal and posterodorsal - posterior angular; round the others.

Shell longitudinal outline subtrapezoidal convex. Regions: anterior declivous, subconcave; dorsal and ventral flattened with a middle faint concavity; posterior broad, regularly declivous. Cardinal area very short and long, with marked chevron-shaped grooves. Hinge with taxodont teeth, small and vertical at the umbo, gradually longer and more oblique at the ends, with lateral fine striations in the adult stages. Interior rather smooth with faint radial striae, marked pallial line. Adductor scars: faint; just below the hinge; anterior elongate pyriform; posterior rhomboidal. Commissure region smooth, weakly crenulated at the margins.

Ornament. Regular concentric costellae and costae. Fine radial dichotomous riblets. Dichotomy more frequent in early adult stages. Imbricating long beads at costella-riblet intersection.

OBSERVATIONS. On the basis of its dimensions Ludbrook (1965) recognized the specimen T 1048-B as the holotype figured by Tate. The silicified juvenile is quite similar to the juvenile T 1048-H.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, North Adelaide, Hd. Yatala Town Acre 717, Bore 5, 22.31-21.98 m depth. Willunga Basin: Maslin Bay,'Uncle Tom's Cabin'and first gully southward of 'Uncle Tom's Cabin'; Aldinga Bay.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation. Late Eocene (P15-middle P16).

FAMILY	PARALLELODONTIDAE Dall, 1898
SUBFAMILY	GRAMMATODONTIDAE BRANSON, 1942
GROUP	CATELIA
GENUS	*Porterius* Clark, 1925
SUBGENUS	*Notogrammatodon* Maxwell, 1966

Porterius (Notogrammatodon) inexpectatus Maxwell, 1966.

FIGS. 528-535

1966 *Pseudogrammatodon (Notogrammatodon) inexpectatus* Maxwell, p.440, figs. 1,8.

MATERIAL. 4 specimens (SAM T 1056 R-U) (2 LV, 2 RV) very well preserved from Tate Collection. 20 specimens from outcrops (11 LV, 7 RV, 2 vv), 4 from bore material (2 LV, 2 RV).

DESCRIPTION. Shell rather small, thick, subtrapezoidal, inflated, very inequilateral, subinequivalve; umbones with prosogyrate prominent beaks. Margins: posterodorsal very long straight; antero dorsal very short, straight; anterior short elliptical to subelliptical; posterior short subelliptical; ventral very long subelliptical with a median concavity. Margin connections: posterior-posterodorsal and anterior-anterodorsal angular; anterior-ventral nearly imperceptible; posterior-ventral rounded.

Shell longitudinal section outline, very convex, subtrapezoidal. Regions: anterior narrow, convex, steep to subvertical at the margin; dorsoventral broad subconvex from declivous to subvertical with broad median sulcus; posterior broad concave from steep to gently declivous to the margin. Region connections: anterior-dorsoventral rounded; posterior-dorsoventral subangular with marked posterior ridge.

Cardinal area narrow, much longer than high, with straight longitudinal striations, slightly divergent to the anterior. Hinge taxodont: anterior teeth 4-5 high short prominent slightly arched, from subparallel to transverse the hinge line; posterior longer, ranging from 4 to 9, first and last reduced. The posterior teeth warrant detailed description.

Specimen R: Four long posteriors parallel to the hinge line: 1st thin, 2nd very long, arched in the middle; 3rd long, slightly sinusoidal, shorter than the 2nd; 4th shorter, straight; 5th, the shortest, straight.

Specimen S: Senile. 9 posteriors gently inclined to the hinge line: 1st, rather long from parallel to gently inclined; 2nd and 3rd, long, inclined; 4th-9th, prominent slightly arched, more and more inclined and short.

Specimen T: 5 posteriors similar to Specimen R, but slightly more inclined and the first 3 slightly arched.

Specimen U: 9 posteriors. 1st-3rd short; transverse, sigmoidal; 4th long sigmoidal; 5th-8th straight subparallel; 9th short bifid. Entire tooth surface irregularly striated.

Median hinge gap broad. Interior faintly striated. Adductor scars ovate triangular. Pallial line marked. Commissure region: RV smooth, connected with the interior by an angularity; LV smooth, with anteroventral socket, postero-ventral part faintly crenulated. The socket suggests a

LV slightly greater than RV.

Ornament. Marked, broad concentric costae. Radial ribs divided by the costae in series of embricated triangular riblets in some places dichotomous (λ-shaped); in the interspaces, frequent secondary riblets can develop into primary in older stages.

DIMENSIONS: (mm):

Spec.	Hmx	Lmx	La	Lp	Tmx	Wca	Waca	Wpca
T 1056-R	5.35	10.40	2.50	7.90	2.15	8.70	2.50	6.20
T 1056-S	9.65	16.45	3.45	7.00	4.10	12.65	3.35	9.30
T 1056-T	5.80	12.30	3.45	9.15	2.50	10.70	3.45	7.35
T 1056-U	5.80	10.35	2.90	7.45	2.15	9.35	2.90	6.40
NZGS9481	4.55	8.95	2.55	5.85	2.85	7.90	2.55	5.35

OBSERVATIONS. This form was initially mistaken by Tate for the Miocene Macrodon Cainozoicus Tate.

The hinge and other features place it in Notogrammatodon Maxwell. The specimens T & R display striking affinity with the coeval type specie N. inexpectatus Maxwell, 1966. Macrodon cainozoicus Tate appears to be the Miocene descendant of the above described form. It differs in rectangular longitudinal shape of the radial ribs, broader and less elevated concentric costae, broader costa interspaces and more marginal socket. The hinge of Macrodon cainozoicus is clearly descending from th hinges displayed by the specimens S and U. More probably, the further arching of the long teeth, already present in the Eocene form, produced a subsequent division of the teeth together with the obsolescence of the b connecting tract. Thus, the trend to shorter and more oblique teeth appears already stabilized in the Miocene form. Therefore, Macrodon cainozoicus Tate is also referred to Notogrammatodon.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide Childrens Hospital: Bore 5, 22.31-21.98 m, 20.67-20.34 m depths; Bore 1, 22.31-21.98 m depth. Adelaide (Kent Town) Bore. Willunga SubBasin: Blanche Point at Aldinga Bay. *Otway Basin*: Browns Creek. *New Zealand*: Lorne, North Otago.

STRATIGRAPHIC RANGE. *New Zealand.* Kaiatan, late Middle-early Late Eocene (P14-P15). *St. Vincent Basin.* Blanche Point Formation, Gull Rock - 'Soft Marl' Members, Late Eocene (middle P16). *Otway Basin.* Browns Creek Formation, Late Eocene.

SUBGENUS *Ludbrookella* subgen. nov.

DERIVATION OF THE NAME. After N.H. Ludbrook, for her contribution to Australian palaeontology.

TYPE SPECIES. *Porterius (Ludbrokella) spinosa* sp. nov.

STRATIGRAPHIC RANGE. Late Eocene-Miocene.

DIAGNOSIS. Shell thick, subtrapezoidal, shorter than *Notogrammatodon*, but more inflated. Cardinal area narrower and shorter, with straight striations, divergent to the anterior. Hinge like that of *Notogrammatodon* , convergent, straight, short teeth: anterior and proximal posterior transverse; distal posterior parallel to the hinge axis. Broad edentulous gap generally present, but absent in some specimens. Teeth granulations like those of *Notogrammatodon* . Adductor scars like those of *Notogrammatodon* but more marked and bound by sharp rims. Margin heavily crenulated.

Ornament. Prominent concentric costae and marked secondary concentric costellae. *RV.* Radial primary ribs, produced by a series of squat, heavy, triangular beads, developing into large spines on the posterior ridge. *LV.* secondary radial riblets between the above described primary.

OBSERVATIONS. Shell outline, hinge, tooth granulations, cardinal area, absence of byssal gap and adductor scar shape place this form near *Notogrammatodon* Maxwell. The erratic presence-absence of edentulous gap, the heavily crenulated margins, and the discrepant ornament separates *Ludbrookella* from *Notogrammatodon*.

The Miocene Barbatia celleporacea Tate (Ludbrook, 1965, p. 98, pl.5, figs. 10-14) is to be referred to Ludbrookella subgen. nov.

Porterius (Ludbrookella) spinosus sp. nov.

FIGS. 536-543

DERIVATION OF THE NAME. From the Latin spinosus, spiny, because of its ornament.

HOLOTYPE. GSSA M 2820-A, Fig. 537-538.

PARATYPES. GSSA M 2820-B, 3427A-B, 3427D, 3433, Figs. 536, 539-543.

TYPE LOCALITY. Murray Basin, B.Q. Butler Hd Kirkpatrick, Sect. 8, Bore 4, 110.34-116.13 m depth.

TYPE FORMATION. Buccleuch Beds (Ludbrook, 1969).

STRATIGRAPHIC RANGE. Late Eocene (P15-P16).

MATERIAL. 11 specimens (5 RV, 6 LV) generally well preserved, but a little worn.

DESCRIPTION. Shell thick, subtrapezoidal, longer than high, inflated, very inequilateral, equivalve; umbones with prominent prosogyrate beaks. Margins: posterodorsal very long, straight; anterodorsal shorter, straight; anterior very convex; posterior concave to convex; ventral very long, subconvex with marked broad median concavity. Margin connections: anterodorsal-anterior and posterodorsal-posterior very angular; posterior-ventral very angular, in some specimens producing a rostrum; anterior-ventral nearly imperceptible.

Longitudinal shell section subtrapezoidal. Regions: anterior declivous, concave; dorsoventral very declivous, anteriorly concave, posteriorly convex; posterior gently declivous, concave. Region connections: anterior-dorsoventral rounded; posterior-dorsoventral angular, producing a sharp posterior ridge. Cardinal area long and short, with straight striations, divergent to the anterior. Hinge convergent, like that of *Notogrammatodon* : anterior teeth thin, short, very transverse; posterior proximal short, transverse, distal very incline to subparallel. Tooth granulations like those of *Notogrammatodon*, covering the entire tooth surface, but more irregularly arranged. Edentulous gap present in the major part of the specimens, but absent in some others. Adductor scars: posterior long, ovate, triangular; anterior subcircular; both bound by a sharp rim. Pallial line marked, depressed. Interior with faint radial ribs. Commissure region heavily crenulated, less heavily at the median sulcus, as with the ventral interior part smooth in some specimens. Median sulcus broad, marked.

Ornament. See the subgeneric diagnosis.

OBSERVATIONS. This form appears to be ancestral to *Ludbrookella celleporacea* (Tate), differing only in bead-shape and more pronounced ornament discrepancy. The specimens of both the species show variable Ht/L ratios.

OTHER LOCALITIES. St. Vincent Basin. Adelaide Plains SubBasin, Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 20.12-20.42 m depth. Willunga SubBasin, Maslin Bay, 'Uncle Tom's Cabin'. (Tortachilla Limestone-Blanche Point Formation)

GENUS *Grammatodon* s.l.

Grammatodon s.l. *margaritatum* sp. nov.

FIGS. 544-550

DERIVATION OF THE NAME. From the Latin *margaritatus*, beaded, because of its ornament.

HOLOTYPE. GSSA M 3432-A, Fig. 544.

PARATYPES: GSSA M 3432-B, 3416-B,-D, Figs. 545-550.

TYPE LOCALITY. Murray Basin, Padthaway Ridge, Tintinara Area School Bore 12, Co Cardwell, hd Coombe, 80-78 m depth.

TYPE FORMATION. Buccleuch Beds (Buonaiuto, in prep.).

STRATIGRAPHIC RANGE. Late Eocene (P16/17-P17).

MATERIAL. 57 LV, 43 RV, 21 vv, mostly well preserved.

DESCRIPTION. Shell thick, subtrapezoidal, inflated, very inequilateral. Umbones with round protruding prosogyrate beaks. Margins: anterodorsal short, straight; posterodorsal long, straight; anterior short, convex; posterior short, subconvex; ventral long, subconvex. Margin connections: posterior-posterodorsal and anterior-anterodorsal angular; posterior ventral rounded; anterior-ventral imperceptible. Longitudinal shell outline subtrapezoidal, very convex. Regions: anterior narrow, declivous, concave; dorsoventral very broad, declivous, convex, markedly concave at the median sulcus; posterior subconcave, broad less declivous. Region connections: anterior-dorsoventral imperceptible; posterior-dorsoventral rounded.

Cardinal area: triangular, much longer than high, with straight striations divergent to the anterior. Hinge with short convergent transverse teeth, *Arcopsis*-like. Tooth striations parallel, on the flanks only. Edentulous gap present. Interior striated. Adductor scars marked, depressed, ovate-triangular. Pallial line imperceptible. Commissure region heavily crenulated, more weakly at the median sulcus.

Ornament. Discrepant. RV marked radial costae, iso-interspaced; fine concentric riblets. At costa-riblet intersections, round beads. LV as in RV, but with narrower interspaces. In senile stages, radial costae; RV dichotomous; LV, simple.

OBSERVATIONS. The striations of the cardinal area place this form in Grammatodontinae. Hinge, commissure, and ornament distinguish this form from the other genera of this subfamily. Due to the scarcity of material, it is here,at the present,referred to *Grammatodon* s.l. The Late Oligocene-Early Miocene *Anadara interclathrata* Ludbrook and the Middle Miocene *Barbatia simulans* Tate are congeneric with *Grammatodon* s.l.

margaritatum sp. nov.

OTHER LOCALITIES. Murray Basin. Waikerie Bore 2, Hd Waikerie, sect. 692, 228.02-226.38 m depth.

FAMILY CUCULLAEIDAE Stewart, 1930

GENUS *Cucullaea* Lamarck, 1801

SUBGENUS *Cucullaea* s. str.

Cucullaea (Cucullaea) adelaidensis Tate, 1886

FIGS. 551-554

1886 *Cucullaea adelaidensis* Tate, p.144, pl.11, fig.14.

1932 *Cucullaea adelaidensis* -Singleton, p.304, pl.26, fig.21-24.

1965 *Cucullaea adelaidensis* -Ludbrook, p.102, pl.4, fig. 11-15.

MATERIAL. Holotype and 8 paratypes (SAM T 1047-B, A,C-J); 2 juveniles from bore material (7 LV, 4 RV).

DESCRIPTION. Shell large, trapezoidal, very inflated, inequilateral, inequivalve (LV > RV). Umbones with smooth, curved, orthogyrate beaks. Margins: anterodorsal straight and short; posterodorsal elliptical, long; anterior short, very elliptical; posterior short, straight; ventral subelliptical, very long. Margin connections: anterior-anterodorsal and posterior-posterodorsal angular; posterior-ventral rounded; anterior-ventral imperceptible.

Longitudinal shell outline: very convex; subtrapezoidal. Regions: anterior narrow, concave, very declivous; dorsoventral, very broad, subconvex, more and more declivous to the margin; posterior subconcave, rather broad, very declivous. Region connections: anterior-dorsoventral nearly imperceptible; posterior-dorsoventral angular, represented by a wide, blunt ridge. Cardinal area high, triangular, with chevron-shaped grooves. Teeth arrangement: transverse the proximal, parallel the distal. Tooth surface with parallel grooves on the sides, covering the entire surface, but, in the extreme distal teeth, truncated by a sulcus on the tooth ridge. Inner faintly striated. Scars triangular, subovoidal, elongated: anterior depressed; posterior with a broad marked inner ridge. Pallial line perceptible. Commissure region: RV faintly crenulated; LV heavily crenulated and with inner socket. Median sulcus marked only in very early stages.

Ornament. Discrepant. LV. Fine radial costae with narrower interspaces; concentric ribs; beaded costa-rib intersections. RV. As in LV, but with dichotomous costae in adult stages and, again, in senile ones near the commissure; beads more prominent.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 21.95-21.64 and 19.20-18.90 m depths. Willunga SubBasin, Maslin Bay, 'Uncle Tom's Cabin'.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation. Late Eocene (P15-middle P16).

FAMILY NOETIDAE Stewart, 1930

SUBFAMILY STRIARCINAE McNeil, 1938

The availability of critical material in the S.A. Museum collections and in the Cossmann Collection, Department of Geology, University of Adelaide, allowed and promoted a further discussion on the classification of some of the genera attributed by Newell (1969) to Striarcinae.

The genera dealt with here are the following: *Arcopsis* Koenen, *Striarca* Conrad, *Scapularca* Cossmann, *Ovalarca* Woodring, and *Allasinazella* gen. nov. The discussion is summarized in the following tables.

Table X shows the historical synopsis of the classification of these genera, as from the major authors. Table XI lists the species examined directly and from the literature. Table XII shows the comparative synopsis of the morphological characteristics, considered diagnostic in the

TABLE X

HISTORICAL SYNOPSIS OF THE GENERA OF THE STRIARCINAE REVISED IN THIS STUDY

AUTHORS	FAMILY	SUBFAMILY	GENUS	SUBGENUS	OBSERVATIONS
Conrad, 1862	Arcidae	---	*Striarca* Conrad	---	
Koenen, 1885	Arcidae	---	*Arcopsis* Koenen	---	
Cossmann, 1887	Arcidae	---	*Arca*(Rumphius) Linné	*Fossularca* Cossmann	
Sacco, 1898	Arcidae	---	*Arca*	*Fossularca*	
Lamy, 1907	Arcidae	---	*Arca*	*Fossularca*	
Cossmann, 1913	Arcidae	---	*Fossularca*	*Fossularca*	
				Galactella Cossmann & Peyrot	
				Scapularca Cossmann & Peyrot	
Woodring, 1925	Arcidae	---	*Fossularca*	*Fossularca*	
				Ovalarca Woodring	
Vincent, 1930	Arcidae	---	*Arcopsis* (*syn. Fossularca)*	---	
Reinhart, 1935	Arcidae	Arcinae	*Arcopsis*	*Arcopsis*	
				Scapularca	
				?Ovalarca	Belonging to Limopsidae ?
			Striarca (*syn. Galactella)*	---	
MacNeil, 1938	Noetidae	Striarcinae	*Striarca*	---	
			Arcopsis		
		Noetinae	*Scapularca*	---	
Reinhart, 1943	Arcidae	Arcinae	*Arcopsis*	*Arcopsis*	
Iredale, 1939	Arcidae	---	*Gabinarca* Iredale		
			Spinearca Iredale		
			Mulinarca Iredale		
			Verilarca Iredale		
Glibert, 1965	Noetidae	Striarcinae	*Striarca*	*Arcopsis*	
				Galactella	
				Striarca	
		Noetinae	*Scapularca*	---	
Newell, 1969	Noetidae	Striarcinae	*Striarca* (*syn. Galactella)*	---	
			Arcopsis (*syn. Fossularca, Scapularca, Gabinarca, Spinearca, Mulinarca, Verilarca)*	*Arcopsis*	
				Ovalarca	
This study	Noetidae	Striarcinae	*Striarca* (*syn. Galactella, Gabinarca, Spinearca, Mulinarca, Verilarca)*	---	
			Arcopsis (*syn. Fossularca)*	---	
			Scapularca	---	
			Allasinazella Buonaiuto	---	
			?Ovalarca	---	Belong to Limopsidae? or Trinacriinae

Arcacea by the authors, in relation to the striarca genera.

ARCOPSIS Koenen. Type: Arca Limopsis Koenen.

Diagnostic characters. Grammatodon-like shell, markedly inequivalve; resilifer isosceles-triangular, higher than long, with apex at the beaks; few vertical resilifer striations. Tooth grooves: proximal, parallel, distal branching, covering the flanks only. Edentulous gap; LV margin crenulations, faint to absent; inner socket; faint to imperceptible median sulcus. (see Figs. 568-571, Arca quadrilatera Lamarck).
Stratigraphic Range. Danian-Holocene
Distribution. World-wide.
Habitat. The living species of Arcopsis are found in very shallow waters just below the low tide mark (Stanley, 1970, p.124).

STRIARCA Conrad. Type: Arca centenaria Say (Fig. 557)

Diagnostic characters: Grammatodon-like shell, subinequivalve; resilifer equilateral to subinequilateral triangular, longer than high, with apex at the beaks; resilifer striations numerous, vertical; tooth grooves parallel, covering the flanks only; marginal socket; absent edentulous gap.
Observations. Newell (in Moore, 1969) figured as Arca centenaria Say a Barbatia sp., erroneously referred by Glen (1904) to that species. Glen indeed quoted in synonymy Say (1824) and Conrad (1832), but Conrad's illustration (Fig. 556) is quite different from Glen's (this study, fig. 555). Reinhart's 1933 diagnosis well agrees with Conrad's illustration.
Stratigraphic Range. Cretaceous-Holocene.
Distribution. World-wide.
Habitat. S. lactea (Linné) and S. terebrica (Reeve) are found just below the low tide level (Stanley, 1970, p.124; Purchon, 1968, p.171;

TABLE XI

LIST OF THE SPECIES EXAMINED IN THE REVISION OF THE STRIARCINAE

Direct observations on actual specimens.

EOCENE	
Arca equidens Tate, St. Vincent Basin, South Australia	(SAM)
Barbatia dissimilis Tate, " "	(SAM)
Fossularca januaria Marwick, New Zealand, Lorne.	(NZGS)
Arca quadrilatera Lamarck, Paris Basin	(SAM)
Arca decipiens Deshayes, " "	(AUGD)
Arca dispar Deshayes " "	(AUGD)
Arca scapulina Lamarck, " "	(SAM)
Arca globulosa Lamarck, " "	(AUGD)
Trinacria crassa Deshayes, " "	(AUGD)
MIOCENE	
Arca nodosa Wood, Wien Basin	(AUGD)
Arca lactea Linné, Paris Basin	(AUGD)
PLIOCENE	
Arca lactea Linné, Pheziers, France	(SAM)
HOLOCENE	
Arca sculptilis Reeve, Philippines	(SAM)
Arca tetragona Poli, East Shetland Islands	(SAM)
Arca zebuensis Reeve, New Caledonia	(SAM)
Arca cuneimeris ? , Florida	(SAM)
Arca symmetrica Reeve, Japan	(SAM)
Arca lactea Linné, Guernsey Island	(SAM)
Gabinarca pellita Iredale, Capricorn Channel, Queensland; Shark Bay, Western Australia	(SAM)

Observations through illustrations and diagnosis.

CRETACEOUS

Arca saffordi Gabb (Wade, 1926, p.47, pl.10, fig.14; pl.11, fig.1-2)

PALEOCENE

Arcopsis quadrangula (Nyst & Lehon) (Vincent, 1930, p.71, pl.4, fig.1)

Fossularca koeneni Cossmann (Cossmann, 1908, p.64, pl.7, fig. 11-12)

EOCENE

Arcopsis sparsiincisa Eames (Eames, 1951, p.333,pl.9, fig.21a-b)

Fossularca africana Newton (Newton, 1922, p.68, pl.8, fig.14-17; Eames, 1957, p.54, pl.8, fig.4)

Arcopsis eba (Hanna) (Reinhart, 1943, p.37, pl.11, fig.15,16)

Fossularca besanconi Cossmann (Cossmann, 1887, p.143, pl.6, fig. 27-28)

Fossularca chevallieri Cossmann (Cossmann, 1887, p.145, pl.6, fig. 24-26)

Arca subglobulosa Wood (Wood, 1862, p.84, pl.15, fig. 9a,b).

MIOCENE

Fossularca papillifera (Hoernes) (Cossmann & Peyrot, 1912, p.313,pl.10, fig.19-22)

Fossularca peyrerensis Cossmann & Peyrot (Cossmann & Peyrot, 1912, p.314, pl.10, fig.45-47)

Fossularca (Galactella) miocaenica Cossmann & Peyrot (Cossmann & Peyrot, 1912, p.315, pl.10, fig. 37-40)

Striarca netsukiensis (Hatai & Nisiyama) (Noda, 1966, p.74, pl.4, fig.1-3; pl.11, fig.4)

Arca centenaria Say (Conrad, 1832, p.16, pl.1, fig.4; Tryon, 1884, pl.127, fig. 66-67; non Glenn, 1904, p.391, pl.106, fig.5-6.

PLIOCENE-HOLOCENE

Striarca interplicata (Graham & King) (Noda, 1966, p.72, pl.11, fig.16-18)

Striarca oyamai Habe (Noda, 1966, p.7, pl.4, fig.4-7)

Striarca terebrica (Reeve) (Noda, 1966, p.74, pl.4, fig.103; pl. 11, fig.4)

HOLOCENE

Arca wendti (Schmeltz) Lamy (Lamy, 1907, p.45, pl.1, fig.11-13)

Arca (Fossularca) nigra Lamy (Lamy, 1907, p.106, pl.1, fig.7-10)

Arca terebrica Reeve (Reeve, 1883, pl.16, fig.105)

Arca olivacea Reeve (Reeve, 1843, pl.16, fig.113)

Arca adamsi (Shuttleworth) Dall (Gardner, 1926, p.28, pl.5, fig.1-4).

Noda, 1966). *S. protrita* at 22-36 m depth (Smith, *in* Iredale, 1939, p.28). *S. adamsi* ((Shuttleworth) Dall) from just below the Low tide mark to 64 m depth (Stanley, 1970, p.124; Gardiner, 1947, p.28).

GALACTELLA Cossmann. Type: *A.lactea* Linné (Figs. 565-567)

Instituted by Cossmann as a section of *Fossularca* Cossmann, for forms with wider amphidetic ligament.

After direct comparison between *A. lactea* and *A. centenaria* Say, Reinhart (1935, p.33) synonymized *Galactella* with *Striarca* Conrad. Although Glibert (1965) restored *Galactella* as subgenus of *Striarca*, this present study did not reveal any particular difference between these two taxa, except a resilifer of variable width in *A. lactea*. Therefore, *Galactella* is at present maintained as junior synonym of *Striarca*, after Reinhart and Newell.

ALLASINAZELLA gen. nov. Type: *Arca equidens* Tate (Figs. 572-579)

Diagnostic characters. *Nemodon*-like shell, markedly inequivalve; flat cardinal area; resilifer scalene triangular, much higher than long, with apex posterior to the beaks; resilifer striations few, parallel to the posterior side; orthogyrate beaks; tooth grooves branching, covering the entire tooth surface; teeth rather long straight; very marked median sulcus.

Observations. For a more exhaustive diagnosis, see Table XII and relative systematic description.

Stratigraphic Range. Late Eocene.

Distribution. Southern Australia.

TABLE XII

COMPARATIVE SYNOPSIS OF THE GENERA OF THE STRIARCINAE HERE STUDIED
(terminology after Noda, 1966)

GENERA CHARACTERS		ARCOPSIS	SCAPULARCA	STRIARCA	ALLASINAZELLA	OVALARCA
CARDINAL AREA	inclination	*flat to U-shaped*	*U-shaped*	*flat to U-shaped*	*flat*	*highly inclined*
	profile	*asymmetrical triangular*	*id.*	*id.*	*id.*	*id.*
	resilifer	*isosceles triangular, apex at the beaks, higher than long*	*inequilateral triangular, apex at the beaks, longer than high*	*triangular, equilateral to subinequilateral, apex at the beaks, longer than high*	*scalene triangular, apex posterior to the beaks, much higher than long*	*isosceles triangular, apex at the beaks, longer than high*
	resilifer striations	*few, vertical*	*few to numerous, vertical*	*numerous, vertical*	*rather few, parallel to the posterior side*	*?*
	cardinal area striations	*very fine, horizontal*	*id.*	*id.*	*id.*	*id.*
	height	*high*	*id.*	*id.*	*id.*	*id.*
BEAKS		*slightly opisthogyrate*	*id.*	*id.*	*orthogyrate*	*prosogyrate*
HINGE	teeth arrangement	*convergent ventrally*	*id.*	*id.*	*subconvergent ventrally*	*nuculoid*
	hinge plate	*straight*	*id.*	*id.*	*id.*	*chevron-shaped*
	tooth grooves	*proximal parallel, distal branching, covering the flanks*	*parallel, covering one flank only*	*parallel, covering the flanks only*	*branching, covering all the tooth surface*	*?*
	Edentulous gap	*present*	*present*	*absent*	*present*	*present*
	tooth shape	*straight, short*	*id.*	*id.*	*straight, rather long*	*chevron-shaped biphid*
SHELL INEQUIVALVENESS: LV > RV		*marked*	*slight*	*slight*	*marked*	*absent*
ADDUCTORS	anterior	*ovate triangular*	*id.*	*id.*	*id.*	*orbicular (?)*
	posterior	*ovate triangular elongate*	*id.*	*id.*	*id.*	*ovate triangular (?)*
	ridges	*present*	*id.*	*id.*	*id.*	*absent*
COMMISSURE	byssal gape	*absent*	*id.*	*id.*	*id.*	*id.*
	crenulations	*only in LV, faint to absent*	*LV heavy; RV blunter, smoothed on the ventral part*	*absent*	*absent*	*absent*
	socket	*inner*	*absent*	*marginal*	*inner*	*absent*
ORNAMENT		*LV's discrepant to RV's*	*id.*	*id.*	*id.*	*LV's equal to RV's*
SHELL CONVERGENT TO:		*Grammatodon* Meek & Hayden	*Modiolus* Lamarck *Sheldonella* Maury	*Grammatodon*	*Nemodon* Conrad	*Limopsis* Sassi
MEDIAN SULCUS		*faint to imperceptible*	*rather marked*	*faint to imperceptible*	*very marked*	*absent*
PALLIAL LINE		*marked*	*id.*	*id.*	*id.*	*id.*

SCAPULARCA Cossmann. Type; *Arca scapulina* Lamarck. (Figs. 558-564)

Diagnostic characters. *Modiolus*- or *Sheldonella*-like shell; subinequivalve; U-shaped cardinal area; resilifer inequilateral triangular, longer than high, with apex at the beaks; resilifer striations few to numerous, vertical; tooth grooves, parallel, covering one flank only; present edentulous gap; margin crenulations, LV's heavy, RV's blunter and smoothed in the ventral part; absent socket; rather marked median sulcus.

Observations. Because of its shell shape, heavily crenulated margins, and ornament pattern, the taxonomic position of *Scapularca* has been an object of disagreement , particularly in regard to its relationships with *Arcopsis* (see Table X). The major disagreement is between McNeil (1938, p.5-8) and Reinhart (1943, p.76). The former places *Scapularca* in Noetidae and considers it an ancestral form of *Sheldonella* Maury and *Eontia* McNeil (McNeil, 1938, p.11). The latter author restores it in its usual location, the Arcinae. Recently, Newell (1969) transferred it into Striarcinae, but he synonymized it to *Arcopsis* Koenen. It is here considered that *Scapularca scapulina*, *S. globosa*, and *S. subglobosa* differ in very distinctive characters from *Arcopsis* and the other striarcid genera (Table XII). Therefore, *Scapularca* should be maintained as a distinct genus within the Striarcinae.

Distribution. Anglo-Paris Basin.

Stratigraphic Range. Eocene.

OVALARCA Woodring.   Type: ?Fossularca ovalina Dall

This genus shows characters quite distinctive from all the other genera and displays characters convergent to Striarcinae, Limopsidae, and Nuculidae, as shown below.

beaks	cardinal area	Hinge plate shape	tooth arrangement	shell shape
limopsid	*limopsid* *trigonodesmid*	*vetoarcid* *limopsid* *nuculid*	*limopsid* *nuculid* *trigonodesmid* *trinacriid*	*limopsid*

Newell (in Moore, 1969) places it in Striarcinae as a subgenus of Arcopsis (Table X).

From the above table, Ovalarca may be referable to either Limopsidae, with which it shows the closest affinities, or to Striarcinae. It is surely separated from Trinacriinae McNeil by the beaks. Therefore, pending on further clarification, it appears more appropriate to consider Ovalarca as 'incertae sedis' distinct from the other striacinid genera.

Distribution. Western Tethys (Jamaica)

Stratigraphic Range. Miocene.

GENUS *Arcopsis* Koenen, 1885

Arcopsis dissimilis (Tate, 1886)

FIGS. 580-582

1886 *Barbatia dissimilis* Tate, p.140, pl.11, fig.4-5.

1965 *Arcopsis dissimilis* -Ludbrook, p.95, pl.5, fig.26-30.

MATERIAL. 2 syntypes and 16 paratypes (SAM T 1059 - D - L; A-C,E-K,M-T); 9 silicified specimens (12 LV, 10 RV, 5 BV); 17 specimens from bore material (11 LV, 6 RV); 37 from outcrops (24 LV, 11 RV, 1 BV, 1 vv).

DESCRIPTION. Shell very small, subtrapezoidal, thick, inflated, very inequilateral; umbones with small prominent slightly prosogyrate beaks. Margins: posterodorsal very long, straight; anterodorsal very short, straight; posterior and anterior short, subelliptical; ventral long, subelliptical. Margin connections: anterodorsal and posterodorsal angular; anterior-ventral imperceptible; posterior-ventral subangular, rounded. Longitudinal shell outline subtrapezoidal, very convex. Regions: anterior flat, declivous; posterior flat, less declivous; dorsoventral flat, more and more declivous to the margin. Region connections: all subangular; posterior ridge marked. Cardinal area short and long, with fine longitudinal striae; triangular and shallow resilifer with two longitudinal weak furrows. Adductor scars faint, triangular-ovate, with interior faint ridge. Pallial line marked. Commissure region: smooth.

Ornament. Regular concentric costae. Radial ribs. At costa-rib intersections, triangular hyotid spines. In some places, secondary riblets in the narrow interspaces, subsequently developing into primary. LV: with broader ribs and narrower interspaces. RV: with finer ribs and wider interspaces.

OBSERVATIONS. In *A. dissimilis* Tate, the RV ornament is generally decorticated except in the anterodorsal and posterodorsal regions.

The coeval New Zealand *A. januaria* (Marwick) (Marwick, 1926, p.310, fig.1,5; Fleming, 1966, p.114, pl.8, figs. 95-96; this study, figs. 583-585) differs from *A. dissimilis* in greater size and ornament. Four topotypes from Lorne (2LV; 1 RV; 1 LV juv), directly examined (Figs. 583-585), display as LV ornament: broad primary radial ribs, alternated with finer secondary ribs, and narrower interspaces in juvenile stages; tertiary riblets in primary-secondary interspaces, in adult-senile stages. As RV ornament, they display: prominent concentric costae and weaker fine radial riblets; beaded costa-riblet intersections.

The topotypes show traces of corrosion and, therefore, they might not completely preserve the original ornament, particularly of the RV. However, the above described characters justify a distinction between *A. januaria* and *A. dissimilis*.

DISTRIBUTION. St. Vincent Basin. Willunga SubBasin: Maslin and Blanche Point at Aldinga Bay. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, Bore 5, 24.28-23.95 m, 23.62-23.29 m, 23.29-22.97 m, 22.64-22.31 m, 22.31-21.98 m, 21.98-21.65 m, 21.33-21.00 depths. Bore 1, 22.64-22.31 m depth.

STRATIGRAPHIC RANGE. Blanche Point Formation (late P15-middle P16).

GENUS *Allasinazella* gen. nov.

DERIVATION OF THE NAME. After A. Allasinaz, C.N.R. palaeontologist, Istituto di Paleontologia, Milano.

TYPE SPECIES. *Arca equidens* Tate, 1886.

DIAGNOSIS. Shell small, subtrapezoidal, like *Nemodon* Conrad, very inflated inequilateral, slightly inequivalve with LV > RV. Hinge taxodont, intermediate between *arcopsid* and *grammatodontid* types. Teeth: proximal, thinner, longer, and very inclined to the hinge line; distal more transverse, thicker, and more prominent. Tooth surface entirely covered by striations, dichotomous in the distal teeth. Teeth arrangement: subconvergent to the ventral.

Cardinal area broad, longer than higher, with straight striations parallel to the hinge line; resilifer broad, shallow, scalene triangular, elongate to the posterior, rather far from the beaks, with striations parallel to the posterior side. Adductor scars ovoidal-subtriangular, just below the hinge, bound by faint inner ridges. Pallial line marked. Commissure region: RV smooth; LV smooth broader, with an inner socket for RV margin; LV edge crenulated by outer ornament. Marked median sulcus.

Ornament. LV: weaker growth lamellae and prominent radial ribs. Hyote spines, at lamella-rib intersections. RV: cancellate pattern of fine prominent concentric costae and radial ribs, with short beads at costa-rib intersections.

OBSERVATIONS. The presence of a resilifer places this genus in Striarcinae McNeil, the only resilifer-bearer of the Arcacea. Broad and long cardinal area, hinge, radial striations of the resilifer, median sulcus, inequivalve and very inequilateral shell, shell shape convergent to *Nemodon* (Conrad) (Grammatodontinae), distinguish this from any of the striarcinid genera (see Table XII).

Allasinazella equidens (Tate, 1886)

FIGS. 572-579

1886 *Arca equidens* Tate, p.139, pl.11, fig.9.

1897 *Arca equidens* -Harris, p.331.

1965 *Barbatia (Cucullearca) equidens* -Ludbrook, p.100, figs.4-7.

MATERIAL. 5 specimens from GSSA Collections (4 LV, 1 RV); holotype and 17 paratypes from Tate Collection (SAM T 1058C, A-B, D-T) (9 LV, 9 RV);

4 silicified specimens (2 LV, 1 RV, 1 BV); 4 LV, 1 RV from outcrops.

DESCRIPTION. See generic diagnosis. Margins: posterodorsal long, straight, anterodorsal short, straight; anterior short, very elliptical; posterior short, subelliptical; ventral subelliptical, long, with median concavity. Margin connections: anterior-anterodorsal and posterior-posterodorsal sharply angular; anterior-ventral rounded almost imperceptible; posterior-ventral rounded subangular.

Longitudinal shell section very convex, subtrapezoidal. Regions: anterior narrow, subconcave, declivous; dorsoventral very broad and convex, from subhorizontal to subvertical at the margin, with very marked median broad sulcus; posterior region rather broad, convex, more gently declivous. Region connections: anterior-dorsoventral nearly imperceptible; posterior-dorsoventral subangular.

Ornament. See generic diagnosis.

OBSERVATIONS. *Arca equidens* Tate was referred to *Cucullearca* Conrad by Ludbrook (1965), although she correctly described the resilifer and its striations.

DISTRIBUTION. St. Vincent Basin, Adelaide Plains SubBasin: Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, 23.47-23.16 m, 22.86-22.55 m, 19.51-19.20 m, 19.20-18.90 m depths. Willunga SubBasin: Maslin Bay and Blanche Point at Aldinga Bay.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation (Late Eocene, P15-middle P16).

SUPERFAMILY LIMOPSACEA Dall, 1895

FAMILY LIMOPSIDAE Dall, 1895

GENUS *Limopsis* Sassi, 1827

HISTORICAL REVIEW OF THE GENUS

The past studies on *Limopsis* Sassi are scarce and desultory and commonly within broader researches on Mollusca. Mainly, the authors gave some brief and unsatisfactory hints about the distinctive intrageneric criteria based on shell morphology and often contradicting each other. They mostly dealt with the validity or non-validity of *Pectunculina* d'Orbigny as a subgenus distinct from *Limopsis* s. str. (Smith, 1885, p.257; Sacco, 1898, p.40; Dall, 1908, p.393; Lamy, 1912, p.108-113; Woodring, 1925, p.54; Prashad, 1932, p.57). Only Lamy (1912), of these conchologists, offered a more detailed discussion on the living species of *Limopsis* in the collection of the Museum d'Histoire Naturelle in Paris. The anatomy of the soft parts was briefly described by Fischer (1886, p.978-9) and in more detail by Pelseneer (1911, p.8-9) who considered their organization so close to the one of *Glycymeris* Da Costa (= *Pectunculus* Lamarck) that he included *Limopsis* in Glycymerididae (= Pectunculidae). Iredale (1929, 1931, 1939) dealt with living Limopsidae and instituted several genera synonymized to *Limopsis* s. str. and *Pectunculina* d'Orbigny by Newell (*in* Moore, 1969). Recently, Dell (1964, p.150-152) discussed the problem of the diagnostic specific features in *Limopsis*, giving evidence that the ornament and epidermal covering, previously considered as secondary, are, on the contrary, the only constant characters. Taylor, Kennedy & Hall (1969, p.78-9, fig.45) described the composition and the structure of the shell of *Limopsis*. Lastly, Cox (*in* Moore, 1969) gives further but again desultory information on the morphology and orientation of the shell and on the soft parts. Newell (*in* Moore, 1969) revises taxonomically the genus, confirming in it two subgenera *Limopsis* s. str. and *Pectunculina* d'Orbigny.

OBSERVATIONS ON *LIMOPSIS* SASSI s. str.

Hitherto the distinctive subgeneric and intrageneric characteristics of *Limopsis* Sassi were commonly emphasized on shell geometry, morphology of the cardinal area, resilifer, and hinge. Ornament was considered meaningless and too variable with age (Dall, 1908, p.393). Newell (*in* Moore, 1969, p.N265) defined the generic characteristics of *Limopsis* as 'orbicular, nearly inequilateral, commonly with slight forward obliquity', and the subgeneric ones of *Limopsis* s. str. as 'surface without radial ornamentation, inner margin not crenulated'. Both the definitions are partly inconsistent with the morphology and the ornament displayed by the type-species *L. aurita* (Brocchi).

The illustration and the diagnosis of the holotype by Rossi Ronchetti (1952-1955, pp. 25-6) and of another 10 specimens by Sacco (1898, pp. 39-40, pl.9, figs.23-32), and the direct observations on two Pliocene specimens of *L. aurita* show that at least these following characteristics are very variable: from orbicular to trigonal shape; from subinequilateral to very inequilateral valves; valve thickness; height/length ratio; heaviness of hinge; length/height ratio of cardinal area. All the dorsal regions display radial ornament . Rossi Ronchetti (*ibid*) describes:

> 'Primary ornament represented by concentric rugae irregularly developed both in size and in interspaces; these rugae are finely crenellated by the intersections with very fine and dense radial striae, more marked toward the valve margins. The umbonal region is worn and rugae and striae are rather faded.' (Translation from Italian by M.F. Buonaiuto)

From direct observation, the radial ornament is more complicated as it is further described and sketched (Fig. 23c) Moreover, Lamy (1912) listed eight varieties of *L. aurita* instituted by Locard (1896-1898 *non vidi*) which differ in shell geometry from the type figured by Brocchi and a ninth by Dall, which differs in size, number of teeth and fainter ornament (see systematic description).

In conclusion, the inadequacy of both the above definitions is revealed by the study of the species here examined, by Dell's observations on Antarctic and Subantarctic living species, consistent with each other, and by the occurrence of such strongly ribbed species as: the Eocene Tethyan

L. costulata Koenen (Goldfuss ?) and Australian L. multiradiata Tate, the Neogene Australian L. maccoyi Chapman and L. beamariensis Chapman, L. belcheri MacCoy, the Pliocene-Recent Australian L. eucosmus Verco and the Recent L. tennison Tennison Woods, L. forteradiata Cotton, L. tenuiradiata Cotton.

Furthermore, Dell (1964, pp. 150-142) after reviewing the very poor history of Limopsis Sassi, discusses it briefly and reveals that the morphological characteristics considered by the authors as distinctive at specific level are of doubtful meaning because of their great variability in continuous series among and within populations. These characteristics are the following:

a) The actual shell ornament and epidermal covering (when present) are constant. The observations on L. campa stock give further evidence on the stability of the ornament . The radial ornament is not constant throughout the growth and the shell but varies through gradual successive modifications.

b) Shell outline, produced by growth lines, varies with age and size and is characterized by a fairly regular tendency toward obliquity with increase in size and age. Some populations are characterized by a very pronounced obliquity regardless of the size.

c) The strength of the hinge plate is considerably variable. In thick shelled populations it may be enormously developed.

d) The relative size of the ligamentary fossette is variable. In thick shelled populations it may be enormously developed.

e) The development of a thickened ridge passing down the posterior part of the interior region varies amongst and within populations. This ridge is considered as a thickening passing through both posterior and anterior muscle scars, more developed through the posterior.

f) Shell thickness appears to be variable too, from Dell's discussion and from observations on the specimens here examined, and probably controlled by the depth at which a population lives.

Taylor, Kennedy & Hall (1969, pp. 78-9, fig.45) in their study of the shell structure and mineralogy of Bivalvia, give the following description of a limopsid shell:

> aragonitic composition; outer layer crossed lamellar; inner layer complex crossed lamellar; pallial myostracum prismatic; tubules occurring in both layers; thin prismatic pillars in the inner layer (based on the genotype *L. aurita* Brocchi).

HISTORICAL REVIEW OF THE AUSTRALASIAN SPECIES HERE DISCUSSED

This study deals with the problematic taxonomy of four main forms: the Neogene-Holocene Tethyan *L. aurita* (Brocchi), the ?Eocene-Oligocene Patagonian *L. insolita* (Sowerby), the New Zealand Late Eocene-Miocene *L. zitteli* Ihering, and the Late Eocene-Miocene *L. chapmani* Singleton. Because of the confusion existing in their literature, it is considered opportune to review it in detail. Zittel (1864) referred to *Limopsis insolita* a very oblique and high form from New Zealand. Hutton (1873) instituted *L. zealandica* for another more recent New Zealand form. McCoy (1875) referred Australian specimens to *L. aurita* (Brocchi), notwithstanding a direct comparison. Tate (1885, 1886), although he doubted the validity of McCoy's referring of the Australian forms to *L. aurita*, kept this name for the more recent ones and *L. insolita* for the older ones; he also synonymized *L. zealandica* Hutton with *L. aurita*. Hutton (1887, p.232) and Harris (1897 , p.346) followed Tate's revision. Ihering (1899, *fide* Ortmann, 1902, 1907), against Ortmann's opinion (1902) invalidated the use of *L. insolita* for the New Zealand form and after direct comparison on the basis of shell geometry, cardinal area and hinge he (1907, p.235) established *L. zitteli* 'nommee *insolita* par Hutton' for it. Pritchard (1901, p. 24) instituted *L. morningtonensis* for an Early-Middle

Miocene form included by McCoy in *L. aurita*. Chapman (1911, p.426 *et sequ.*), in his revision of Limopsidae, separated the Australian forms from *L. aurita* (Brocchi) and referred them to *L. insolita* (Sowerby). Suter (1914, p.37) considered still valid the use of *L. aurita* for the New Zealand Neogene forms but accepted Ihering's distinction of *L. zitteli* for the older ones. Only with Cossmann (in Marshall, 1917) and Marwick (1924, p.329) is the name *L. zealandica* Hutton eventually restored for the forms previously referred to *L. aurita*. Since then, several Paleogene-Neogene species had been instituted in both New Zealand and Australia, all of which are closely related to the *L. campa* stock. The Waiauan *L. producta* Finlay & McDowall, 1923, later considered by Finlay (1927, p.448) an anomalous morpha of *L. zealandica*; the Bortonian *L. campa* Allan, 1926; the Kaiatan-Runangan *L. wahiaoensis* Allan, 1926; the Duntroonian *L. parma* Marwick, 1929; the Aldingan-Janjukian *L. chapmani* Singleton, 1929; the Janjukian-Longfordian *L. chapmani valida* Singleton, 1932; the Waiauan-Kapitean *L. lawsi* King, 1933.

Ludbrook (1965) redescribed the Australian representatives of *L. campa* stock within the revision of Tate's Molluscan types. Lastly, Ludbrook (1973) quotes a *Limopsis* sp. nov. from the Palaeocene Pebble Point Formation. This form hitherto represents the oldest record of the subgenus in Australasia. The only known specimens, collected by N.H. Ludbrook, Adelaide, and by T.A. Darragh, National Museum of Victoria, are all juveniles and all of them unfortunately display their ornament completely obliterated by abrasion. Hence, no taxonomic conclusion or comparison with the other species can be carried out. Therefore, pending possible discovery of better material, this form is excluded from the present discussion.

OBSERVATIONS ON EVOLUTIONARY TRENDS IN *L. CAMPA* STOCK.

Before beginning the present discussion, it is here opportune to point out some possible biases that may produce successive modifications and revisions.

The biasing factors are as follows:

a) General scarcity of information on genus *Limopsis* Sassi;

b) General scarcity of information on Molluscan fossil faunas, taxonomy and stratigraphy, mainly in Australia and South America;

c) The abrasion of the shell surface, due to in life movements, that can obscure entirely the radial ornaments mainly on the dorsal region, and bad preservation. Both factors have further reduced the number of the specimens suitable for investigation and caused difficulties in photography.

Nevertheless, it is considered as possible to attempt to reconstruct evolutionary trends and to overcome part of the taxonomic confusion existing in this stock.

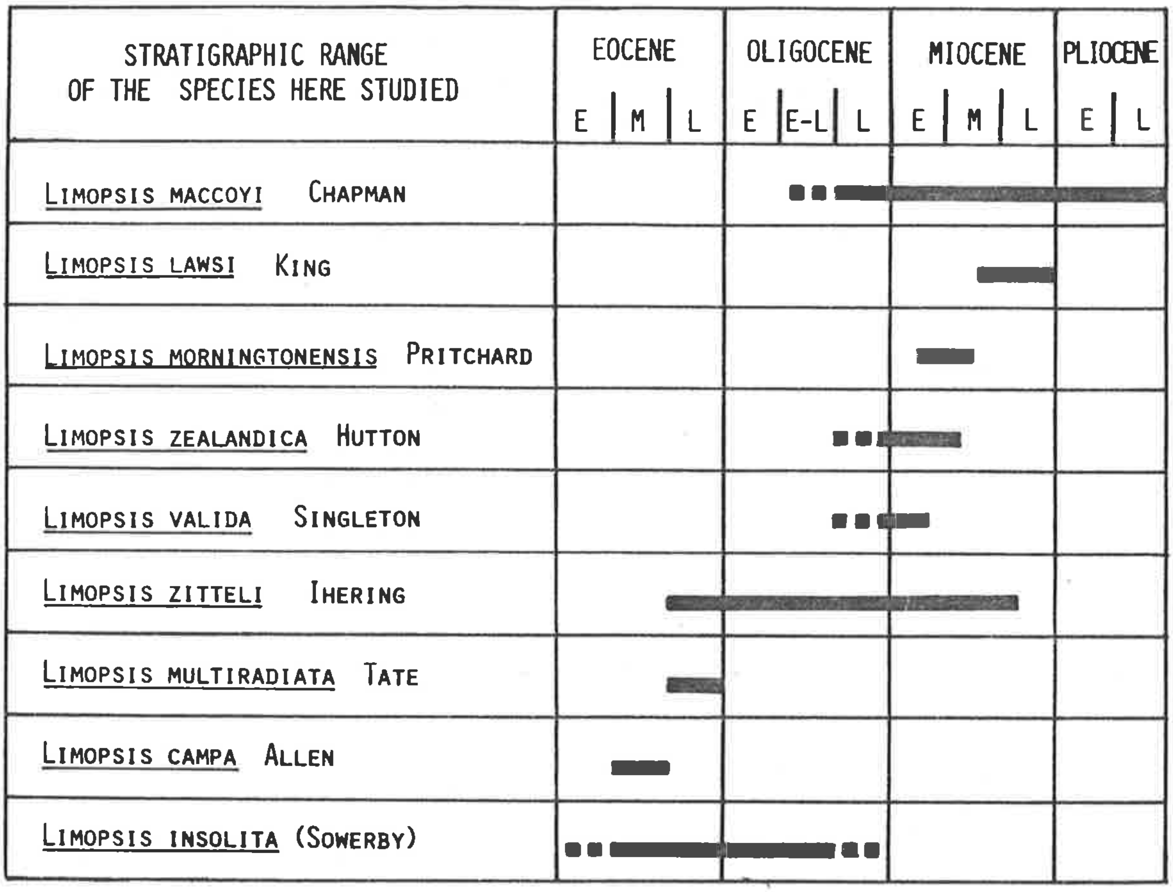
L. campa stock is represented in Australasia by a long succession of species, recorded from the Middle Eocene to the Pliocene. As Dell (*ibid.*) states, ornament and epidermal covering appear to be the only constant specific features in the living *Limopsis*. Consequently, in the fossil ones the only distinctive character available would be the ornament. In *Limopsis* the primary ornament is concentric costae and the secondary radial microcostellae limited to each concentric costa; but they are regularly aligned and simulate a radial costella. In some species these radial ornament can develop into primary ornament.

In disagreement with the past authors, this study revealed that these microcostellae vary ontogenetically not in random but in regular patterns. *L. campa* stock is characterized by a λ-shaped radial microcostella. This radial microcostella does not always fully occur.

FIG. 23 A) Stratigraphic range of the species of *Limopsis* Sassi, here revised.

B) Trends of the radial ornament of amphinotic species of *Limopsis* Sassi, in time and place.

C) Stylized illustration of the ontogenetic variation in radial ornament of the *Limopsis campa* Allan stock, in time and place.


STRATIGRAPHIC RANGE OF THE SPECIES HERE STUDIED
EOCENE
OLIGOCENE
MIOCENE
PLIOCENE
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M
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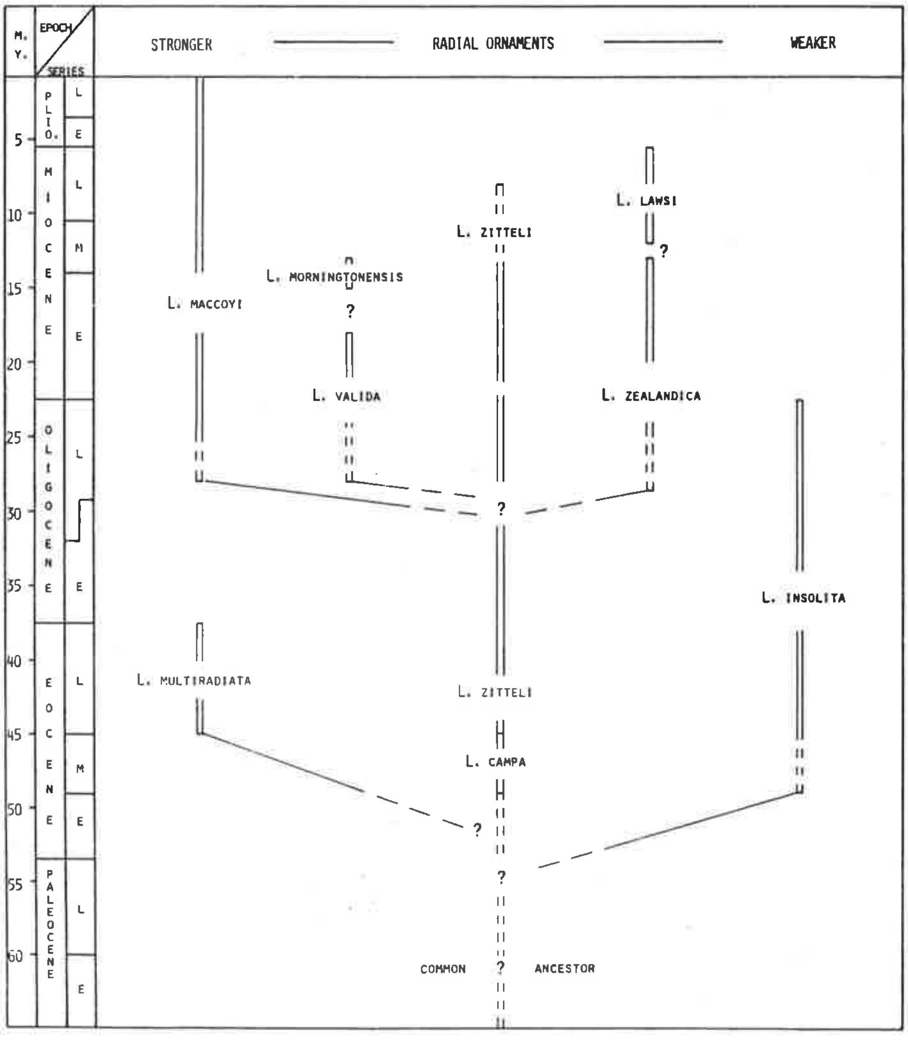
E
E-L
L
E
M
L
E
L
LIMOPSIS MACCOYI CHAPMAN
LIMOPSIS LAWSI KING
LIMOPSIS MORNINGTONENSIS PRITCHARD
LIMOPSIS ZEALANDICA HUTTON
LIMOPSIS VALIDA SINGLETON
LIMOPSIS ZITTELI IHERING
LIMOPSIS MULTIRADIATA TATE
LIMOPSIS CAMPA ALLEN
LIMOPSIS INSOLITA (SOWERBY)

A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EPOCH
SERIES
STRONGER
RADIAL ORNAMENTS
WEAKER
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10
15
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PLIO.
MIOCENE
OLIGOCENE
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L. MACCOYI
L. MORNINGTONENSIS
L. VALIDA
L. ZITTELI
L. LAWSI
L. ZEALANDICA
L. INSOLITA
L. MULTIRADIATA
L. ZITTELI
L. CAMPA
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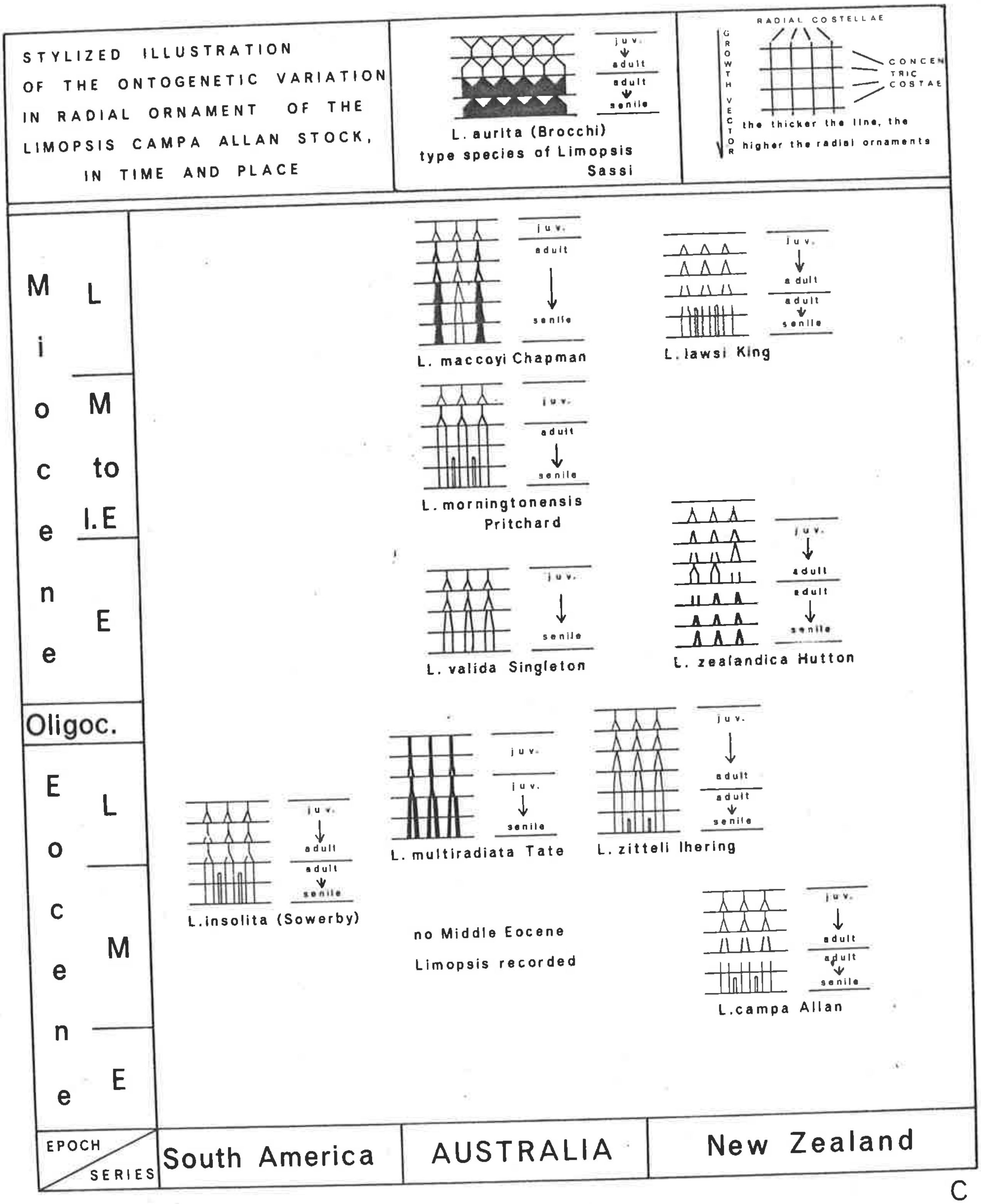

STYLIZED ILLUSTRATION OF THE ONTOGENETIC VARIATION IN RADIAL ORNAMENT OF THE LIMOPSIS CAMPA ALLAN STOCK, IN TIME AND PLACE

C

It varies from individual to individual during the ontogenesis yet always through gradual transition. This was revealed by observations on juveniles of L. zitteli from Adelaide Plains SubBasin. In these specimens the upper branch can be gradually obscured further to the diverging point and the length of the dichotomous diverging branches increases the nearer the diverging point is to the preceding concentric costa. In some juveniles only the two diverging branches may be present. In L. multiradiata and L. maccoyi the dichotomous branches can be found obsolete and the diverging point is still present.

The other distinctive characteristic of the species in this stock with weak radials is the dichotomy occurring in the radial interspaces between microcostellae on the dorsoventral region. Apparently, in adult and senile stages, when the interspaces become too wide, a radial middle groove develops dichotomizing the interspace. This dichotomy may occur again in older stages. In L. multiradiata the dichotomy occurs only in the radial riblets that are the primary ornament in this species. In L. maccoyi, where again the radials are primary, in broader interspaces a secondary microriblet develops into either a secondary radial costella or into a primary one.

The third characteristic is that in the Australian forms the general trend is toward stronger radials and a relatively less inflated and thick shell, meanwhile in the New Zealand forms it is more conservative toward weaker radials and a stronger concentric costa and thicker and more inflated shells. In order to simplify and make easier the further discussion the reader is referred to FIGS. 23b,c, where the development and the ontogenetic variation of the radial ornament in time and place are synoptically illustrated for each species.

L. campa, L. zitteli, L. isolita display a pattern of ornament very close to each other. The precise relationships of the first two with the third are not clear because of the still uncertain age of Vera Cruz

Formation. The relationships between *L. campa* and *L. zitteli* are so close that the only distinction could be found in the ontogenetic sequence of the radials which are more specialized in *L. zitteli*. The ontogenetic sequence of ornament in *L. campa* and *L. insolita* indicates clearly that these two species have a common ancestor that could be *L. campa* itself or more probably another form older than Middle Eocene, possibly the Palaeocene *Limopsis* sp. nov. of Ludbrook (1973).

During the Late Eocene there is the appearance (short ?) of the very strongly ribbed *L. multiradiata.* The juvenile T 1031-R display a heavier but clearly λ-shaped ribbing already dichotomous in juvenile stages with gradual but quick reduction of the diverging branches. A few paratypes (T 1031 -A,C,D,J,K) display in the adult stages, on the part of the ribs bound by the concentric costae, features recalling the upper branch and the diverging point.

From the Late Eocene and throughout the Early and Middle Oligocene the stock is represented by *L. zitteli*, called *L. chapmani* in Australia. In the early part of its stratigraphic range the Australian and New Zealand forms display a very close affinity in radial ornament weakness and sequence (Fig. 23c). During the Oligocene these forms seem to have diverged toward a relative lesser inflation and more marked radials in Australia. Meanwhile, the New Zealand forms remained more conservative with weaker radials. The increasing diversification probably reached its critical moment sometime during the Late Oligocene and produced several offspring: the very specialized and long lived *L. maccoyi*, whose strong, primary, secondary and tertiary riblets frequently bear on their top the usual λ-riblet, still recognizable; the short lived *L. valida*, in which the λ-riblets are prominent and present throughout the entire shell surface; the other short lived *L. morningtonensis*, successive to *L. valida,* in which only the subparallel dichotomous branches are displayed in adult and senile stages, whereas the full λ-riblets are present in juvenile stages only.

The position of L. morningtonensis in this evolutionary series has some problematic aspects. Among the forms here examined there is an Early Miocene New Zealand one that displays similar radial pattern, differing only in more shell inflation and thickness. This form can represent:

a) the direct ancestor of the Australian L. morningtonensis, and therefore, indicate a possible migration of this species to Australia during the early part of the Early Miocene;

b) a simple case of convergence.

In New Zealand, together with the above mentioned form, L. zealandica appears at the end of the Oligocene and is characterized by strong concentric costae and consequent fading of the upper branch of the λ-riblets and thickening and joining together of the diverging branches in the senile stages. The last New Zealand form is the Late Miocene L. lawsi with marked concentric costae but fainter radial riblets and with a reappearance of dichotomous interspaces on the dorsal region.

ENVIRONMENTAL OBSERVATIONS

According to the authors, the living species of Limopsis s. str. seem to prefer: low energy conditions (Sacco, 1898); fine grained sediments - a substratum such as mud, sands and glauconitic sands, green and foraminiferal oozes (Dall, 1908); water temperature at the bottom ranging between 2.1-8.9^{o}C; extremely variable depth between 82-4085 m (Dall, 1908; Smith, 1885; Prashad, 1932; Dell, 1964). From this scarce information by the authors it would appear that the habitat of Limopsis s.str. is controlled more by the water temperature than by other environmental factors. As a matter of fact, the depth of the colonies decreases remarkably toward the polar and subpolar regions and increases very sharply toward the intertropical belt. The Australian living species seem to have a rather wider habitat. Cotton & Godfrey (1938, p.51-56) give as habitat: warm seas at variable depth also abysmal. In detail the depth quoted for the Australian species are: L. penelevis Verco, 90-300 fms; L. tenisoni Tenison Woods, 10-130 fms; L. forteradiata Cotton, down to 35 fms; L. tenuiradiata Cotton, down to 81 fms; L. vixornata Verco, 45-110 fms; L. eucosmos Verco, 40-300 fms. An inverse relationship between radially ribbed forms and depth could exist for the Australian species.

SUBGENUS Limopsis s. str.

Limopsis (Limopsis) aurita (Brocchi, 1814)

FIGS. 586-587

1814 Arca aurita Brocchi, p.485, pl.11, fig.9 (non vidi)
1886 Limopsis aurita -Fischer, p.979, pl.17, fig.17.
1898 Limopsis aurita -Sacco, p.39, pl.9, fig. 23-28
1912 Limopsis aurita -Lamy, p.113.
1956 Limopsis aurita -Rossi Ronchetti, p.25, textfig. 7.

MATERIAL. 2 specimens (1 RV, 1 LV) very well preserved.

DESCRIPTION. Shell from ovoidal to trigonal, from rather to very inflated, from strongly to scarcely inequilateral; umbones with small acute, orthogyrate beaks. Margins: posterodorsal and anterodorsal subelliptical convex; anterior and ventral very elliptical; posterior from subelliptical to elliptical. Margin connections: anterior-anterodorsal from imperceptible to angular; anterior-ventral imperceptible; posterior-posteroventral from weakly to markedly angular; posterior-ventral from round to subangular.

Shell section outline longitudinal from convex to very convex. Regions: anterior and posterior subconvex from declivous to steep; dorsal and ventral convex. Cardinal area triangular, narrow, longer than higher; resilifer triangular deep; hinge with 7 anterior and 6 posterior straight to hooked teeth, the anteriors separated from the posteriors by a smooth broad to narrow interspace iso-orientated with the posterior ridge. Lateral tooth surface with parallel grooves. Interior from smooth to striated. Adductor scars ovoidal: the posterior, in the middle-marginal part, very large and shallow; the anterior, very high, below the hinge plate, very small and marked. Scar rims: very feeble the posterior; more marked the anterior. Pallial line from imperceptible to perceptible, marked by the truncation of the interior striae. Commissure region smooth.

Ornament. Fine growth lines, concentric broad triangular costae, with dorsal side very steep and ventral regularly declivous; the dorso-ventral connection, represented by a rim, is crenellated by secondary radial plications. These plications display a rather complicated pattern. From a point in a costa connecting rim, corresponding to a riblet in the preceding costa, two riblets diverge with broad angle, each of them flowing with a lateral one into each other and with a sharp angle the new riblet runs normal to the costa. In the older stages and ventrally these riblets develop into squat triangular to trapezoidal beads separated by triangular to subrectangular interspaces.

OBSERVATIONS. The radial micro-ornament pattern in *L. aurita* displays some superficial resemblance to the one in *L. campa* stock. The former can be stylized as Y-shaped; the latter as λ - or Λ-shaped.

The authors instituted or recognized the following fossil and living varieties within *Limopsis aurita* (Brocchi) (from Lamy, 1912, p.115; Sacco, 1898, p.40):

L. aurita aurita (Brocchi), the type figured by Brocchi.

L. aurita paucidentata Dall, 1886, with smaller and lesser teeth (4 + 4) and fainter ornaments.

L. aurita oceanica Locard, 1896, somewhat smaller than the type, but somewhat less convex.

L. aurita minor Locard, 1898, a half size smaller, same shape, but rather variable.

L. aurita obliqua Locard, 1898, more oblique than the type.

L. aurita acuta Locard, 1898, markedly oblique with a rostrum more or less sharp.

L. aurita curta Locard, 1898, shorter, weakly transverse.

L. aurita subrotunda Locard, 1898, shorter, rather oblique, nearly orbicular, with very faint rostrum.

L. aurita inflata Locard, 1898, more inflated.

L. aurita recta Locard, 1898, less oblique than the type.

L. aurita taurinensis Rovereto in Sacco, 1898, concentric costae less prominent, thinner shell. ('Helvetian' auct., Early Miocene)

L. aurita tauroblique Sacco, 1898, shell more or less smooth, more oblique. ('Helvetian' auct., Early Miocene).

For further information the reader is referred to Lamy (ibid.).

In the above original diagnosis, the major part of these varieties was based on the geometry of the shell, but none of them on radial ornament which, at that time, was considered completely of secondary value. Hence, in this study the above varieties are considered following Dell's standpoint, as possible topo- or chrono-morphae, but it is not excluded that they might represent higher taxa. Only further investigations can clarify this problem. Nevertheless, there is enough evidence that L. aurita displays the same variability in shell geometry and morphology as the L. campa Allan and L. marionensis Smith stocks.

DISTRIBUTION. Common in the Neogene Recent North Atlantic and Mediterranean regions.

STRATIGRAPHIC RANGE. Miocene-Holocene.

Limopsis insolita (Sowerby, 1848)

FIGS. 588, 591-598

1848 Trigonocelia insolita Sowerby, p.252, pl.2, fig. 20-21 (non vidi).

1876 Trigonocelia insolita -Sowerby, p.608, pl.2, fig. 20-21.

1902 Limopsis insolita -Ortmann, p.91, pl.25, fig. 6.

1907 Limopsis insolita -Ihering, p.235.

1932 Limopsis insolita -Singleton, p.298, pl.25, fig.18 a-c.

MATERIAL. 8 topotypes (2 LV, 2 RV, 4 BV) well preserved (BMNH 12530-1/8)

DESCRIPTION. Shell very thick, subtrigonal, inflated, very inequilateral; umbones with small orthogyrate beaks; height varies from the same as to more than the length. Margins: anterodorsal, posterodorsal and posterior straight; anterior from elliptical to very-elliptical; ventral from elliptical to subelliptical. Margin connections: anterior-anterodorsal and posterior-posterodorsal angular; ventral-posterior rounded; ventral-anterior from broadly rounded to imperceptible. Shell cross outline very convex. Regions: anterior very steep, rather narrow, subconvex, display a shallow radial concavity just above the connection with the ventral region; posterior flattened and steep; dorsoventral convex. Cardinal area rather narrow and high with resilifer very broad - in some specimens can include nearly all the cardinal area. Hinge very heavy with straight to hooked teeth: anterior 8-12; posterior 10-12; the anteriors are separated from the posteriors by a smooth gap, in some cases very narrow to nearly imperceptible, iso-orientated with the posterior ridge; lateral tooth surfaces with parallel grooves. Interior with striated but very irregular surface, the more irregular the surface the narrower the specimen; the irregular reliefs separated by intersecting furrows. Adductor deep subovoidal scars: posterior large just above the posterior-ventral connection; anterior very small just below the hinge plate. Scar ridges very developed. Pallial line well marked. Commissure region smooth.

Ornament. Growth lines and concentric costae. Flat radial ribs regularly bifurcating. In the anterior and posterior regions and in the neanic part of the dorsal region micro-riblets are observable diverging from the primary; these micro-riblets either fade within the costa or develop in a main bifurcating costa.

OBSERVATIONS. In the past, the true nature of the ornament has been subject of argument, because shell surface is generally abraded , mainly on the dorsoventral region whereas the anterior and the posterior are better preserved. Some well preserved specimens and anterior and posterior regions of others let the ornament pattern be reconstructed.

DISTRIBUTION. Patagonia, South America; Santa Cruz las Salinas, La Cueva, Yegua Quemada, Golfe de San Jorge, Punta Nava, Cabo tres Puntas, Punta Casamayor. Chile: Llanchaue.

Quoted Lithostratigraphic Locations: Vera Cruz Formation (type); Navidad Beds (Chile).

STRATIGRAPHIC RANGE. Lower Patagonian-Suprapatagonian (Eocene-Oligocene) C.P. Nuttall, British Museum (Natural History), (pers. comm., 1973) remarks that the correct age of Vera Cruz Formation is still doubtful.

Limopsis campa Allan, 1926

FIGS. 599-600

1926 *Limopsis campa* Allan, p.345, textfig.

1966 *Limopsis campa* -Fleming, pl.12, fig.129-134.

MATERIAL. 5 topotypes (3 LV, 2 RV) well preserved but with outer surface worn and teeth broken.

DESCRIPTION. Shell thick, trigonal, inflated, strongly inequilateral; umbones with small orthogyrate beaks; the shell height varies from greater to smaller than length. Margins: posterodorsal and anterodorsal subelliptical; anterior very elliptical; ventral elliptical; posterior straight. Margin connections: posterior-posterodorsal and anterior-anterodorsal angular; anterior-ventral imperceptible; posterior-ventral broadly angular.

Shell longitudinal outline very convex; Regions: anterior and posterior subconvex and steep; dorsal and ventral convex. Cardinal area narrower, longer than higher, but rather high; resilifer broad and deep with radial ondulation. Hinge very heavy with straight to hooked teeth: 7-10 anterior, 6-11 posterior; second posterior can occur bifurcated; 2 specimens display more anterior than posterior teeth, one just the contrary, the other two equal number; the anterior and the posterior teeth are separated by a broad to narrow interspace iso-orientated with the posterior ridge. The vertical sides of the teeth display transverse striae. Interior region with radial striae and plicae. Ovoidal adductor scars: posterior very large just above the posteroventral connection; anterior very small just below the hinge plate; anterior and posterior scar rims well marked, in some specimens the posterior is finer. Pallial line well marked by the truncation of the inner striae. Commissure region smooth.

Ornament. Growth lines and concentric costae. On the costae radial λ-shaped riblets, which can occur fully or only the bifurcated part developed. On the ventral region the above radial pattern can develop into main flat ribs. The specimen NZGS 11.148-A displays also on the dorsoventral region dichotomous ribbing.

OBSERVATIONS. L. campa displays already the radial pattern characteristic of its group. The flat main dorsoventral ribs and their dichotomizing suggest that L. campa could represent a geographical differentiation from L. insolita (Sowerby) stock, in which the diverging secondary microriblet became a stable primary radial ornament.
Being the oldest representative, L. campa gives the name to its stock.

DISTRIBUTION. New Zealand: Waihao Downs; South Canterbury.

STRATIGRAPHIC RANGE. Bortonian (Middle Eocene).

Limopsis zitteli Ihering, 1907

1864 *Limopsis insolita* -Zitteli, p.48, pl.13, fig. 1a,b.

1886 *Limopsis insolita* -Tate, p.134.

1897 *Limopsis insolita* -Harris, p.334.

1907 *Limopsis zitteli* Ihering, p.235.

1914 *Limopsis zitteli* -Suter, p.38, pl.4, fig.4.

1926 *Limopsis wahiaoensis* Allan, p.346, p.77, fig.8a,b.

1929 *Limopsis parma* Marwick, p.908, fig.14-15.

1932 *Limopsis chapmani* Singleton, p.296, pl.24, fig.12-14; pl.24, fig.16.

1965 *Limopsis chapmani* -Ludbrook, p.83, pl.1, fig.1-9.

FIGS. 601-604, 608-611, 615, 619,
629-635

MATERIAL. 177 specimens from Southern Australia from Tate collection (SAM) and GSSA collection. 52 from New Zealand from GSSA and NZGS Collections. Generally well preserved.

DESCRIPTION. Shell thick, from ovoidal to trigonal, inequilateral to very inequilateral, from slightly to very inflated; umbones with beaks from small orthogyrate beaks; shell height varies from about the same as to greater than the length. Margins: anterodorsal and posterodorsal subelliptical; posterior from straight to subelliptical; anterior from subelliptical to very elliptical; ventral from subelliptical to elliptical. Margin connections: anterodorsal-anterior and posterodorsal-posterior angular; posterior-ventral from rounded to subangular; anterior-ventral from angular to imperceptible.

Longitudinal shell section from convex to very convex. Regions: anterior subconvex to convex, from gently to very declivous, in which case a faint radial concavity can be present from the umbo to the anterior-ventral connection; posterior from flat to convex, from gently to very declivous but always less than in anterior region; dorsoventral from flat to convex, declivous; Region connections: posterior-dorsoventral represented by a faint to marked posterior ridge; anterior-dorsoventral from imperceptible to slightly marked. Cardinal area longer than higher; resilifer with extremely variable length (it can include 2/3 of the cardinal area). Hinge to light to very heavy, in which case it can be bound by a marked groove. Teeth from straight to hooked, including entirely or partially the hinge plate; the anteriors separated by the posteriors by a smooth gap, from broad to nearly imperceptible, and iso-orientated with the posterior ridge. The number of the posterior and anterior teeth generally increase with the age but in adult and senile stages it is variable independent of age: anteriors from 7 to 11; posteriors from 7 to 13; the anteriors can be less or more than or the same as the posteriors. In some specimens bifurcated or secondary embryonic or anomalous teeth can occur. Usually, the first and the last posterior and anterior are reduced, the middle ones are more developed. The tooth hookness is variable from absent to very marked. The lateral tooth sides in adult and senile stages display transverse parallel grooves. Interior: smooth in juveniles, striated in adults and seniles; seniles very convex, high and narrow, may display feeble irregularities similar to the ones in *L. insolita* (Sowerby). The adductor scars as in *L. campa* are with scar rims from feeble to very marked, but the anterior rim is more marked depending on the convexity. Pallial line: imperceptible in juveniles; marked by the truncation of the inner striae in adult and seniles. Commissure region: flat, smooth, broad, interiorly bound by an angularity and in some specimens also by a fine rim.

Ornament. Concentric costae more prominent in senile or very inflated specimens. Fine radial λ-shaped riblets, bound within each costa, with a deep furrow between the diverging branches, simulating a faint main ribbing. On the anterior and posterior regions and in neanic stages the λ-ribs are better preserved, but the pattern is not constant, both in specimens and throughout the ontogenesis, but varies regularly. In younger stages the λ-pattern is nearly always present and during the growth early or later is partially reduced to the diverging branches and the tracts of costa between two adjacent riblets simulate radial series of pseudo-embricated concave tiles. In a ventral direction these tracts can dichotomize.

OBSERVATIONS. The different samples of Southern Australian and New Zealand specimens were compared with each other and, afterwards, grouped as marker samples for comparison with each sample of the other Australian and New Zealand species recognized within the stock here studied. The general scarcity of available material against the great morphological variability displayed by this stock discouraged the statistical approach. However, qualitative and semiquantitative observations revealed enough evidence That among *L. chapmani* Singleton s. str., *L. zitteli* Ihering, *L. wahiaoensis* Allan and *L. parma* Marwick are conspecific. In particular, *L. wahiaoensis* is nothing else than a juvenile form of *L. zitteli*, quite similar to a great deal of juveniles from Adelaide Plains SubBasin. Specimens of New Zealand *L.zitteli* fall within the morphological variability displayed by the large sample of specimens of *L. chapmani* here examined. *L. parma* did not reveal any particular distinctive character against *L. zitteli*.

Throughout all the specimens, the only characers appearing to be stable in both Australian and New Zealand forms are the radial λ-shaped microriblets and their pattern. The only difference could be found in a greater inflation of the New Zealand specimens that, following Dell's discussion, could be due to environmental factors, or more simply, to a sampling which could represent only a few of the possible morphae. Apparently, *L. zitteli* seems to maintain more stability in New Zealand than in Australia, where it was characterized by a trend in a decrease of the shell thickness and inflation, and in prominence of radial ornament. This trend began some time toward the end of the Oligocene.

Maxwell (1973-75) correspondence) and Fleming (1973, correspondence) raised two points on this species: a) possible invalidity of the name; b) situation of the type locality.

a) *L. zitteli* Ihering might be a '*nomen dubium*'. The name was instituted by Ihering (1907) with a too brief note, although with a rather clear reference to Hutton. This name was subsequently accepted by Suter (1914, p.38). Since Suter's diagnosis and illustrations are according to ICZN rules, were *L. zitteli* Ihering to be invalidated, the name *L. zitteli* (Ihering) Suter, 1914,should be considered valid.

b) Maxwell (1973, correspondence) remarks 'Hutton (1973) cited three localities, but two of these (Waikerie and Kaniere) cannot be relocated precisely, although both are probably Upper Miocene or Early Pliocene. The other locality, The Cliffs, Nelson, would be a logical choice, as Zittel (1864) figures a specimen from here as *L.insolita*; unfortunately the preservation of material from this locality is so poor that it would be difficult, if not impossible to tell if the *Limopsis* specimens from other localities were conspecific. However, if The Cliffs is selected as the type locality of *L. zitteli* it seems likely that *L. parma* (Duntroonian) would prove to be a synonym.'

Suter (1914) unfortunately quotes the same three localities with no particular specification or observation. Hence at present the problem is still open. In the writer's opinion *L. parma* Marwick is a junior synonym of *L. zitteli* and the name *L. zitteli* should be maintained for the Paleogene forms, otherwise major nomenclatural problems might be created.

DISTRIBUTION. AUSTRALIA. *St. Vincent Basin* Adelaide Plains SubBasin. Adelaide Childrens Hospital: Bore 5, throughout from 26.25 to 20.34 m depths; Bore 1,24.93-24.60 m, 23.95-23.62 m, 22.64-22.31 m, 21.65-21.33 m 21.33-21.00 m depths. Adelaide (Kent Town) Bore; Adelaide Metropolitan Subway

Bore CH3 (DDH), 20.10 m depth. Willunga SubBasin. Maslin and Aldinga Bays.
Murray Basin Padthaway Ridge, B.Q. Butler Bore 4, Hd Kirkpatrick, Sect.8, 125-118.77 m depth.
Otway Basin Port Campbell Embayment, Browns Creek. Torquay Embayment, Bird Rock.
NEW ZEALAND. Waitiki River, Otago; Otiake, North Otago; Sutherland, South Canterbury; Shell Gully, Chatton; McCullough's Bridge, Waihao River; The Cliffs, Nelson; Waikeri and Kaniere (fide Zittel, 1864).
STRATIGRAPHIC RANGE. Australia, Late Eocene-Late Oligocene. New Zealand, Late Eocene-?Middle Miocene.

Limopsis multiradiata Tate, 1886

FIGS. 589-590

1886 *Limopsis multiradiata* Tate, p.135, pl.12, fig. 1a-b.
1897 *Limopsis multiradiata* -Harris, p.346.
1911 *Limopsis multiradiata* -Chapman, p.423, pl.84, fig.4; pl.85, fig.10.
1965 *Limopsis multiradiata* -Ludbrook, p.86, pl.1, fig.25-27

MATERIAL. Holotype and 14 paratypes (SAM T 1031 A-P, R) (6 LV, 8 RV 1 BV); 5 specimens from GSSA Collection (2 LV, 3 RV).

DESCRIPTION. As the *L. campa* stock. Differences: shell more orbicular less inflated, thinner, smaller.

Ornament. Concentric costae, secondary in adult and senile stages. Primary dichotomous ribs. Juvenile stages: very prominent microriblets generally in younger stages with λ-pattern, but in older stages the upper branch develops more and more and the lower dichotomous branches are more and more obscured up to their diverging point; the upper branch becomes more and more prominent. Adult-senile stages: the radial series of microriblets develop into prominent ribs. Of the λ-pattern only a triangular broadening of the microriblet remain at costa-rib intersections.
In older stages it is completely obsolete. The radial ribs may dichotomize

more times the older the stage. Prodissoconch with concentric costae.

OBSERVATIONS. The juveniles T 1031 R, M 2979, M 2981-2 give some evidence that L. multiradiata Tate is related to L. campa stock. This form therefore could be considered as a very specialized short-lived form diverged from the main L. campa lineage. The two specimens T1031 Q and S are to be referred to Limopsis (Pectunculina) cancellata sp.nov., a species frequent in the Blanche Point Formation in both Adelaide Plains and Willunga SubBasins. The juvenile from Adelaide Childrens Hospital, Bore 5, 22.64-22.31 m depth displays the ornament of the adult stage.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin. Adelaide (Kent Town) Bore; Adelaide Childrens Hospital, Bore 5, 26.25-25.83 m, 25.59-25.26 m, 24.28-23.95 m, 23.62-23.29 m, 22.64-22.31 m, 21.98-21.65 m depths.

STRATIGRAPHIC RANGE. Blanche Point Formation, Late Eocene (late P15-middle P16).

Limopsis valida Singleton, 1931

FIGS. 620-622

1931 Limopsis chapmani valida Singleton, p.229, pl.25, fig.17.

MATERIAL. Cast of the holotype and 3 specimens from NMV collection (NMV P 31297) (3 RV, 1 LV); 1 RV from Tate Collection (SAM T 1020 E).

DESCRIPTION. Similar to L. campa. Differences: shell ovate-subtrigonal, rather inflated, rather thick.

Ornament. Marked concentric costae. Prominent radial microriblets λ -shaped in juveniles. In adult and senile stages the upper branch is obsolete down to the diverging point. The lower dichotomous branches vary from diverging to parallel, generally in a ventral direction.

OBSERVATIONS. L. valida was initially considered as a subspecies of L. chapmani Singleton. Here, it is considered as a species directly descended from the Late Oligocene Australian forms of L. zitteli (syn. *L. chapmani*).

DISTRIBUTION. Otway Basin: Birregurra. Bass Basin: Table Cape.

STRATIGRAPHIC RANGE. Gellibrand Marls, Table Cape Group, Longfordian (Early Miocene).

Limopsis morningtonensis Pritchard 1901

FIG. 623

1875 *Limopsis aurita* -McCoy, p.23 (*non* Brocchi, 1814) (*pars*)

1886 *Limopsis aurita* -Tate, p.134 (*non* Brocchi, 1814) (*pars*)

1901 *Limopsis morningtonensis* Pritchard, p.24, pl.2, figs.6,6a.

1911 *Limopsis morningtonensis* -Chapman, p.420, pl.83, fig.1; pl.85, fig.7.

1965 *Limopsis morningtonensis* -Ludbrook, p.85, pl.1, figs.11-13.

MATERIAL. 13 specimens from Tate collection (SAM T 1020 A-D); T 1021 A-I (7 RV, 5 LV, 1 BV).

DESCRIPTION. As *L. campa*. Differences: shell suborbicular to trigonal, rather thin, little inflated.

Ornament. Rather prominent flat concentric costae. Radial microriblets with λ -pattern in juvenile stages. The upper branch is commonly obsolete in adult and senile ones and the dichotomous branches become parallel and fainter. The groove between them is very narrow and marked. The narrow tract of costa between two adjacent microriblets becomes somewhat more prominent. The marked diverging point produces a crown-like aspect.

OBSERVATIONS. This short lived form probably differentiated from *L. valida* through further specialization of the microriblets.

DISTRIBUTION. Otway Basin: Gellibrand River, Muddy Creek.

STRATIGRAPHIC RANGE. Gellibrand Marls-Muddy Creek Marls. Late Early-Middle Miocene.

Limopsis maccoyi Chapman, 1911

FIG. 636

1875 Limopsis belcheri -McCoy, p.25, pl.19, figs. 8-9 (pars)

1886 Limopsis belcheri -Tate, p.134 (pars)

1911 Limopsis maccoyi Chapman, p.421, pl.83, fig.2; pl.85, fig.8.

1955 Limopsis maccoyi -Ludbrook, p.24, pl.1, fig.10.

1965 Limopsis maccoyi -Ludbrook, p.84, pl.1, figs. 17-22.

MATERIAL. 2 specimens from GSSA collections (1 RV, 1 LV); 26 from Tate Collection (10 RV, 16 LV) (SAM T 1023 A-F, I-Z).

DESCRIPTION. As L. campa. Differences: shell suborbicular-subtrigonal, less inflated, rather thin.

Ornament. Faint concentric costae; prominent primary radial ribs. The radial ribs distinguish two main morphae.

MORPHA A. More marked concentric costae. Prominent radial ribs which each tract of them within a costa produced by a very thickened λ -microriblet. Adjacent microriblets become closer and closer and the groove between the dichotomous branches fainter and fainter, the older the stage. Primary rib slightly more marked; secondary intermediate ribs somewhat less marked; tertiary ribs increase in number with the age, from 2 to 6. In primary-secondary interspaces from a faint λ-microriblet a tertiary rib develops rapidly to the ventral.

MORPHA B. Concentric costae less prominent, lamellose. Primary radial ribs very developed, secondary fainter. Two tertiary represented in younger stages by λ-microriblets developing into tertiary only in older stages (T 1023 U).

OBSERVATIONS. L. maccoyi Chapman and L. multiradiata Tate are the two very strongly ribbed forms of L. campa stock, but with no direct relationships, the gap between them being nearly the Oligocene (Ludbrook, 1965). This form could represent an extreme differentiation from morphs characterized by a trend to prominence of the microriblets.

The specimens referable to Morpha A are: T1023 A, M, Q, R, Y, Z, 6a,b; GSSA 1: 3431A to Morpha B: GSSA 2: 3431B: T 1023 B, D, E. F. I-L, N-P, S-V, W, X. The specimens here examined are at the present separated as two probable morphae, because they both occur in the same locality and stratigraphic interval. Only the discovery of these two forms from the same bed or different beds could give a better indication of their actual relationships.

DISTRIBUTION. Otway Basin: Muddy Creek, Gellibrand River, Balcombe Bay, Fyansford, Spring Creek, Mornington.

STRATIGRAPHIC RANGE. ?Late Oligocene-Late Pliocene.

L. zealandica Hutton, 1873

FIGS. 612-614, 616-618

1873 Limopsis zealandica Hutton, p.28.

1914 Limopsis aurita -Suter, p.37, pl.4, figs. 3a,b.

1965 Limopsis zealandica -Boreham, p.16, pl.3, figs. 6-7.

1966 Limopsis (Limopsis) zealandica -Fleming, p.120, pl.122-124.

MATERIAL. 3 topotypes perfectly preserved.

DESCRIPTION. As L. campa and L. zitteli. The specimens observed differ from the above species in more inflation, longer and shorter shell, and margin constrictions at both hinge ends.

Ornament. Marked step-like concentric costae. Radial λ-microriblets observable still in juvenile stages but in adult-senile the upper branch is located on the steeper part of the concentric costa, meanwhile the dichotomous branches are displayed on the subhorizontal part of the costa. The λ-riblets are generally thicker, but show the same variation in the λ-pattern as in L. campa and L. zitteli; in the senile stages only the dichotomous branches can be displayed, generally merged into each other and simulating a primary radial ribbing.

OBSERVATIONS. L. zealandica Hutton differs from the other species of L. campa stock in its strong gradating concentric costae. The λ-riblets are generally thicker and the upper branch much longer and the diverging one shorter. According to Boreham (1965) L. zealandica shows great variability in shell, too. For further detailed discussion and observations the reader is referred to the initial paragraphs of this study and to Boreham (1965, p.16-18). It is here considered that three specimens are insufficient for further conclusions of any sort on this species.

DISTRIBUTION. New Zealand: Awamoa, Oamaru.

STRATIGRAPHIC RANGE. ?Waitakian-Clifdenian (?Late Oligocene-early Middle Miocene).

L. lawsi King, 1933

FIGS. 624-628

1933 Limopsis lawsi King, p.353, figs. 18-19.

1966 Limopsis (Limopsis) lawsi -Fleming, p.122, pl.12, figs. 137, 140-141.

MATERIAL. 3 topotypes with badly preserved shell surface.

DESCRIPTION. Very close to L. zealandica. It differs in fainter constrictions.

Ornament. Faintly gradating irregularly interspaced concentric costae. Very faint radial λ-riblets, which fade very early on the dorsoventral region down to the dividing sulcus, meanwhile they persist in the lateral regions. Dichotomy reappears in the prominent interspaces between riblets in adult-senile stages.

OBSERVATIONS. The poor preservation of the shell surface in these specimens does not allow a good diagnosis. The only sure characters are the fainter concentric costae, the dichotomy of the interspaces, and the λ-riblets on the lateral regions.

DISTRIBUTION. New Zealand: Hurupi Creek, Palliser Bay; Taranaki, Wairarapa, Marlborough, Southland.

STRATIGRAPHIC RANGE. Waiauan-Tongaporutuan (?)(late Middle-early Late Miocene).

SUBGENUS *Pectunculina* d'Orbigny, 1843

Limopsis (Pectunculina) cancellata sp. nov.

FIGS. 637-640

DERIVATION OF THE NAME. From the Latin *cancellatus*, cancellate, because of its ornament pattern.

HOLOTYPE. SAM P 21205-A, Figs. 637-638.

PARATYPE. SAM P 21205-B, Figs. 639-640.

TYPE LOCALITY. Blanche Point, at Aldinga Bay, Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation, Gull Rock Member.

STRATIGRAPHIC RANGE. Late Eocene (late P15-P17).St. Vincent Basin: 'Transitional Marl' to 'Soft Marl' Members, Blanche Point Formation. Murray Basin: Buccleuch Beds.

MATERIAL. 457 specimens from outcrop material (5 silicified) (234 LV, 181 RV, 15 BV, 27 vv); 82 specimens from bore material (47 LV, 34 RV, 1 vv).

DESCRIPTION. Shell thick, orbicular or ovate, convex, more or less inflated, inequilateral; umbo situated a little to anterior, small, orthogyrate, prominent on cardinal area. Margins: dorsal elliptical; the others strongly elliptical. Connections: postero and antero-dorsal angular; posteroventral more or less rounded; anteroventral imperceptible.

Shell longitudinalsection more or less strongly convex, with anterior and posterior regions steep or very steep, with a maximum at the umbo-posteroventral connection axis; dorsal region may be concave, in flatter forms, underneath umbos.

Cardinal area short and broad; resilifer inequilateral, triangular, deep and narrow; vertical striations.

Hinge line arched with 5 teeth on each side of the resilifer, but posterior teeth often 4. Anterior teeth very protruding: 1 small, hooked, underneath resilifer; 2-4 hooked; 5 subconical. Posterior teeth far from resilifer, straight or little arched, inclinated or nearly parallel to hinge line, with the last tooth very reduced.

Commissure region broad, strongly denticulate, separated from the interior region by a marked angularity.

Anterior scar high, very small, ovate, interiorly bounded by a straight rim; posterior scar low, broad and ovate; pallial line very inconspicuous; interior region smooth.

Ornament. Cancellate pattern: concentric irregularly prominent broad and flattened costae; radial regular costellae more prominent. Radial and concentric costae intersections protruding as rounded radial nodules.

OBSERVATIONS. This species shows variability in convexity and in inclination of posterior teeth. The number of teeth depends on the age. The vertical striations of the cardinal area, in contrast with the horizontal ones of *Limopsis* s. str., may justify raising *Pectunculina* d'Orbigny to generic rank (Fig. 640).

OTHER LOCALITIES. *St. Vincent Basin.* Adelaide Plains SubBasin. Adelaide (Kent Town) Bore. Adelaide Children's Hospital: Bore 5, from 26.25 to 20.34 m depths, throughout; Bore 1, 23.95-23.62 m, 22.64-22.31 m depths. Adelaide Metropolitan Subway Bore CH3 (DDH), 20.1 m depth.

Murray Basin. Waikerie Bore 2, Hd Waikerie, Sect. 692, 223.10 m depth. B.Q. Butler Bore 4, Hd Kirkpatrick, Sect.8, 125-118.77 m depth.

FAMILY GLYCYMERIDIDAE Newton, 1922
SUBFAMILY GLYCYMERIDINAE Newton, 1922
GENUS *Glycymeris* Da Costa, 1778
SUBGENUS *Glycymeris* s. str.

OBSERVATIONS. *Glycymeris* s. str. is represented in the Australian Cainozoic by two groups, both with Late Eocene representatives. One displays strong round radial costae, the other very fine or faint costellae. The following species are referred to the former group: the Late Eocene *G. lenticularis* (Tate), the Late Oligocene-Early Miocene *G. ornithoptera* Chapman & Singleton; Early Miocene *G. maccoyi* (Johnston), late Early Miocene *G. granti* Singleton, early Middle Miocene *G. gunyoungensis* Chapman & Singleton and the Pliocene *G. decurrens* Chapman & Singleton and *G. convexa* (Tate).

The species belonging to the latter group are: the Late Eocene *G. kaurna* sp. nov., the Early Miocene *G. cainozoica* (T. Woods) and the other Neogene forms hitherto referred to *G. cainozoica* by previous authors.

G. cainozoica represent one of the several composite species, the existence of which was revealed during this research. At present, it is possible to distinguish only the Late Eocene form as *G. kaurna* sp. nov. from the Neogene ones. The name *G. cainozoica* has here been restricted to the Early Miocene form from Table Cape.

It may be that the Middle Miocene form from Muddy Creek (SAM T 1055 A-G, J) and the Pliocene forms from Cheltenham and Camperdown (SAM T 1068 A-E) should be distinguished from *G. cainozoica*. However, the specimens show some degree of variability in characters and many of them have worn surfaces. Thus, no conclusion is possible at this stage. Much more material, stratigraphically well located, is needed to clarify this problem.

The Middle Miocene *G. halli* Pritchard shows transitional features between the *G. lenticularis* and the *G. kaurna* groups, since it displays weaker primary radial costae complicated by very fine secondary radial costellae. Thomas's 1975 criteria of classification has here been adopted. Thomas (1975) indicated for Glycymeris a normal marine, subtidal environment. The environment is usually 'physically rigorous, and harbours faunas of low diversity', of high energy, and with a substratum of gravel or coarse sands. The flat striated rib forms are recorded at a depth range of 16-100 m.

Glycymeris (Glycymeris) lenticularis (Tate, 1886)

FIGS. 515-516

1886 Pectunculus lenticularis Tate, p.138, pl.11, fig.1

1925 Glycymeris lenticularis -Chapman & Singleton, p.31, pl.1, fig. 8a-b; pl.4, fig.6.

1965 Glycymeris (Tucetona) lenticularis -Ludbrook, p.93, pl.3, fig.11-13.

MATERIAL. Holotype and 10 paratypes (SAM T 1011 A-B, C-L) (1 BV, 8 RV, 2 LV); 4 juvenile specimens from bore material (3 RV, 1 LV) very well preserved.

DESCRIPTION. Shell suborbicular, little inflated, equivalve, subinequilateral. Umbones with small protruding opisthogyrate beaks. Margins: anterodorsal and posterodorsal short and straight; anterior, posterior and ventral long, convex. Margin connections: anterior-anterodorsal and posterior-posterodorsal broadly angular; posterior- and anterior-ventral imperceptible. A weak angularity on the posterior margin at the adductor scar. Shell longitudinal section regularly convex. Regions subconvex, subdeclivous. Region connections imperceptible. Cardinal area very narrow, longer than high, with marked chevron-shaped striations. Hinge arched, with short, straight, transverse teeth. Distal tooth ridge with a longitudinal shallow trough. Tooth striations on the flanks only, parallel in some places, divergent and arborescent in others. Interior finely striated. Adductor scars ovate, triangular, subequal, innerly bound by a flange. Pallial line marked; commissure region broad, with large heavy crenulations from scar to scar. Denticles triangular, with ridges dichotomous to the interior. Marked broad furrow between the diverging ridges.

Ornament. Strong subtriangular radial costae, with interspaces narrower to the anterior, wider to the posterior; in the interspaces concentric prominent subimbricate microcostellae in the juvenile stages, gradually developed into flat costellae in the adult and senile stages.

OBSERVATIONS. Some of the glycymeridid moulds from Tortachilla Limestone, Maslin Bay, could be referred to this species.

Ludbrook (1965) referred this species to *Tucetona* Iredale, synonymized by Newell (1969) with *Glycymeris* s. str.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore, 66.45-45.72 m depth; Adelaide Childrens Hospital, North Adelaide, Hd Yatala, Town Acre 717, Bore 5, 23.16-22.86, 21.95-21.64 and 19.20-18.90 m depths. Willunga SubBasin: Maslin Bay.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation. Late Eocene (P15-16).

Glycymeris (Glycymeris) kaurna sp. nov.

FIGS. 517-520

1886 *Pectunculus cainozoicus* -Tate, p.136 (*pars*)

1925 *Glycymeris cainozoica* -Chapman & Singleton, p.20 (*pars*)

1965 *Glycymeris (Glycymeris) cainozoica* - Ludbrook, p.87, pl.1, fig.34 (*pars*).

DERIVATION OF THE NAME. After the Kaurna, the people of the Eastern Gulf St. Vincent.

HOLOTYPE. SAM T 1055 U; fig. 517-518.

PARATYPE. SAM T 1055 W, figs. 519-520.

TYPE LOCALITY. St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore.

TYPE FORMATION. Blanche Point Formation, 'Transitional Marls'.

STRATIGRAPHIC RANGE. Late Eocene, (P15-P16).

MATERIAL. 2 LV specimens (Types); several moulds.

DESCRIPTION. Shell thick, inflated, suborbicular, equivalve, subequilateral. Umbones with small little protruding beaks. Margins: anterodorsal and posterodorsal straight; convex all the others. Region connections: anterior-anterodorsal and posterior-posterodorsal subangular; imperceptible all the others. Shell longitudinal section regularly convex. Regions: anterior and posterior subequal, declivous, concave; dorsoventral convex declivous. Region connections imperceptible. Cardinal area narrow, longer than high, with deep chevron-shaped striations. Hinge arched with very transverse, short teeth, straight to slightly arched. Tooth striations parallel, more irregular to the cardinal area, on the tooth flanks only. Inner region smooth. Adductor scars marked, ovate-triangular. Pallial line marked. Commissure region broad, finely crenulated at the margin. Denticles short subrectangular.

Ornament. Faint radial costellae, dichotomous to the ventral. Fine concentric growth lines.

OBSERVATIONS. Following Thomas (1975), the Late Eocene form hitherto included into G. cainozoica (T. Woods) has to be distinguished on the basis of its finer costellae, more orbicular shape and commissure morphology. In particular, G. kaurna is characterized by shorter subrectangular denticles, with a weak depression on the inner side, in comparison with the longer and triangular denticles of G. cainozoica.

OTHER LOCALITIES. Willunga SubBasin: Maslin Bay (Tortachilla Limestone).

FAMILY ?PHILOBRYIDAE Bernard, 1897

GENUS *Limarca* Tate, 1886

Limarca angustifrons Tate, 1896

FIGS. 641-647

1896 *Limarca angustifrons* Tate, p.135, pl.8, fig.5a,b.

1969 *Limarca angustifrons* -Newell, *in* Moore, p. N270, fig.C15,5.

DESCRIPTION. Shell small, thick, suborbicular to ovoidal, very inequilateral, inflated; umbo with a flat cap formed by prodissoconch. Margins: dorsal and anterior straight or subelliptical; posterior and ventral strongly elliptical. Connections: antero-dorsal strongly angular; posterodorsal and anteroventral angular; posteroventral imperceptible. Shell longitudinal outline convex; anterior region rather declivous; posterior declivous; posterior-dorsal concave; anterior very reduced. Cardinal area short and very narrow; resilifer deep lanceolate, very inequilateral; hinge line arched, with 3 teeth on each side. Anterior teeth underneath umbo: 1 straight, 2 -3 hooked. Posterior straight elongated, normal to the anterior. Teeth irregularly striated on both flanks, smooth on the top. Commissure region broad crenulated by radial denticles, more marked to the posterior; commissure-interior connection angular; interior region finely punctated. Anterior scar lacking; posterior ovate, broad, in the middle of the posterior region; pallial line inconspicuous. Prodissoconch distinct.

Ornament. Cancellate pattern: concentric flat broad costae and radial fine costellae flattened on costae; flat and very little prominent nodules at costae-costellae intersections. Prodissoconch punctate.

OBSERVATIONS. *L. angustifrons* Tate is the type species of *Limarca* Tate.

DISTRIBUTION. St. Vincent Basin. Adelaide Childrens Hospital, Bore 5, 24.28-23.95 m depth; Adelaide (Kent Town) Bore. Murray Basin. B.Q. Butler Bore 4, Hd Kirkpatrick, Sect.8, 125-118.77 m depth.

STRATIGRAPHIC RANGE. St. Vincent Basin, Blanche Point Formation, Murray Basin, Buccleuch Beds. Late Eocene (late P15-P17).

ORDER	MYTILOIDA Férussac, 1822
SUPERFAMILY	MYTILACEA Rafinesque, 1815
FAMILY	MYTILIDAE Rafinesque, 1815
SUBFAMILY	MYTILINAE Rafinesque, 1815
GENUS	*Septifer* Recluz, 1848
SUBGENUS	*Septifer* s. str.
	Septifer (Septifer) sp. nov.

FIGS. 648-650

MATERIAL. 3 badly preserved silicified specimens (1 LV, 2 RV); 4 well preserved and 3 broken specimens from bore material (4 LV, 2 RV, 1 vv).

DESCRIPTION. Shell small, thick, mytiliform, strongly inequilateral, inflated, equivalve. Umbones with small orthogyrate beaks, at the anterior end. Margins: anterior and anterodorsal, posterior and posterodorsal undifferentiated, straight; ventral very elliptical. Margin connections: posterior-ventral roundly angular; anterior-ventral broadly angular. Shell longitudinal outline triangular. Regions: anterior flattened, very declivous; dorsoventral narrow, subconvex; posterior concave, very broad. Region connections: anterior-dorsoventral sharply angular, represented by an anterior ridge; posterior-dorsoventral subangular. Hinge dysodont with two small posterior teeth, below the beaks. Resilifer triangular, broad, on a cardinal plate. Interior smooth, but radially ondulated. Elongated posterior adductor scar. Inner layer subdetached at the pallial line in some specimens. Pallial line marked at the end of the inner layer. Commissure region crenulated: finely the anterior; coarsely the ventral and posterior.

Ornament. Fine marked concentric costae. Dichotomous broad prominent radial ribs with wide interspaces on the dorsoventral and posterior regions. On the anterior region, from the anterior ridge repeatedly dichotomous riblets. At rib-costa intersections, beads, more developed on the anterior region.

OBSERVATIONS. Septum and commissure crenulation place this form in *Septifer* s. str. *Septifer* sp. nov. represents the oldest record of the genus in Australia. Troon Sot-Ryen (*in* Moore, 1969) indicates a tropical-subtropical climate for *Septifer* s. str.

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Maslin Bay, first gully southward of 'Uncle Tom's Cabin'. Murray Basin, B.Q. Butler Bore 4, Sect. 8, Hd Kirkpatrick, 126.13-110.34 m depth.

STRATIGRAPHIC RANGE. St. Vincent Basin, 'Transitional Marls'. Murray Basin, Buccleuch Beds. Late Eocene (P16-P17).

SUPERFAMILY PINNACEA Leach, 1819

FAMILY PINNIDAE Leach, 1819

GENUS *Pinna* Linné, 1758

Pinna ?sp

FIG. 651

MATERIAL. 1 silicified fragment of valve.

DESCRIPTION. The fragment displays a well developed median ridge.

Ornament. Faint radial costae.

OBSERVATIONS. The fragment represents the oldest record of Pinnidae in the Australian Tertiary. The median ridge places this form in *Pinna* Linné.

LOCALITY. St. Vincent Basin, Willunga SubBasin, Maslin Bay, first gully southward of 'Uncle Tom's Cabin'.

STRATIGRAPHIC RANGE. Late Eocene (early P16). Blanche Point Formation, upper 'Transitional Marl' Member.

ORDER	PTERIOIDA Newell, 1965
SUBORDER	PTERIINA Newell, 1965
SUPERFAMILY	PTERIACEA Gray, 1847
FAMILY	MALLIDAE Lamarck, 1819
GENUS	*Vulsella* Röding, 1798
	Vulsella laevigata Tate, 1886

1886 *Vulsella laevigata* Tate, p.122; pl.3, fig.3.

FIGS. 652-655

MATERIAL. 2 RV specimens (SAM P 21237 A-B); holotype and paratype (SAM T 975 A-B).

DESCRIPTION. Shell linguliform, subequivalve, inequilateral, rather thin, with gaping valves, flattened; umbo prosogyrate with small acute beaks. Margins: posterodorsal short and elliptical; anterodorsal very short and elliptical; anterior and posterior very long, straight the former and subelliptical the latter; ventral very short and very elliptical. Margin connections: posterior-posterodorsal imperceptible; angular the others.

Shell longitudinal outline regular and slightly convex; Regions: anterior and posterior steep; dorsal slightly convex; ventral flattened. Ears absent; hinge reduced to a broad triangular shallow resilifer concentrically striated, bound by two narrow triangular bourrelets, and with the ventral margin protruding. One adductor scar reniform, higher than wider, in the posterior middle region; pallial line imperceptible.

Ornament. Concentric growth lines and rather irregularly interspaced broad shallow concentric grooves corresponding on the interior to concentric broad flattened costae.

OBSERVATIONS. The above diagnosis is also based on Tate's own specimens

(S.A. T. 975 A-B, where A is the holotype).

LOCALITIES. St. Vincent Basin, Witton Bluff (Noarlunga SubBasin). Aldinga (Willunga SubBasin).

STRATIGRAPHIC RANGE. Blanche Point Formation, 'Transitional Marl' Member. Late Eocene (late P15-early P16).

FAMILY PTERIIDAE Gray, 1847 (1820)

GENUS Pinctada Röding, 1798

SUBGENUS Pinctada s.str.

Pinctada(Pinctada) sp. nov.

FIGS. 656-659

MATERIAL. 1 silicified, half preserved specimen (1 BV).

DESCRIPTION. Shell subquadrate, posterior ear long, narrow, triangular. Umbones with small orthogyrate beaks. Cardinal area flat, broad, with broad deep triangular resilifer, iso-orientated with the posterior ridge. Hinge edentulous. Marked round adductor scar, just below the resilifer. Marked Pallial line.

Ornament. Well developed concentric lamellae.

OBSERVATIONS. The cardinal area and the preserved part of the dorsal region and ornament place this form in Pinctada Röding s. str. Pinctada (Pinctada) sp. nov. represents the oldest record of the genus, the stratigraphic range of which is here extended far back to the Late Eocene. Hertlein & Cox (in Moore, 1969) indicate Pinctada as characteristic of pantropical waters.

DISTRIBUTION. St. Vincent Basin, Willunga SubBasin, Maslin Bay, first gully southward of 'Uncle Tom's Cabin'.

STRATIGRAPHIC RANGE. Blanche Point Formation, upper 'Transitional Marl' Member. Late Eocene (early P16).

SUPERFAMILY PECTINACEA Rafinesque, 1815

FAMILY PROPEAMUSSIIDAE Abbott, 1954

Thiele (1935) placed the Early Jurassic-Holocene *Propeamussium* de Gregorio in the subfamily Amusiinae Ridewood, 1903 (Pectinidae Rafinesque). Abbott (1954), on the basis of unspecified morphological grounds, was the first to remove this genus from the Pectinidae into a new family of its own. Korobkov (*in* Ebersin, 1960) and Hertlein (*in* Moore, 1969) followed Thiele, but the latter lowered Thiele's subfamilies to the more conservative rank of "groups". Waller (1971, 1972) validated Abbott's 1954 familial distinction of *Propeamussium* on the basis of shell microstructure (see Waller, 1972, for details) and anatomical characters such as the absence of ocelli, velum guard tentacles and LV pedal retractor insertion. Following Thiele's 1935 arrangement Robba (1968) and Abbott (1974) lowered Propeamussiidae to subfamily. Yonge (1973, 1975, 1978) considers a familial rank as the more appropriate for this group.

Newell & Hertlein (*in* Moore, 1969) consider Amusiidae Ridewood of uncertain relationships with the Pectinidae, and although they included *Propeamussium* in their *Amusium* Group, they considered it as a distinct group from *Amusium* Röding.

Waller (1971, 1972) suggests that the Propeamussiidae Abbott may represent the last extant relict of the Paleozoic 'Pernopectinidae' (= Entoliidae Korobkov). As a result of Allasinaz's 1973 thorough study on the Triassic Pectinacea, a close link may be assumed among the Paleozoïc (*Pernopecten* Winchell) and the Triassic (*Entolium* Meak and *Filopecten* Allasinaz) Entoliidae, and the Early Jurassic-Holocene Propeamussidae. In particular, the calcitic foliated mesoendostracum of the Ladinian-Rhaetian *Filopecten* (Allasinaz, 1973) seems to suggest that within the Entoliidae this genus may occupy a position branching toward the Propeamussiidae. At present, *Propeamussium* de Gregorio and its subgenus Parvamussium Sacco are the only taxa recognized in Propeamussiidae.

GENUS Propeamussium De Gregorio, 1884

SUBGENUS Parvamussium Sacco, 1897

Propeamussium (Parvamussium) sp.

1886 Pecten zitteli -Tate, p.115 (pars).

1899 Amusium zitteli -Tate, p.272 (pars).

1955 Propeamussium atkinsoni -Ludbrook, p.33 (pars).

MATERIAL. 71 LV, 89 RV, 70 vv, in various states of preservation.

DESCRIPTION. Shell thin, orbicular, inequilateral, equivalve, flattened, umbo central, orthogyrate with beaks small acute, just protruding from the hinge margin. Margins: anterior and posterior straight and winged; ventral very elliptical. Connections: antero- and postero-ventral broadly angular. Auricles triangular, inequal, higher than long, posterior shorter; anterior longer, in some specimens reflected; RV anterior auricle aliiform, with a deep byssal sinus.

Longitudinal shell section regularly subconvex. Hinge region: crura nearly imperceptible; triangular resilifer. Commissure region smooth. Adductor scar and pallial line imperceptible.

Ornament. Inner 9-12 RV and 9-11 LV rounded and marked radial ribs, ending at the commissure region, the number of the ribs depending upon the ontogenetic stage. Outer RV: fine concentric costellae with regular interspaces, wider than the costellae; LV: cancellate, with concentric riblets more developed than radial costellae; primary and secondary radial riblets widely interspaced with primary more marked. Auricles: anterior RV concentric riblets and beaded radial cord limiting the byssal sinus; anterior LV cancellate, with few broad radial riblets;

posterior concentric lamellae, scaly at the intersection with radial riblets.

OBSERVATIONS. The specimens from Tortachilla Limestone and Blanche Point Formation are at present lumped together for convenience, although the extremely bad preservation of the older specimens does not allow any comparison whatsoever.

The two New Zealand specimens of '*Pecten zitteli* Hutton' from Waihao River (?Bortonian), mentioned by Tate (1886) display traces of ornament and inner ribs clear enough to place them close to the Australian Late Eocene form here described. However, the closeness of their relationships is still impossible to define because of their bad preservation.

In the Tate Collection, two sets of specimens were found which are referred by him to *Pecten zitteli* Hutton. In the uncatalogued part of his collection a box was found containing a large number of specimens labelled '*Pecten zitteli* Hutton, Blanche Point, Aldinga, *Turritella* Marls'. On the evidence of matrix and preservation, these specimens, however, appear to be from at least two localities, Aldinga and Muddy Creek. Some of them may also be from Table Cape, Gellibrand River, and Adelaide Bore. Therefore, they cannot safely be utilized for study purposes. The other set is in the catalogued part of the Tate Collection (SAM T 957). The tablet bears specimens from the following localities. A) Muddy Creek (-3, 3A-C); these specimens are those figured by Tate (pl.7, figs. 3a-c). B) Adelaide Bore (-2). C) Table Cape (-4), topotypes of *Amusium atkinsoni* Johnston. D) Murray River (-6). E) Gellibrand River; one specimen subsequently destroyed. F) Aldinga (-7, the writer's numbering).

The examination of these specimens led to the conclusion that they represent more than one species. Differences in valve outline and in valve and auricle ornament indicate that the Late Eocene St. Vincent Basin form, here described, and the Middle Miocene Muddy Creek and Murray River ones probably belong to discrete groups, distinct from each other and from Amusium atkinsoni. More material with better preservation and stratigraphic location is needed for a proper definition of the distinctive characters of these groups.

The relationships between the Australian and the New Zealand forms referred by the authors to P. zitteli are not yet properly known. Marwick (1924) considered them distinct and referred the Australian forms to A. atkinsoni. However, Marwick's conclusions were based on the comparison between the Early Oligocene New Zealand P. zitteli s. str. and an Australian Middle Miocene form from Balcome Bay.

Any further discussion, on the basis of the scant material available, is futile at this stage and it may only add to the already existing confusion. The revision of the Australian and New Zealand forms of Parvamussium and their relationships requires investigations which might exceed the scope of this study. Research on this particular topic is planned jointly with Dr. P. Maxwell, New Zealand Geological Survay, in the near future.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin; Adelaide (Kent Town) Bore. Willunga SubBasin; Maslin and Aldinga Bay.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation Late Eocene (P15-middle P16).

FAMILY	PECTINIDAE Rafinesque, 1815
GROUP	Chlamys Röding, 1798
GENUS	Chlamys Röding, 1798
SUBGENUS	Chlamys s. str.

Chlamys(Chlamys) aldingensis (Tate, 1886)

FIGS. 668-670

1886 Pecten aldingensis Tate, p.109, pl.7, fig. 1a-c.

1924 *Pecten aldingensis* -Marwick, p.325, pl.6, fig.14.

1970 *Chlamys aldingensis* -Ludbrook, *in* Lowry, fig. 21-A.

MATERIAL. 138 specimens (17 RV, 46 LV, 75 vv), generally badly preserved cotypes and paratypes (SAM T 942 A-G).

DESCRIPTION. Shell ovate, slightly inequivalve, inequilateral, poorly inflated, little higher than longer; umbo central, small, acute; Margins: dorsal angular winged, the others elliptical; connections: antero- and posterodorsal markedly angular; the others imperceptible. Ears triangular longer than higher, anteriors longer, deep byssal notch in anterior right ear. Shell longitudinal outline regularly and faintly convex; hinge very faint, resilifer deep and little. Commissure line crenulate.

Ornament. About 50 radial rounded costellae very weakly scaled, narrow in the interspaces microriblets oblique to the margins in anterior and posterior regions, often crossed in the dorsal region. Ears with radial ribs, the anteriors scaly too.

OBSERVATIONS. Hutton (1886, p.482) considers *C. aldingensis* (Tate) synonym of *C. williamsoni* (Zittel) (Zittel, 1864, p.50, pl.9, fig. 11a-c). Suter (1915, p.51, pl.5, fig.5) separates again the two species and refers to the former a New Zealand Oligocene form. Marwick (1924, p.325, pl.6, figs. 11, 14-15) remarks that *C. aldingensis* is close to *C. williamsoni*, as both are referable to *Chlamys* Röding although as distinct species. He further observes that Suter's New Zealand '*C. aldingensis*' is distinguishable as a new species *P. uttley* Marwick (Marwick, *ibid.*) which later Marwick named as type-species of *Janupecten* Marwick, subgenus of *Serripecten* Marwick (Marwick, 1928, p.455).

C. aldingensis differs substantially from *C. williamsoni* by the number of ribs: 50 in the former, 27 in the latter (Marwick, 1924).

LOCALITIES. *St. Vincent Basin.* Willunga SubBasin: Maslin Bay. *Eucla Basin.* Abrakurrie Cave, Toolinna Cove, Haig Cave.

STRATIGRAPHIC RANGE. St. Vincent Basin: Tortachilla Limestone. Eucla Basin: Wilson Bluff Limestone and Toolinna Limestone. Middle to Late Eocene.

OBSERVATIONS. In the St. Vincent Basin C. aldingensis (Tate) is restricted to Tortachilla Limestone (early P15). The lack of record of this species upward the section may very well be environment-controlled, but it remains a meaningful event, locally. The Eucla Basin record for this and for the other two species of Chlamys has to be considered with some doubt, since it has not been given with a comparable stratigraphic resolution as in this study. Furthermore, the Eucla Basin specimens referred to C. aldingensis and the other two species were not examined and therefore their conspecificity with these species cannot yet be ascertained.

Chlamys (Chlamys) flindersi (Tate, 1886)

FIGS. 664-667

1886 Pecten flindersi Tate, p.108, pl.8, fig. 7.

MATERIAL. 329 specimens (34 LV, 43 RV, 2 BV, 251 vv), generally badly preserved. Holotype and paratypes (SAM T 931 A-F).

DESCRIPTION. Shell thick, ovate, inequilateral, more or less high, little inflated; umbo acute, orthogyrate. Margins: dorsal winged and angular, the others elliptical; connections antero- and postero-dorsal angular, imperceptible the others. Ears: short and high, the posterior; rather long, the anterior; right anterior with wide byssal sinus. Shell longitudinal outline regularly convex; cardinal crura weak, resilifer small, deep and triangular; pallial line and scar very inconspicuous. Commissure region crenulate.

Ornament. About 35 flat rounded costae, widely interspaced; in the flat interspaces very fine costellae radial in the dorsal region, oblique to the margins in the anterior and posterior regions.

Concentric growth lines producing to the ventral lamellae and on the ribs, concentric rare scales. Ribs and interspaces occur in negative in the interior region.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore. Willunga SubBasin: Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Tortachilla Limestone, Blanche Point Formation. Late Eocene (P15-P16).

OBSERVATIONS. The record of this species from the Early Miocene Abrakurrie Limestone of Madura Cave, Eucla Basin (Ludbrook, in Lowry, 1970) is at present considered doubtful.

Chlamys (Chlamys) peroni (Tate, 1886)

FIGS. 660-663

1886 Pecten peroni Tate, p.108, pl.10, figs. 1a-b.

1970 Chlamys peroni -Ludbrook, in Lowry, fig. 21-G.

MATERIAL. 349 specimens (66 LV, 43 RV, 240 vv), mostly badly preserved. Holotype and paratypes (SAM T 930-C, A-B, D-K; SAM T 934 A-M).

DESCRIPTION. Shell rather thin, ovate, inequilateral, little inflated; umbo acute, prosogyrate. Margins: dorsal angular, winged; the others elliptical. Ears: anterior longer, posterior little longer than higher. Connections antero- and postero-dorsal angular, rounded; imperceptible the others. Shell longitudinal outline regular subconvex; cardinal crura weak; resilifer small deep and triangular; adductor scar and pallial line imperceptible, commissure region crenulate.

Ornament. About 35 radial triangular ribs, with adherent secondary riblets on one or both sides, some diverging; concentric regular scales variably shaped on ribs and in the interspaces. Very fine radial microriblets arborescent irregular, often hook-shaped; ears radially ribbed with marked or faint concentric lamellae.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin. Adelaide (Kent Town) Bore. Willunga SubBasin. Maslin and Aldinga Bays. Eucla Basin: Booanya Well. Otway Basin: Browns Creek. The other localities mentioned by Dennant & Kitson (1903), Corio Bay, Waurn Ponds, Spring Creek, and by Ludbrook (*in* Lowry, 1970), Firestick Cave, are stratigraphically much younger and they are therefore considered doubtful.

STRATIGRAPHIC RANGE. St. Vincent Basin: Tortachilla Limestone, Blanche Point Formation. Otway Basin: Browns Creek Formation. Eucla Basin: Toolinna Limestone. Late Eocene (P15-middle P16).

SUPERFAMILY PLICATULACEA Watson, 1930
(*nom. transl.* Yonge, 1975, *ex* Plicatulinae Watson,1930)

Yonge (1973, 1975, 1978) separates Spondylidae Gray, Dimyidae Fischer and Plicatulidae Watson from their usual location, Pectinacea Rafinesque, and groups them in the new superfamily Plicatulacea Watson. Yonge (1975) indicates as distinguishing characters for this new superfamily: cemented RV, transverse ligament, secondary teeth and sockets (though absent in Spondylidae) and ctenidial ciliations. Yonge (1975, 1978) also stresses that the development of the monomyarian condition was probably achieved by this superfamily subsequent to cementation and not following byssal attachment as it did in the Pectinacea.

FAMILY SPONDYLIDAE Gray, 1826
GENUS *Spondylus* Linné
SUBGENUS *Spondylus* s. str.

Spondylus (Spondylus) tortachillensis sp. nov.

FIGS. 671-673

1886 *Spondylus gaederopoides* -Tate, p.121 (*pars*).

1899 *Spondylus gaederopoides* -Tate, p.275 (*pars*).

1970 *Spondylus gaederopoides* -Ludbrook, *in* Lowry, fig. 21-B.

DERIVATION OF THE NAME. From the name of the formation, Tortachilla Limestone, from which come the oldest specimens.

HOLOTYPE. SAM T 987 A, Figs. 671-672.

PARATYPES. SAM P 21238, Fig. 673.

TYPE LOCALITY. Blanche Point at Aldinga Bay, Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. Blanche Point Formation (late P15-middle P16).

STRATIGRAPHIC RANGE. Tortachilla Limestone - Gull Rock Member, Late Eocene (P15-middle P16).

MATERIAL. 51 specimens (9 LV, 3 RV, 39 vv) some with shell partially preserved, some as moulds. 10 specimens from Tate Collection (T 987 A-E; T 989 A-E).

DESCRIPTION. Shell rather thin, oval, inequilateral, inequivalve, with RV more inflated, winged. Hinge isodont with two big and rough teeth and a deep triangular resilifer (LV). Cardinal area variably broad, generally longer than higher. Pallial line marked; commissure region crenulated; adductor scar subcircular, broad, at middle-posterior position.

Ornament. LV: radial undulating ribs: primary more marked and bearing large and long spines; in the broad interspaces, 3 secondary finer ribs with small spines; between two secondary, one finer spiny riblet; between tertiary-secondary and teriary-primary one very fine spiny microriblet. RV: broad flat ribs. Growth lines and regularly interspaced high growth lamellae, protruding normal to the surface, in some specimens substituted by lamellar spines generally on the ventral region.

OBSERVATIONS. Tate (Ibidem) includes within S. gaederopoides McCoy (McCoy, 1876, D. 4th, p.27, pl.38, figs.1a-d; 1877, D. 5th, p.17, pl.45, figs.1,3) 10 specimens from Aldinga and Adelaide Bore, referable to S. tortachillensis. However, the simpler hinge and the ornament of S. tortachillensis clearly distinguish the latter from the former. In fact, S. gaederopoides McCoy displays on the LV only broadly interspaced primary radial ribs and secondary ribs, on the RV concentric lamellae more adherent to its surface.

OTHER LOCALITIES. St. Vincent Basin. Adelaide Plains SubBasin: Adelaide (Kent Town) Bore. Eucla Basin: 19.3 km east of Eucla, 25.2 m above sea level; Wilson Bluff (Wilson Bluff Limestone).

FAMILY DIMYIDAE Fischer, 1886

Newell (in Moore, 1969) recognizes only Dimya Rouault and Dimyodon Fischer in this family. Yonge (1975, 1978) offers a detailed anatomical description of the living Dimyidae and also confirms in it two recently instituted, living genera, Basiliomya Bayer and Dimyella Moore.

GENUS Dimya Rouault, 1850

Dimya sigillata Tate, 1886

FIGS. 674-681

1886 Dimya sigillata Tate, p.100, pl.8, fig. 8a (pars)
1970 Dimyodon sigillata -Ludbrook, in Lowry, fig. 21-H.
1973 Dimya sigillata -Ludbrook, pl.24, fig.14 (pars)

MATERIAL. 2016 specimens in various states of preservation (917 LV, 872 RV, 28 BV, 199 vv); 5 syntypes, four paratypes from the Tate Collection (SAM T 913 A/B, J-L).

DESCRIPTION. Shell thin, small, oval, slightly inequilateral, scarcely convex. Umber central, small, little prominent. Margins: dorsal subelliptical anterior, posterior and ventral elliptical; connections: antero and posterodorsal angular, antero-ventral imperceptible, postero-ventral rounded. Shell longitudinal outline convex; cardinal crura weak and short, resilifer small. Commissure region flattened, irregularly waved, broader at postero-ventral connection, bounded from the interior region by a crenulated narrow belt, produced by the ends of the interior ribs in the LV. RV crenulations restricted to the dorsal margins. Pallial line and scars very inconspicuous.

Ornament. Rounded radial bifurcating costae, intersected by irregular, faint and broad grooves. Internal radial ribs.

OBSERVATIONS. The type series of *D. sigillata* Tate is composite with specimens referable to two different species, the Middle-early Late Eocene *D. sigillata* s. str. (SAM T 913A/-C, -J, -L) and the middle Late Eocene *D. asseretoi* sp. nov. (SAM T 913D/-H,-K) described below.

All the specimens of the latter group appear to be from Aldinga Bay, as indicated by similarity in preservation with specimens of *D. asseretoi* from Blanche Point. By exclusion, the holotype and paratypes of *D. sigillata* appear to be from Adelaide (Kent Town) Bore, which thus becomes the type locality of this species.

DISTRIBUTION. *St. Vincent Basin*. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin and Aldinga Bay. *Eucla Basin*. Bunda Cliffs, Abrakurrie Cave.

STRATIGRAPHIC RANGE. *St. Vincent Basin*. Tortachilla Limestone - 'Transitional Marl' Member (Blanche Point Formation). *Eucla Basin*. Wilson Bluff Limestone. Middle-Late Eocene (P14-early P16) (Quilty, 1974, 1977; McGowran, 1978a, b, c; Ludbrook, 1973).

Dimya asseretoi sp. nov.

FIGS. 682-689

1886 Dimya sigillata Tate, p.100, pl.8, fig. 8b (pars)

1973 Dimya sigillata -Lubdrook, pl.23, fig.15 (pars)

DERIVATION OF THE NAME. After the late Professor Riccardo Assereto, Istituto di Geologia, Università degli Studi, Milano, Italia.

HOLOTYPE. SAM P 21206-A, Fig. 682.

PARATYPES: SAM P 21206-B/-D, Figs. 683-689.

TYPE LOCALITY. Blanche Point, at Aldinga Bay, Willunga SubBasin, St. Vincent Basin.

TYPE FORMATION. 'Soft Marl' Member, Blanche Point Formation.

STRATIGRAPHIC RANGE. Gull Rock-'Soft Marl' Members. Late Eocene (middle P16).

MATERIAL. 513 specimens in various states of preservation (364 LV. 145 RV, 3 BV, 1 vv); 7 specimens from Tate's collection (SAM T 913-D/-H, -K).

DESCRIPTION. Similar to D. sigillata Tate. It differs from it in the following characters. Smaller and thinner shell, more concave LV, commissure inner crenulations: more interspaced and present throughout in the RV; present only in the antero and postero-dorsal margin in the LV. Absent inner radial riblets in both valves. Finer radial costae on the outer RV. Reduced lamellae on the outer LV.

SUPERFAMILY	LIMACEA Rafinesque, 1815
FAMILY	Limidae Rafinesque, 1815

The revision of the Tertiary composite species Limatula jeffreysiana (Tate) and Lima bassi T. Woods has recently been dealt with in two separate papers (Buonaiuto, 1977a,b; Appendix F). Limatula jeffreysiana is now restricted to the Early Miocene and the new names L. margaritata and L.

ludbrookae have been instituted for the Late Eocene and the Pliocene forms, respectively. Because of the lack of material a middle Miocene form among those previously referred to *L. jeffreysiana* remains to be studied. This form may also represent a new species distinct from the others (see discussion in Fleming, 1978, p.66). Fleming (1978) referred these species to the subgenus *Stabilima* Iredale, transferred by him from *Limaria* Link to *Limatula* Wood.

Lima bassi T. Woods has been restricted to the Early Miocene, and the new names *L. maslinensis*, *L. morganensis*, *L. elianae* have been instituted for the Late Eocene, Middle Eocene and Pliocene forms, respectively (Buonaiuto, 1977b).

GENUS *Ctenoides* Mörch, 1853

Ctenoides sp.nov. aff. *linguliformis* (Tate, 1886)

FIG. 690

MATERIAL. 1 v. Only the ventral region preserved.

DESCRIPTION. Shell rather thick, ovate, inequilateral, little inflated; umbo orthogyrate, beak small, acute. Margins: dorsal short and straight; winged; anterior and posterior short ans straight; ventral elliptical. Connections: antero and posterodorsal angular, rounded the others. Ears: anterior smaller, posterior broader, thicker and reflected to the umbo. Byssal gape.

Shell longitudinal outline regular convex with maximum convexity at the posterior ridge. Cardinal area very narrow and long, resilifer shallow and triangular two long posterior crura, very weak the anteriors. Commissure region crenulate and narrow, bounded from the interior by a marked sulcus. Interior region smooth finely striated. Scar and pallial line imperceptible.

Ornament. Rare concentric growth lamellae, regular concentric very faint striae, radial undulating flat pseudodiverging ribs, originated from the ventral axis to the margins, in an inverted V-shape pattern.

OBSERVATIONS. This species seems to be very close to the Middle Miocene *C. linguliformis* (Tate, 1886), from which it differs in more convex shell and presence of weak concentric striae, instead of weak concentric costellae. The only specimen available is too damaged for a proper definition and for the establishment of a new name.

Ctenoides sp. nov. represents the oldest known record of the genus in Australasia. The only other fossil form known is the New Zealand Pliocene *C. naufragus* Marwick.

LOCALITY. St. Vincent Basin: Willunga SubBasin, Maslin Bay at 'Uncle Tom's Cabin'.

STRATIGRAPHIC LOCATION. Tortachilla Limestone. Late Eocene (early P15).

GENUS *Divarilima* Powell, 1958

Divarilima cf. *polyactina* (Tate, 1886)

FIG. 891

1886 *Lima polyactina* Tate, p.118, pl.8, fig. 4a-c.

MATERIAL. (2 RV, 1 LV, 1 vv) 4 specimens, badly preserved.

DESCRIPTION. Shell small, thin, trigonally ovate, strongly inequilateral, inflated; backward-pointing umbones with small, acute prosogyrate beaks. Margins: anterior straight and shorter; posterior straight and longer; ventral very elliptical and wider. Connections: antero- and postero-ventral rounded. Ears very reduced. Shell cross outline convex with maximum at the posterior ridge. Regions: anterior posterior and ventral regularly declivous, the second a little steeper; anterodorsal convex; posterodorsal concave and very steep with maximum concavity at the umbones. Cardinal area high, narrow, strongly asymmetrical; with shallow asymmetrical triangular resilifer; hinge nearly edentoulous; commissure region smooth; pallial line and adductor scar imperceptible.

Ornament. Interior: faint broad radial ribs and narrow grooves. Exterior: fine radial rounded ribs with narrower interspaces.

OBSERVATIONS. The above diagnosis is based both on the specimens collected and on Tate's syntypes (SAM T 979).

LOCALITIES. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin Bay, 'Uncle Tom's Cabin'.

STRATIGRAPHIC RANGE. Tortachilla Limestone, Blanche Point Formation. Late Eocene (P15-middle P16).

GENUS Limea Bronn, 1831

SUBGENUS Isolimea Iredale, 1929

Limea (Isolimea) alticosta Tate, 1886

FIGS. 692-696

1886 Limea alticosta Tate, p.120, pl.3, fig.8.

1899 Limea alticostata -Tate, p.274.

MATERIAL. 390 specimens (202 vv, 102 RV, 86 LV), generally badly preserved and worn. 1 silicified specimen (RV).

DESCRIPTION. Shell small, thick, trigonally ovate, very inflated, strongly inequilateral, umbo central. Margins: anterior short, posterior longer, both subelliptical; ventral elliptical. Connections anteroventral rounded; posteroventral angular. Ears very small.

Shell longitudinal outline: very convex with maximum at the posterior ridge. Regions: anterior and posterior very steep; dorsal convex; ventral rather steep. Hinge generally badly preserved; with small straight transverse teeth. Pallial line and adductor scar imperceptible. Commissure regions: anterior and posterior thin and smooth; ventral broad and crenulate with large subrectangular prominent denticles.

Ornament. On dorsal and ventral regions: broad and rounded primary ribs; in the narrower interspaces secondary fine rounded ribs bound on each side by fine deep grooves; concentric fine grooves producing a scaly-beaded pattern on the ribs. On anterior and posterior regions and ears: the radial ribs abruptly fading toward the umbo, concentric subrounded costae prevailing. Shell interior. On dorsal and ventral regions: flat broad radial ribs, corresponding to the outer primary ones and both ending in the denticles, with flat broad interspaces. On anterior and posterior regions: fine concentric riblets.

OBSERVATIONS. The above described morphological characteristics allow this species to be referred to *Isolimea* Iredale. The stratigraphical range of the subgenus is lowered down to the Upper Eocene (see also Ludbrook, 1973, p.247). Tate's holotype from Adelaide Bore is preserved in the S.A. Museum on the tablet n^{0} T 981.

Tate, in the paper in which he instituted this species, used two spellings for the specific name: '*alticosta*' in the text (p.120) and '*alticostata*' in the explanation of the plates (p.155). Later he used the latter spelling as a '*nomen nudum*'. Dennant & Kitson (1903, p.119) and Ludbrook (1973, p.247) list this species as *L. alticostata*. Here the spelling of the spcific name is revised to *L. alticosta*.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin Bay.

STRATIGRAPHIC RANGE. Tortachilla Limestone, 'Transitional Marl' Member, Late Eocene (P15-early P16).

FAMILY	GRYPHAEIDAE Vyalov, 1936
SUBFAMILY	PYCNODONTEINAE Stenzel, 1959
GENUS	*Pycnodonte* Fischer de Waldheim, 1835
SUBGENUS	*Pycnodonte* s. str.

Pycnodonte sp. cf. tatei (Suter, 1913)

FIG . 713

MATERIAL. 1 LV damaged on the ventral region and only the interior part visible.

DESCRIPTION. Shell very thick, suborbicular, inflated geniculate rather higher than longer. Ligament area triangular, broad, and flat, separated by furrows from the auricles; bourrelets, flat and broad, of same size; resilifer broad and rather shallow, slightly hooked, chomata arborescent, weak in the posterior, marked in the anterior margin; commissure shelf broad. Under the resilifer a broad squat boss. Adductor scar large rather high subcentral, slightly to the posterior, suboval.

Ornament. The margins suggest a growth lamellae pattern.

OBSERVATIONS. This form is a new discovery in South Australia. The type of hinge, the position and the shape of the adductor scar, the occurrence of arborescent chomata and the probable geniculation of the valve (unfortunately damaged on the ventral border) let it be referred to *Pycnodonte*. Because it is uncertain whether this form may represent a senile specimen of *P. tatei* or a distinct species, it is here preferable to refer it in general to *Pycnodonte* sp.

LOCALITY. Maslin Bay at 'Uncle Tom's Cabin'.

STRATIGRAPHIC RANGE. Tortachilla Limestone, Late Eocene (early P15).

Pycnodonte (Pycnodonte) tatei (Suter, 1913)

FIGS. 714-718

1886 *Ostrea arenicola* Tate, p.97 (*pro parte*)

1886 *Ostrea hippopus* Tate, p.98, pl.4, figs. 1a-b.

1913 *Ostrea tatei* Suter, p.889, pl.57, fig.4.

MATERIAL. 184 specimens (76 RV, 103 LV, 1 BV, 4 vv) generally juvenile morpha, in various states of preservation.

DESCRIPTION. Shell form suborbicular to ovoidal, thin, inequivalve, inequilateral, LV and RV geniculate. Umbo prosogyrate, protruding, and adherent to anterodorsal margin. Variably elliptical margins, and variable connections, generally angular, depending on the substratum. Attachment area very wide.

Shell longitudinal outline generally subrectangular: commissure shelf very steep or vertical with broad wave-like plications.
LV regions: dorsal concave, very steep or vertical the others; LV region connections: all very angular. RV regions: dorsal from flattened to convex; from flattened to concave the others.
Ligament area broad and narrow, resilifer long, narrow, prosogyrate; posterior bourrelet elongated and flattened, anterior short and protruding; chomata few, weak, and arborescent; scar reniform and broad, at central-posterior position and rather high toward the hinge plate. Commissure region broad and irregularly wave-shaped.

Ornament. Growth lamellae, producing hyote scales on the peripheral regions. Irregular weak radial ribs. On the connection between dorsal region and commissure shelf irregular squat sometimes high protrusions. In some specimens auricles are present (LV). On RV only growth lamellae.

OBSERVATIONS. Chomata and vesicular layers let this form be referred to Pycnodonteinae. The ribs, the large attachment area, the protruding lamellae which suggest hyote spines, the shape of the resilifer, position of adductor scar, and the flattened RV allow this form to be included in *Pycnodonte* Fischer de Waldheim.

Tate (1886, p.98) included in *O. arenicola* Tate as variety 6 specimens (1 LV, 4 RV, 1 BV) from the Adelaide Bore (S.A. T 885 A-F), but a closer comparison places these specimens as morphae of *N. tatei*. Suter (1913, p.890) changed the name of *O. hippopus* Tate to *O. tatei* Suter (*nomen novum*), because of the priority of *O. hippopus* Lamarck, 1818 (see also Tate, 1889, p.268). He also referred to this species New Zealand Neogene and living forms (Dunedin rock oysters). Finlay (1928, p.265) restricted *O. tatei* only to the Australian forms (Eocene) and institutes for the others the species *O. hefferdi* Finlay. Tate (1889, p.268) considers his *O. hippopus* as an individual monstrosity of *G. tarda* Hutton (=*Notostrea lubra* Finlay), but the discovery of other specimens in the Tortachilla Limestone and the consequent comparison with specimens of *P. tarda* separates *P. tatei* as a distinct species, whereas *P. tarda* should be referred to *Phygraea* Vyalov, 1936.

DISTRIBUTION. St. Vincent Basin. Adelaide Plains SubBasin. Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin Bay, Blanche Point.

STRATIGRAPHIC RANGE. 'Tortachilla Limestone'-Gull Rock Member, Late Eocene (P15-middle P16).

SUBGENUS *Phygraea* Vyalov, 1936

Phygraea Vyalov is recognized in Australasia for the first time. This subgenus is represented in the amphinotic regions by the Cretaceous-Danian Patagonian *P. burckhardti* (Boehm), the Palaeocene-middle Late Eocene Australasian *P. tarda* (Hutton) and, as the last known representative, the specialized middle Late Eocene *P. andreai* sp. nov.

Phygraea seems to disappear in New Zealand by the Early Eocene (Mangaorapan) and in Australia by the end of the middle Late Eocene. This disappearance represents an earlier event than in the Central Tethys, where *Phygraea* survives to the end of the Oligocene, with *P. brongniarti* (Bronn) (Sacco, 1897; Buonaiuto, 1971).

Pycnodonte (Phygraea) tarda (Hutton, 1873)

FIGS. 724-743

1873 *Gryphaea tarda* Hutton, p.35.

1886 *Gryphaea tarda* -Tate, p.98, pl.6, fig.2a-b.

1897 *Gryphaea tarda* -Harris, p.303.

1914 *Gryphaea tarda* -Suter, p.47, pl.13, fig.1a,b.

1928 *Notostrea tarda* -Finlay, p.267.

1928 *Notostrea lubra* Finlay, p.267.

1928 *Notostrea tarda* -Marwick, p.462, figs. 86-96.

1965 *Ostrea (Notostrea) tarda* - Boreham, p.48, pl.13, figs.4-5.

1966 *Notostrea tarda* -Fleming, p.23, 144-45, pl.23, figs. 223-233.

1969 *Notostrea lubra* -Ludbrook, p.193, fig.2.

1970 *Notostrea lubra* -Ludbrook, *in* Lowry, p.68, fig.F.

MATERIAL. 10 LV and 2 RV from Tate Collection (SAM T 912, 916); 4 topotypes (3 LV, 14 RV) (NZGS 1177); 129 LV, 48 RV, 2 BV from outcrop material.

DESCRIPTION. Shell of medium size, very thick, very inequivalve, very inequilateral.

LV. Shell very convex; umbo squat, small to large, prosogyre; ligament area triangular of variable size oblique to vertical in relation to the hinge axis; resilifer wide, flanked by wide flattish triangular bourrelets; chomata vermiculate, well developed, sunken. Margin outlines very variable, generally convex, except the anterodorsal and posterodorsal ranging from concave to straight and convex, varying from one morph to another ; posterior margin convex to rostrate; posterior ridge from weak to very pronounced, and from subvertical to very inclined, in relation to the hinge axis; interior region smooth; pallial line marked, in inner position; muscle scar posterior high, at the level of the distal chomata; inner margin faintly ondulated, in some specimens; longitudinal section very convex; outer shell regions of variable relative width and declivity, depending on the morphae; rostrum and auricles from absent to well developed.

RV. Flat to subconcave thick, of outline varying from one morpha to another ; flanges absent to well developed; anachomata from reduced to well developed; ligament area from oblique to vertical, in relation to the hinge axis. Quenstedt's scars present in both valves.

Ornament. LV. Very adpressed growth squamae; fine growth lines; weak concentric welts and rare knobs. RV. Concentric lamellae.

OBSERVATIONS. Like other ostreid groups, this form shows a great morphological variability. The shell outline can generally be stylized as ovate, ranging from longer than high to higher than longer. The shape varies from typical gryphoid to capuliform, with all sorts of intermediate morphae (Figs. 724-743). A wide range of very irregular phenotypes are also present, one of them being even comma-like (Fig. 743d).

The name Gryphaea tarda Hutton was applied to both the Australian and the New Zealand forms until Finlay (1928) separated the two forms and instituted the name 'lubra' for the Australian one. Ortmann (1902) extended the use of the name 'tarda' to include a Late Cretaceous-Early Palaeocene Patagonian form, which Ihering (1907) and Chamacho (1968) referred to Gryphaea burckhardti Boehm. Finlay (1928) referred Gryphaea tarda Hutton to Notostrea, a genus he established for the New Zealand Ostrea subdentata Hutton (Duntroonian).

The examination of topotypes and Marwick's (1928) and Boreham's (1965) illustrations and their comparison with specimens from the acme-horizons of the Eucla, Otway and St. Vincent Basins did not reveal any significant difference in either LV or RV. On the contrary, they all appear to fall within the morphological range of the Australian forms. The differences noted by Marwick (1928) in posterior lobation, more knobby and rugose surface, and stronger hinge crenulations also appear to be of phenotypic rather than specific significance. Therefore, the Australian forms are restored to P. tarda (Hutton) and Finlay's name 'lubra' is synonymized with Hutton's.

The populations of *P. tarda* from the Eucla and St. Vincent Basin generally show a size range similar to that of the New Zealand specimens, but are smaller than those from the Otway Basin. In particular, the Browns Creek forms reach a height of 7-8 cm., about a half size more than the maximum observed in specimens from the other localities (5 cm a.)

LV sections of *G. tarda* Hutton revealed a well developed vesicular structure typical of the Pycnodonteinae (Stenzel, 1971). Chomata, very concave to gryphoid LV and flattish RV, muscle scar shape and position, adpressed growth squamae, knobs and welts place *G. tarda* in *Phygraea* Vyalov rather than in *Notostrea* Finlay. *Notostrea* significantly differs: in very shallow and simpler chomata; in muscle scar which is faint, round, and small in relation to shell size; and in shallow spoon-shaped LV ((diagnosis on a topotype of *Ostrea subdentata* Hutton (Figs. 719-20) and on Boreham's 1965 and Stenzel's 1971 illustrations and descriptions)).

Stenzel (1971) considers *Notostrea* as *incertae sedis*, possibly referable to Pycnodonteinae because of its chomata. Its taxonomic location still depends upon its unknown shell structure. Unfortunately, like Stenzel, the writer had only one topotype available, and it could not obviously be wasted for sectioning. Therefore the solution of this particular problem has to be deferred to the near future.

DISTRIBUTION. New Zealand: Chatham Island, Tioriori. Australia: Eucla Basin, Wilson Bluff, Weebubbie Cave, Abrakurrie Cave (Wilson Bluff Limestone) (Ludbrook, *in* Lowry, 1970); Otway Basin, Browns Creek (Browns Creek Formation, green sands); St. Vincent Basin, Maslin Bay, Blanche Point, Whitton Bluff, Moana Beach at Ochre Point (Blanche Point Formation, lowermost Gull Rock Member).

STRATIGRAPHIC RANGE. New Zealand: Waipawan-Mangaorapan (Palaeocene-Early Eocene). Australia: Eucla Basin; ?Middle-Late Eocene (undetermined); Otway Basin: Late Eocene, P15/16 about (McGowran, 1978a,b,c); St. Vincent Basin: Late Eocene, early to ?middle P16.

Pycnodonte (Phygraea) andreai sp. nov.

FIGS. 721-723

DERIVATION OF THE NAME. After the collector, Mr. Andrea Uzelin, Campbelltown, South Australia.

HOLOTYPE. SAM P 21259, Figs. 721-23.

TYPE LOCALITY. Blanche Point, southern slope, Willunga SubBasin.

TYPE FORMATION. Blanche Point Formation, topmost 'Soft Marl' Member.

STRATIGRAPHIC RANGE. Middle Late Eocene (late middle P16, about).

MATERIAL. The holotype only, a well preserved LV.

DESCRIPTION. Like the winged rostrate morpha of *P. tarda* (Hutton). It differs in more marked concentric growth lines and rugae, in presence of prominent fine radial costae, and in weakly crenulated inner margin.

OBSERVATIONS. This form is here separated from *P. tarda*, because of its radial costae and also because of its weakly crenulated margin. No ribbing but only a weak undulation of the inner margin has been observed in any of the specimens of *P. tarda* here examined. Therefore, such a distinction seems justified. Stenzel (1971) indicates radial ribs as the other type of ornament characteristic of *Phygraea* Vyalov.

From its stratigraphic location, *P. andreai* sp. nov. appears to be a specialized immediate descendant of *P. tarda*. The development of radial costae might be caused by gradual geographic and climatic isolation, as suggested by Sylvester-Bradley's 1977 study of the grypheid *Catinula knorri* (Voltz) and by the stratigraphic distribution of *Phygraea* in Australia.

SUBCLASS	HETERODONTA Neumayr, 1884
ORDER	VENEROIDA H. Adams & A. Adams, 1856

SUPERFAMILY CARDITACEA Fleming, 1828
FAMILY CARDITIDAE Fleming, 1828
SUBFAMILY CARDITESINAE Chavan, 1941
GENUS *Paraglans* Chavan, 1941

Paraglans latissima (Tate, 1886)

FIGS. 697-698

1886 *Cardita latissima* Tate, p.153, pl.2, fig.5.
1927 *Venericardia latissima* -Chapman & Singleton, p.118, pl.11, fig.22-23.
1973 *Glans latissima* -Ludbrook, pl.24, fig. 11-12.

MATERIAL. 2 valves (1 LV, 1 RV) badly preserved. 11 valves (7 LV, 3 RV, 1 BV) in very good preservation (type series).

DESCRIPTION. Shell thick, subquadrate, inflated, equivalve, strongly inequilateral; umbones prosogyrate, with small acute beaks; lunule convex, triangular. Margins: anterodorsal concave; posterodorsal long elliptical; anterior subelliptical short; posterior elliptical and long; ventral very long and subelliptical. Connections: all angular but more rounded the posterodorsal-posterior and the anterior-ventral.

Shell longitudinal outline very convex with maximum convexity at the posterior ridge. Regions: anterior regularly declivous; dorsal-ventral convex; posterior subconcave. Hinge heterodont with two long arched posterior teeth alternating with long arched furrows; below the umbo, a protruding triangular squat tooth separated from the posterior hinge by a long arched broad flattened triangular furrow; the anterior hinge is represented by a reduced triangular tooth separated from the central tooth by a narrow arched furrow (LV); on the RV to the furrows on the LV correspond teeth. Commissure region crenulated by squarish flat denticles, more prominent the ventral ones. Pallial line integripalliate, well marked. Hollow adductor scars: broader and pyriform the anterior; the posterior subtriangular -ovoidal and smaller . From the scars to the umbo two round rims, fainter the posterior.

Ornament. High and narrow radial ribs from 15 in the most juvenile form up to 30-32 in the older forms, separated by broader triangular deep interspaces. The ribs bear scales, occasionally developed in short spines.

OBSERVATIONS. Darragh (1971) and Ludbrook (1973) refer *P. latissima* (Tate) to *Glans* Megerle. The hinge and the shape of the margin interspaces allow this form to be better referred to *Paraglans* Chavan. The name of the subfamily in the Treatise (Moore, 1969, p. N, p.556) appears in two spellings: in the text as CARDITESINAE; in the fig. E56 and E57 as GLYPTOACTININAE. Here, the spelling in the text is adopted.

The above diagnosis is chiefly based on Tate's typic series (S.A. T 1130 A-L, where the specimen T 1130 A is the holotype).

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide Bore; Willunga SubBasin, Blanche Point.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation (P15-middle P16).

ORDER	MYOIDA Stoliczka, 1870
SUBORDER	MYINA Stoliczka, 1870
SUPERFAMILY	MYACEA Lamarck, 1809
FAMILY	CORBULIDAE Lamarck, 1818
SUBFAMILY	CORBULINAE Gray, 1823
GENUS	*Corbula* Bruguière, 1797
SUBGENUS	*Caryocorbula* Gardner, 1926

Corbula (Caryocorbula) pixidata (Tate, 1887)

FIGS. 699-701

1887 *Corbula pixidata* Tate, p.177, pl.17, fig.12a,b.

MATERIAL. 1 right valve, well preserved.

DESCRIPTION. Shell, small, thick, subtrapezoidal, inequivalve - LV smaller than RV - very inequilateral; umbones prosogyrate with small and acute beaks. Margins: anterodorsal rather short, straight; posterodorsal straight and long; anterior very short and subelliptical; posterior very short and subconcave; ventral long and elliptical. Margin connections: anterior-posterodorsal, imperceptible; posterior posterodorsal, angular; anterior-ventral round; posterior-ventral very angular, producing a rostrum.

Shell longitudinal outline: subtrapezoidal. Regions: anterior narrow and very steep; dorsal very broad and convex; ventral narrow and subvertical; posterior concave in the anterodorsal part, flat and subvertical in the posteroventral; a concentric rim divides the former part from the latter, and the dorsal from the ventral region. The posterior ridge is represented by a sharp carina ending into a rostrum. Hinge very reduced with a single straight triangular and high tooth just below the umbo RV. corresponding to a simple sinus in LV. RV commissure region smooth generally narrow with a broadening at the rostrum separated from the interior by a step accommodating the LV margins. Pallial line integripalliate or with imperceptible sinus, given by a broad faint groove; adductor scars well marked, the posterior broader and high.

Ornament. Concentric round costae with narrower interspaces; very faint and fine radial grooves; both fading in the posterior region.

OBSERVATIONS. The reduced hinge and pallial sinus allow this form to be referred to the subgenus *Caryocorbula* Gardner. Ludbrook (1973) also refers this form to *Caryocorbula* Gardner, but Darragh (1971) to *Notocorbula* Iredale.

The above diagnosis is based also on the Tate typic series (SAM T 312A-M, where T 312F is the holotype).

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town)Bore. Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Blanche Point Formation. Late Eocene (late P15-middle P16).

OBSERVATIONS. Dennant & Kitson (1903) record C. pixidata from several southern Australian localities which are of a much younger age. Because no comparative material was available the stratigraphic range of this species is conservatively restricted to the Late Eocene, pending further studies.

SUPERFAMILY	HIATELLACEA Gray, 1824
FAMILY	HIATELLIDAE Gray, 1824
GENUS	Hiatella Bosc (ex Daudin), 1801)
SUBGENUS	Hiatella s. str.
	Hiatella (Hiatella) ?vera (Deshayes, 1824)

FIGS. 702-704

?1767 Mya arctica Linné, p. 3220.

?1824 Saxicava vera Deshayes, p.170, pl.10, figs. 15-17 (non vidi)

?1866 Saxicava vera -Deshayes, p.170, pl.10, figs.15-17.

1886 Saxicava australis -Tate, pl.12, fig.8.

1887 Saxicava arctica -Tate, p.178.

?1969 Hiatella (Hiatella) arctica -Keen (in Moore), p. N700, fig.E61, 1a-d.

MATERIAL. 139 moulds (89 RV, 49 LV); 13 specimens from Tate Collection (SAM T 853 A-M) (AUDG 1544 A-E) (6 LV, 7 RV).

DESCRIPTION. Shell small, thin, trapezoidal, inflated, very inequilateral: umbo small with very prosogyrate beaks; Margins subelliptical, postero-dorsal and ventral very long; anterior and posterior short; anterodorsal very short. Margin connections: very angular, anterior-anterodorsal imperceptible.

Shell longitudinal section subtrapezoidal. Regions: posterior broad, subconcave to subconvex, declivous; dorsoventral very broad, subconcave to convex, more declivous; posterodorsal very narrow, vertical; anterior very narrow very convex subvertical. Region connections: all angular represented by a ridge. LV hinge rudimental with 1 tooth cardinal and two sockets, the overgrowth of the nymph covering the rest of the hinge.

Scars triangular-ovate and marginal; anterior smaller, depressed, just above the anteroventral connection; posterior faint just below the hinge, rather near the posterior-posterodorsal connection. Interior region with irregular concentric costae. Pallial sinus marked with irregular outline on the posterior. Commissure region smooth posteriorly striated.

Ornament. Irregular growth lamellae. In some specimens the posterior and the posterodorsal-posterior ridges bear a series of spines.

OBSERVATIONS. *Hiatella arctica* Linné is the type species of *Hiatella*. In the general opinion of previous authors this subgenus is monotypic and its type species may represent a living fossil.

The oldest records of this species are the small form of *H. vera* (Deshayes) and *H. jeurensis* (Deshayes) (5-6 mm length) from the Middle Eocene and Oligocene Paris Basin, and the form described by Tate (1886) as *H. australis/arctica* from the Late Eocene St. Vincent Basin. The still living *H. arctica* (Linné) and *H. australis* (Lamarck) are sometime separated or sometime grouped together by previous authors. After Hunter's revealing study (1949), the taxonomy of this species was completely reviewed from the standpoint of its discovered great phenotypic variability. The revision culminated in 53 names synonymized with *H. arctica* by Dell (1964).

Strauch (1968) contributed fundamentally to a further and better understanding of this species by demonstrating the inverse relationship between water temperature and shell size: 'the adult size attained by Hiatella increases gradually with falling temperatures, at first gradually but at winter temperatures of 2-3° sharply'.

It is now agreed that Hiatella is represented in the Northern hemisphere only by H. arctica, as a living and as a fossil form. In the Southern hemisphere Dell (1964) maintained, although with some doubts, the names of H. solida (Sowerby) for the antarctic and subantarctic forms on the basis of a longer retention of hinge teeth in senile stages and H. australis (Lamarck) for the Australian ones on the basis of shell size. The later study by Strauch would synonymize H. solida to H. arctica (Beu, 1969). Beu (ibid.) however, maintains as valid H. australis Lamarck for the Australian forms. Here, no opinion is reached. H. subalata (Gatliff & Gabriel) (McPherson & Gabriel, 1962, p.379, fig.446) should be synonimized to H. arctica/australis because it falls within their phenotypic variability.

As far as the Eocene forms are concerned, the following possibilites should be considered:

1) Hiatella a) did not change, b) did change throughout the Tertiary up to now;
2) Behaviour and geographical distribution a) remained constant, b) did not remain constant through time.

Strauch's study and the length of the Australian Eocene form, longer than the coeval warmer Parisian one, should exclude the possibility 2b), but cannot discharge completely the possibility 1b). The great phenotypic variability does not allow for the existence or the absence of an evolutionary trend or differentiation to be ascertained in the lineage of this species. In a conservative fashion, the Australian Late Eocene form is tentatively referred to H. vera (Deshayes), but the question of the validity of this name versus *H. arctica/australis* is left open and the necessity of a comparative study of fossil and living forms from the different known localities is here urged.

As from above, *H. jeurensis* (Deshayes) could be synonymized to either *H. vera* or *H. arctica/australis*, depending on which name is valid. *Hiatella arctica/australis* is found from intertidal to very shallow waters in tropical and temperate waters (Strauch, 1968; Cotton, 1956; McPherson and Gabriel, 1962), from 0 down to 2000 m in cold waters (Strauch, 1968; Dell, 1964).

The habitat is of two types (Hunter, 1949): non boring but byssally attached into an empty shell (*Solen*, barnacles, *Venerupis*, *Mytilus*, etc.) or in the root clusters of *Laminaria* or boring only in relatively soft rocks with acid-soluble cement. The unworn posterior ridges of the Adelaide Bore specimens suggest a non-boring habitat.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin and Aldinga Bays.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation.

OBSERVATIONS. Due to the taxonomic difficulties outlined above, no other locality or stratigraphic information is further given on this species.

SUBORDER	PHOLADINA H. Adams & A. Adams, 1858
SUPERFAMILY	PHOLADACEA Lamarck, 1809
FAMILY	PHOLADIDAE Lamarck, 1809
SUBFAMILY	JOUANNETIINAE Tryon, 1862
GENUS	*Jouannetia* Des Moulins, 1828
SUBGENUS	*Pholadopsis* Conrad, 1849
	Jouannetia (Pholadopsis) cuneata (Tate, 1887)

FIGS. 705-708

1887 Jouannetia cuneata Tate, p.183, pl.17, fig. 2.

MATERIAL. 1 mould of bivalve shell. Holotype and paratype (SAM T 350 A-B).

DESCRIPTION. Shell thin, rostrate, very inflated, very inequilateral and inequivalve; from the LV the undivided callum envelopes the anterior part of the RV without adhering to it; umbonal-ventral sulcus very fine; posterior ridge round well marked; umbonal reflection rather broad and long. Margins: anterodorsal and posterodorsal short and subelliptical; anterior long a very elliptical; ventral not preserved; posterior long and subelliptical. Margin connections: anterior-anterodorsal angular; anterior-ventral imperceptible; posterior-ventral very angular; posterior-posteroventral slightly angular. Regions anteroventral very convex; dorsoventral concave and V-shaped; posterior declivous and subconcave.

Ornament. Very fine and high concentric costae with far broader interspaces; very fine and faint radial microriblets.

OBSERVATIONS. The above diagnosis is based on Tate's badly preserved holotype (S.A. T 350). The undivided callum and the general outer shape allow this form to be referred to the subgenus Pholadopsis Conrad.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin Bay at 'Uncle Tom's Cabin'.

STRATIGRAPHIC RANGE. Tortachilla Limestone Blanche Point Formation. Late Eocene (P15-middle P16).

SUBCLASS	ANOMALODESMATA Dall, 1889
ORDER	PHOLADOMYOIDA Newell, 1965
SUPERFAMILY	CLAVAGELLACEA d'Orbigny, 1843
FAMILY	CLAVAGELLIDAE d'Orbigny, 1843

This family was recently revised by L.A. Smith (1962a,b), by L.A. Smith & M. Keen (in Moore, 1969), and by B.J. Smith (1971, 1974). However, its classification at generic and specific level still remains uncertain (B.J. Smith, 1971, pp. 135-6).

GENUS Clavagella Lamarck, 1818

SUBGENUS Clavagella s. str.

Clavagella (Clavagella) lirata (Tate, 1887)

FIGS. 709-712

1887 Aspergillum (Humphreya) liratum Tate, p.184, pl.19, fig.11 (*pars*)

1972 Clavagella (Clavagella) multiangularis -Smith, p.137, pl.10, fig. 3 (*pars*)

1976 Clavagella (Clavagella) multiangularis -Smith, p.188, fig.3.

MATERIAL. The Holotype (SAM T 323); two fragments of sacculus (SAM T 322 A-B); 3 moulds (SAM T 322C-E); 31 moulds from outcrops.

DESCRIPTION. Shell thin, fragile, siphonal part of the tube, elongate, straight, subcircular in section. Thin irregular tubules at the anterior end of the sacculus. Sacculus rather compressed at the anterior end. Tubules on the anterior end present.

Ornament. 6 faint axial costellae on the tube.

OBSERVATIONS. B.J. Smith (1971) transferred this form to Clavagella Lamarck s. str. and synonymized it to C. multiangularis (Tate, 1887, non 1886). Direct comparison between topotypes of the extant C. multiangularis (Tate, 1887, p.64, pl.4, fig.4a-b) and the specimens of C. lirata revealed the following differences in the latter: tube octagonal to enneagonal section, narrower and curved tube, 8-9 axial costae, costae interspaces concave to falt; tube -sacculus connection - sharp and narrow; sacculus - longer and narrower; thinner shell.

Although B.J. Smith (1971) considers the number of the costae variable, on the basis of the other differences, it appears more appropriate to restore C. lirata as a distinct species.

C. lirata has been a composite species since its institution. The original specimens mentioned by Tate (1887) are from the Late Eocene localities Adelaide Bore (SAM T 323, 322 A-B) and Aldinga (Maslin Bay) (SAM T 322 C-E), and from the Miocene Murray River (near Morgan) and Muddy Creek (SAM T 322 F-H). The Miocene specimens bear the same number of axial costae as *C. lirata* but they appear to be closer to the extant *C. multiangularis* in shell thinness, size, in more marked sacculus/tube connection, and in sacculus shape. On the basis of these differences, they probably represent a species distinct from both the Late Eocene and the extant forms. However, the preservation and the paucity of the material available discourages its formal institution at this stage.

This Miocene form, *C. lirata* and *C. multiangularis* seem to constitute a homogeneous group and they may represent a discrete lineage as suggested by the ornament. An Early Miocene form, observed in the field in the Puebla Formation (Bird Rock, Torquay Embayment) may belong to this group.

DISTRIBUTION. St. Vincent Basin: Adelaide Plains SubBasin, Adelaide (Kent Town) Bore. Willunga SubBasin, Maslin Bay.

STRATIGRAPHIC RANGE. Tortachilla Limestone - Blanche Point Formation. Late Eocene (P15-middle P16).