Oligocene and Miocene larger Foraminiferida from Australia and New Zealand

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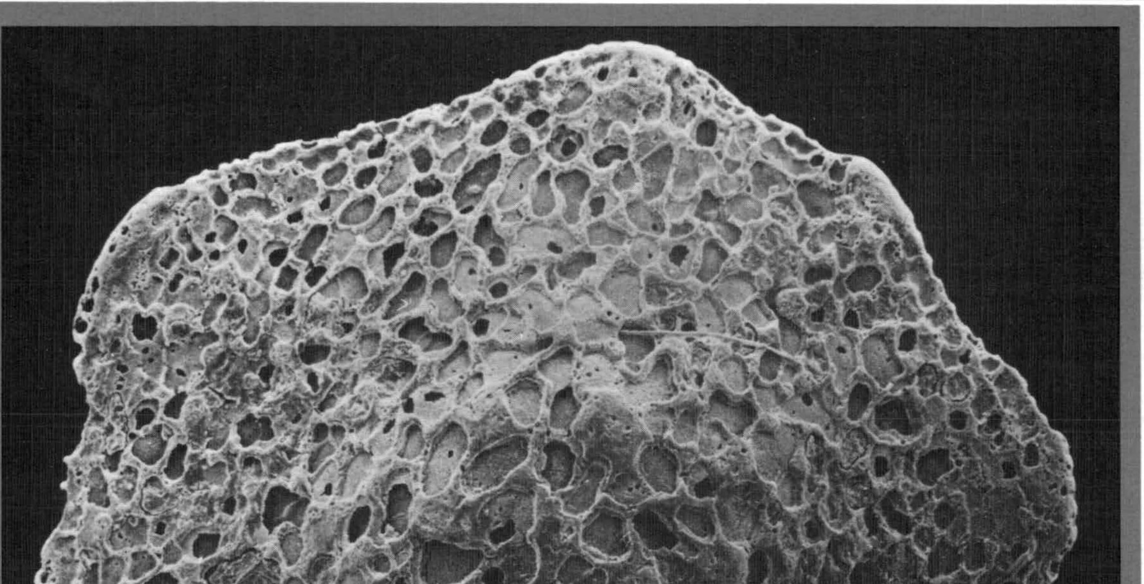
188

G. C. H. Chaproniere



DEPARTMENT OF RESOURCES AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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GEORGE C. H. CHAPRONIERE

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Cover: *Lepidocyclina (Nephrolepidina) howchini howchini* Chapman & Crespin, 1932; topotype (CPC21583) ×45 from Hamilton, Victoria.

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ABSTRACT

The lithostratigraphy and biostratigraphy, and the systematics, of larger foraminiferids at several Late Oligocene to Middle Miocene localities in Australia are described. In particular, sediments of this interval in the North West Cape area of the Carnarvon Basin, Western Australia, have yielded diverse faunas of larger and planktic foraminiferids. Sections studied and sampled elsewhere were Ashmore Reef No. 1 well in the Bonaparte Gulf Basin; Gage Roads No. 2 well in the Perth Basin; the Batesford and Bochara Limestones in Victoria; Wreck Island No. 1 well in Queensland; and the Tutamoe, Puketi, and Waitiiti Formations, the Waikuku Limestone, the Stillwater Mudstone, and the Orakei Greensand Member of the East Coast Bays Formation, all in New Zealand.

Forty species and subspecies, representing 25 genera or subgenera of larger foraminiferids, have been recorded. Wherever possible, biometric methods have been used to discriminate between taxa. Such studies suggest that the rates of evolution of some groups of larger foraminiferids in New Zealand were different from those in the Australian region. Among the taxa that are illustrated and described in detail are two subspecies of *Lepidocyclina* (*Nephrolepidina*) proposed as new: *Lepidocyclina* (*Nephrolepidina*) *howchini praehowchini* and *Lepidocyclina* (*Nephrolepidina*) *orakeiensis waikukuensis*. Topotypes of *L.* (*N.*) *orakeiensis hornibrooki* and *L.* (*N.*) *howchini howchini* have been discussed and figured.

INTRODUCTION

This work represents the taxonomic part of a series of papers on mid-Tertiary larger foraminiferids from Australia and New Zealand. In the earlier papers (Chaproniere, 1975, 1980a,b, 1981b) various aspects (e.g., palaeoecology and biometrics) were investigated, but, with one exception, nomenclature concepts were not described. The purpose of this Bulletin is to give this information.

Larger foraminiferids are mainly a highly variable group of organisms, a feature which poses many problems for taxonomy. This has resulted in a large number of names being applied to particular morphotypes. Studies that I have made have shown that many of the morphotypes are part of a continuous variation within a single species population (Chaproniere, 1980a). Thus, for example, where Crespin (1955a; table 6) listed 17 species of *Lepidocyclina* in three subgenera from the Mandu Calcarenite and Tulki Limestone in the North West Cape area (see Figs. 1,4), only two subspecies, two species, and two subgenera are recognised in this work.

Though this study is centred on the North West Cape area of Western Australia (Fig. 1), sections from elsewhere in Australia (Fig. 1) and New Zealand (Fig. 2) have been used for biostratigraphic and taxonomic comparison. In addition, topotypic material of *Lepidocyclina* (*Nephrolepidina*) *howchini howchini* Chapman & Crespin from the Hamilton Bore (Hamilton, Victoria) and of *L.* (*N.*) *orakeiensis hornibrooki* Matsumaru from Alexander Street, Greymouth, New Zealand, together with some specimens of *L.* (*N.*) *orakeiensis orakeiensis* (Karrer) from near its type locality (Takaparawha Point, Auckland, New Zealand), have been incorporated.

The larger foraminiferal associations referred to in this work are those of Chaproniere (1975, 1981b).

Areas studied and locations of samples

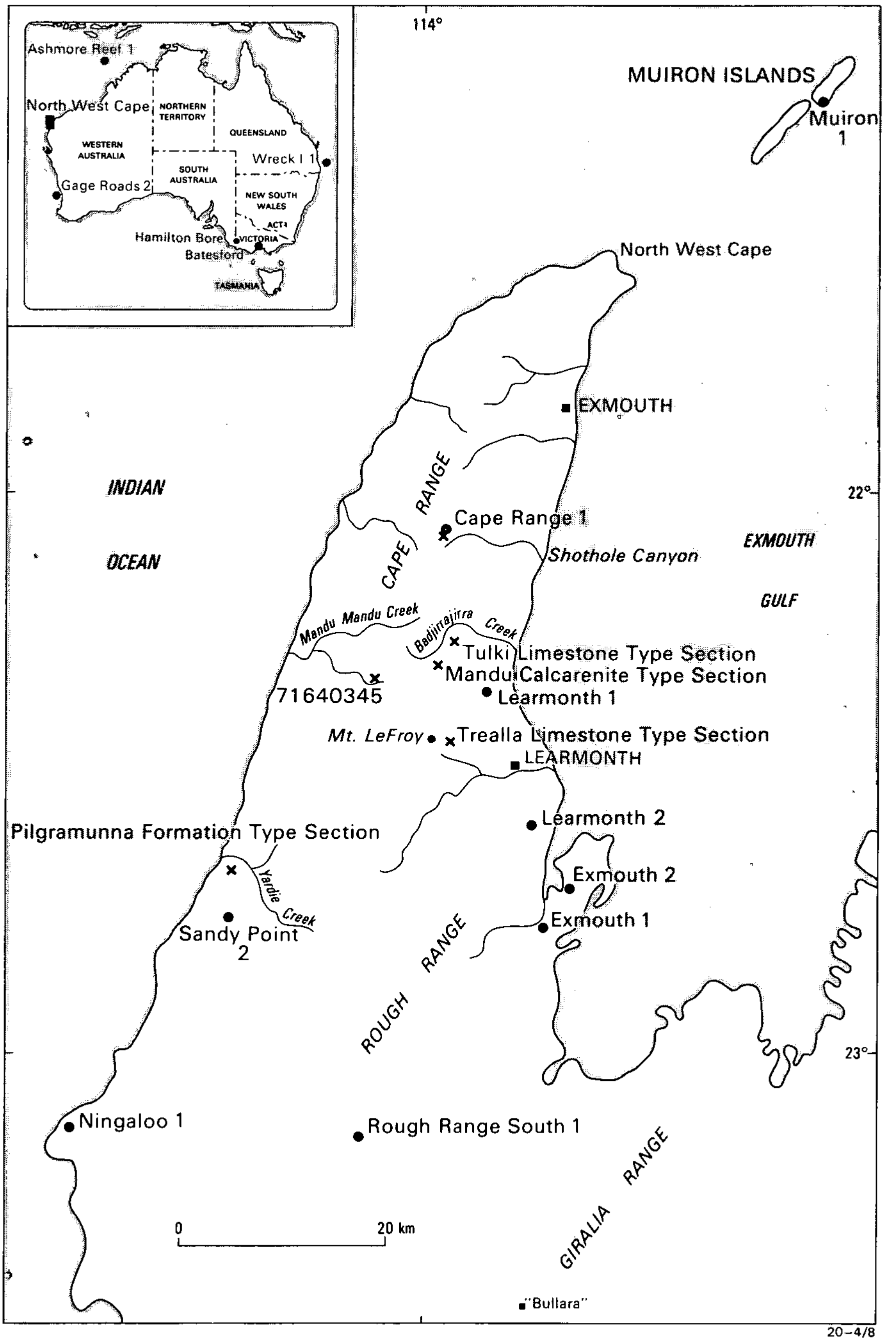
Figures 1 and 2 show the locations of the areas studied in Australia and New Zealand, and Figure 3 relates biostratigraphic and lithostratigraphic occurrences. Full locality details are given in Appendixes 2 and 4. The samples studied are from nine wells and seven surface sections in the North West Cape area (Fig. 1) of the Carnarvon Basin, from Ashmore Reef No. 1 well in the Bonaparte Gulf Basin (Fig. 1), and from Gage Roads No. 2 well in the Perth Basin (Fig. 1), in Western Australia; from Batesford Quarry in the Otway Basin of Victoria (Fig. 1); and from Wreck Island No. 1 well in the Capricorn Basin of Queensland (Fig. 1). Samples were studied from Hukatere Peninsula in Kaipara Harbour, from Hokianga South Head in Hokianga Harbour, and from Waikuku Beach at North Cape, all from Northland, New Zealand; in addition a sample from Poanui Beach—near Pourerere, south of Hawkes Bay—one from the Alexander Street cutting in Greymouth, and one from Takaparawha Point in Auckland Harbour (Fig. 2) were also examined. Lithostratigraphic and biostratigraphic summaries, together with sample locations for the subsurface and surface sections from the North West Cape area and Ashmore Reef No. 1 well, are given in Appendix 4.

Distribution charts (Figs. 3 to 6) list all the larger foraminiferids identified from most of the samples studied. Five samples (77640513, 79640006, 77640025, 79640027, and UWA72224) have been omitted from the distribution charts because they represent either isolated samples or populations of a single taxon; instead, a faunal list is supplied where appropriate in the stratigraphic column.

All samples studied, as well as type and figured specimens, have been given numbers (see Appendixes 2 and 3 for a full listing): those prefixed by UWA are stored in the collections of the Department of Geology, University of Western Australia; and those without a prefix or prefixed by MF are stored in the collections of the Bureau of Mineral Resources, Canberra. All types have been given separate numbers: those stored at the Department of Geology, University of Western Australia, are prefixed by UWA; those stored in the Commonwealth Palaeontological Collection in the Bureau of Mineral Resources are prefixed by CPC; those stored in the collections of the Department of Geology, University of Auckland, New Zealand, are prefixed by F; and those stored in the collections of the New Zealand Geological Survey are prefixed NZGSTF. Some paratypes will be stored in the ESCAP collection at the Bureau of Mineral Resources, or at the New Zealand Geological Survey, Lower Hutt. All faunas studied have been given the same number as the sample from which they came.

Taxonomic approach

Because of the great morphologic variation observed in larger foraminiferids and because in certain groups some characters evolve with time, a biometric approach has been used wherever possible. This work draws heavily on the biometric work of Chaproniere (1980a) for those groups which clearly show measurable evolutionary change. For those where such study is limited or cannot be made, the traditional taxonomic approach has been used.



● *Subsurface Section (WAPET well)* × *Surface Section*

Fig. 1. Sample localities, North West Cape; rest of Australia (inset).

Definitions

The so-called 'larger foraminiferids' are not a separate taxonomic entity, but are scattered through several superfamilies and most are closely related to smaller forms. The term is used in this work to differentiate those foraminiferids that have complex arrangements of chambers which are best studied by means of thin-sections or X-ray techniques. Many 'simpler forms' (those with a normal pattern of growth) grow to large sizes. However, because they lack the complicated test morphology they are normally regarded simply as 'smaller benthics'. The term 'orbitoids' has

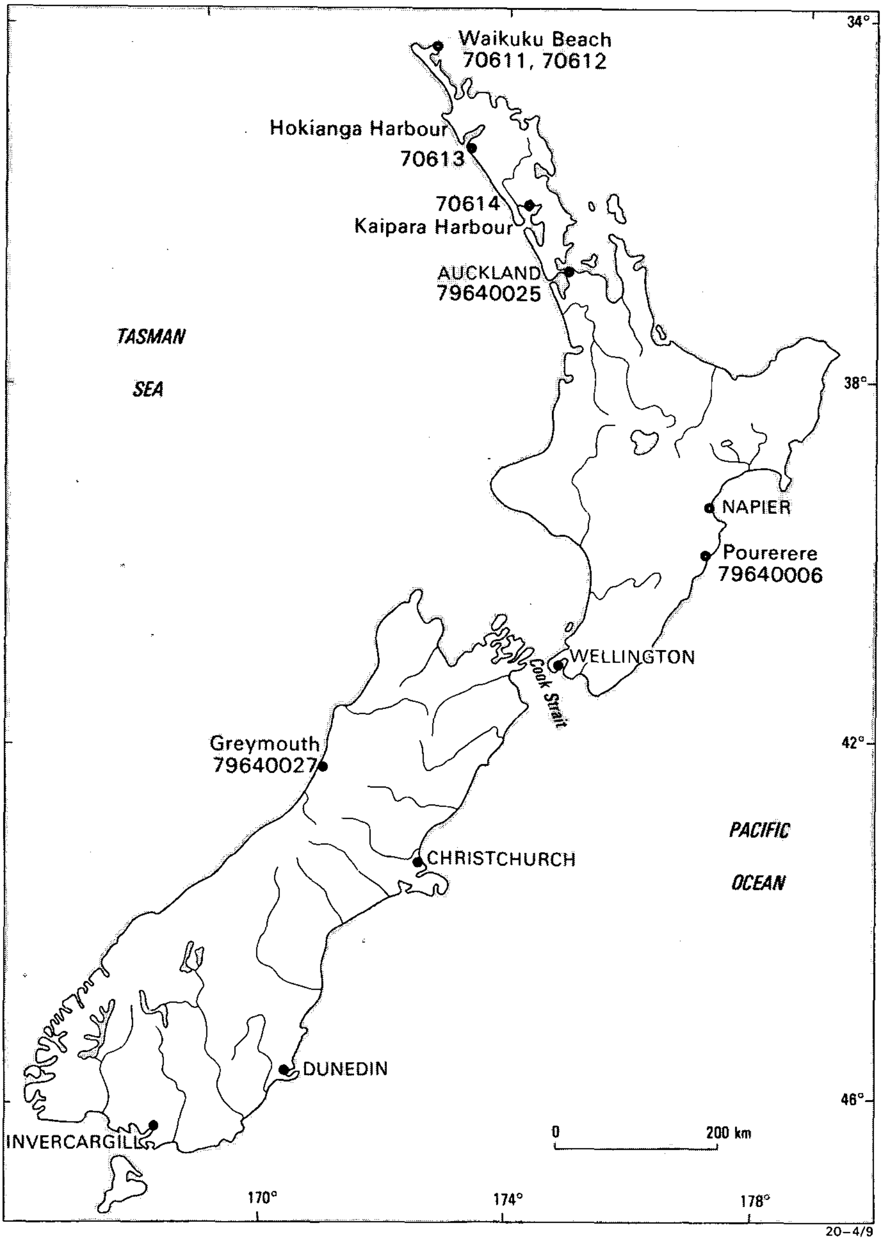


Fig. 2. Sample localities, New Zealand.

LOCALITY	Batesford	Rough Ra	Shothole Canyon						Mount LeFroy							Trealla Limestone Type Section											Rough Range South 1						Mandu Calcarenite Type Section																Tulki Limestone Type Section										
UWAGD Catalogue Number TAXON	10653	51524	51886	51887	51888	51889	51890	51891	51892	51893	51894	51895	51896	51897	51898	51899	51900	51901	51902	51903	51904	51905	51906	51907	51908	51909	53673	53674	53675	53676	53677	53678	68307	68308	68309	68310	68311	68312	68313	68314	68315	68316	68317	68318	68319	68320	68321	68322	68323	68324	68325	68326	68327	68328	68329	68330	68331	68332	68333
MILIOLINA																																																											
Miliolacea																																																											
Austrotrillina																																																											
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sp.		×																							×		×	×																															
Spirolina																																																											
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Sorites																																																											
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Marginopora																																																											
vertebralis		×							?	?			?	?								×	×	×	×	×	×	?																															
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pygmaeus		?																					×		×	×		×																															
Flosculinella																																																											
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bontangensis globulosa																																																											
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Textulariina undiff.		×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×				×	×	×		×	×	×		×	×			×		×	×			×			×	×	×	×	×	×		×	×	×	×	×	×
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Rotaliacea																																																											
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cf. *carpenteri*										×					?	×																																											
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cf. *annulatus*			×																×																																								
Heterostegina																																																											
borneensis																												×																															
suborbicularis					?																																																						
Spiroclypeus																																																											
cf. *margaritatus*		×																																																									

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Fig. 3a. Distribution charts for larger foraminifera—1.

LOCALITY	Batesford	Rough Ra	Shothole Canyon						Mount LeFroy							Trealla Limestone Type Section											Rough Range South 1						Mandu Calcarenite Type Section																Tulki Limestone Type Section										
UWAGD Catalogue Number TAXON	10653	51524	51886	51887	51888	51889	51890	51891	51892	51893	51894	51895	51896	51897	51898	51899	51900	51901	51902	51903	51904	51905	51906	51907	51908	51909	53673	53674	53675	53676	53677	53678	68307	68308	68309	68310	68311	68312	68313	68314	68315	68316	68317	68318	68319	68320	68321	68322	68323	68324	68325	68326	68327	68328	68329	68330	68331	68332	68333
Miogypsina (Miogypsina)																																																											
globulina																																																											
intermedia																																																											
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dehaarti																																																											
Orbitoidacea																																																											
Amphistegina																																																											
bikiniensis																												×	×	×	×	×																											
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septentrionalis																																																											
Gypsina																																																											
globulus	×			×	×	×	×	×	×	×	×	×	×	×	×	×	×		×			×	×	×	×			×												×		juv		juv		×	×	×	×	×	×			×	×	×	×	×	×
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sp.																																								×																			
Halkyardia																																																											
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Victoriella																																																											
conoidea																																																											
Biarritzina																																																											
alternata																																?	?	×	?	×	×	×		?	×	?		?			×	×				×			?				
carpenteriaeformis																																			×					×	×			×								×							
proteiformis		cf.			cf.																																																						
Lepidocyclina (Eulepidina)																																																											
badjirraensis																																							juv			×	×	×	×	×			×										
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Rotaliidae undiff.	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×				×	×			×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

20–4/48

Fig. 3b. Distribution charts for larger foraminifera—I.

LOCALITY	Tulki Limestone Type Section							Trealla Limestone Type Section						GR 2	Various Localities Badjirrajirra Creek								Shothole Canyon					
TAXON \ UWAGD Catalogue Number	68334	68335	68336	68337	68338	68339	68340	68342	68343	68344	68345	68346	68347	70433	70469	70470	70471	70472	70473	70474	70475	70476	70477	70478	70479	70480	70481	70482
MILIOLINA																												
Miliolacea																												
Austrotrillina																												
howchini						x			x		x	x																
striata																												
Lacazinella																												
cf. *wichmanni*																												
Peneroplis																												
sp.													x															
Spirolina																												
sp.																												
Sorites																												
sp.																												
Marginopora																												
vertebralis					x	x	x		x	x	x	x	x															
Borelis																												
pygmaeus												x	x															
Flosculinella																												
bontangensis bontangensis												x	x															
bontangensis globulosa																												
Miliolina undiff.	x	x		x	x	x	x	x	x		x	x	x					x	x						x			
Textulariina undiff.	x	x	x	x	x	x	x		x		x	x	x		x	x	x	x	x	x	x	x		x			x	
ROTALIINA																												
Rotaliacea																												
Operculina																												
complanata	x	x	x	x	x	x	x	x		x	x	x			x	x		x	x	x	x	x	x	x	x	x	x	x
Operculinella																												
venosa											x					x												
Cycloclypeus (Cycloclypeus)																												
eidae															x	x	x	x		x	x	x	x	x	x	x	x	juv
cf. *eidae*	x	x	x	x															x									
carpenteri																												
cf. *carpenteri*					x		x	x	x	x																		
Cycloclypeus (Katacycloclypeus)																												
cf. *annulatus*			?				x	x																				
Heterostegina																												
borneensis																												
suborbicularis																	x											
Spiroclypeus																												
cf. *margaritatus*																												

LOCALITY	Ningaloo 1												Sandy Point 2										Cape Range 1					Muiron 1				
TAXON \ UWAGD Catalogue Number	70485	70486	70487	70488	70489	70490	70491	70492	70493	70494	70495	70496	70501	70503	70504	70505	70506	70507	70508	70509	70510	70511	70532	70533	70534	70535	70536	70555	70556	70557	70558	70559
MILIOLINA																																
Miliolacea																																
Austrotrillina																																
howchini													x																			
striata																																
Lacazinella																																
cf. *wichmanni*																																
Peneroplis																																
sp.																																
Spirolina																																
sp.																																
Sorites																																
sp.																																
Marginopora																																
vertebralis													x																			
Borelis																																
pygmaeus																																
Flosculinella																																
bontangensis bontangensis																																
bontangensis globulosa																																
Miliolina undiff.		?	x		x			x	x	x		x		x			x	x				x	x									
Textulariina undiff.												x			x		x	x					x		x	x	x		x			
ROTALIINA																																
Rotaliacea																																
Operculina																																
complanata			x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x			x	x	x		x	x
Operculinella																																
venosa						x			x																							
Cycloclypeus (Cycloclypeus)																																
eidae								x	x	x	x												x	x	juv	juv	juv					
cf. *eidae*																																
carpenteri		x		x		x	x													x												
cf. *carpenteri*														x	x	x	x	x	x									x	x			
Cycloclypeus (Katacycloclypeus)																																
cf. *annulatus*																																
Heterostegina																																
borneensis																																
suborbicularis																																
Spiroclypeus																																
cf. *margaritatus*																																

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Fig. 4a. Distribution charts for larger foraminifera—II.

LOCALITY	Tulki Limestone Type Section							Trealla Limestone Type Section						GR 2	Various Localities Badjirrajirra Creek								Shothole Canyon						Ningaloo 1												Sandy Point 2										Cape Range 1					Muiron 1				
TAXON / UWAGD Catalogue Number	68334	68335	68336	68337	68338	68339	68340	68342	68343	68344	68345	68346	68347	70433	70469	70470	70471	70472	70473	70474	70475	70476	70477	70478	70479	70480	70481	70482	70485	70486	70487	70488	70489	70490	70491	70492	70493	70494	70495	70496	70501	70503	70504	70505	70506	70507	70508	70509	70510	70511	70532	70533	70534	70535	70536	70555	70556	70557	70558	70559
Miogypsina (Miogypsina)																																																												
globulina																																																												
intermedia																																																												
Miogypsina (Lepidosemicyclina)																																																												
thecideaeformis																				x																																								
cf. *thecideaeformis*					x	x		x											x																										x															
Miogypsina (Miogypsinoides)																																																												
dehaarti																																				x		x	x																					
Orbitoidacea																																																												
Amphistegina																																																												
bikiniensis																																																												
hauerina	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x			x	x				x	x	x	x	
Borodinia																																																												
septentrionalis						x													x																																									
Gypsina																																																												
globulus	x		x	x	x		x	x	x	x	x	x	x			x	x	x	x	x		x						juv		x	x	x			x	x	x			x		x			x	x	x	x		x						x				
howchini	x	x			x	x	x	x	x	x	x	x																												x					x		x													
mastaelensis				?								x	x																																															
sp.																																																												
Halkyardia																																																												
cf. *minima*																																																												
Victoriella																																																												
conoidea																																																												
Bierritzina																																																												
alternata																x	x									x																x								x										
carpenteriaeformis															x		x	x																								x						x		x										
proteiformis																																										x																		
Lepidocyclina (Eulepidina)																																																												
badjirraensis															x	x	x				x			?	x	x	x																								x									
ephippioides																																																												
Lepidocyclina (Nephrolepidina)																																																												
howchini howchini														x																x	x	x	x	x											x	x	x	x		x		x	x	x						
howchini praehowchini															x	x	x	x		x	x	x													x	x	x	x	x	x																				
howchini s.l.	x	x	x	x	x	x	x	x	x	x	x	x							x										juv													x	x	x												x	x	x		x
japonica																																																												
orakeiensis orakeiensis																																																												
orakeiensis waikukuensis																																																												
sumatrensis																																																												
Discorbidae undiff.	x	x	x	x	x	x		x	x	x	x	x			x	x	x	x	x	x	x	x			x	x		x				x	x	x	x	x	x			x			x	x	x	x	x	x		x		x	x	x	x			x		
Elphidiidae undiff.																x	x	x		x	x	x			x	x			x	x	x	x		x	x		x	x				x			x	x	x	x		x	x		x	x	x	x	x	x	x	
Rotaliidae undiff.	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

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Fig. 4b. Distribution charts for larger foraminifera—II.

LOCALITY	Learmonth 1						Learmonth 2		Exmouth 1			Exmouth 2											RRS 1		Ashmore Reef 1									New Zealand				GR 2	W Is 1	Badj. Creek	AR 1	Mandu Calr Type Section				Tulki Limestone Type Section									Mt LeFroy	Various Localities Cape Range				
TAXON / UWAGD / BMR Catalogue No.	70564	70565	70566	70567	70568	70569	70573	70574	70577	70578	70579	70586	70587	70588	70589	70590	70591	70592	70593	70594	70595	70596	70599	70600	70601	70602	70603	70604	70605	70606	70607	70608	70609	70611	70612	70613	70614	72223	72224	72225	72226	CR113	CR114	CR117	CR118	CR6	CR7	CR9	CRC3	CRC4	CRC5	CRC6	CRC7	CRC8	CR83	CR12	CR13	CR24	CR28	CR46
MILIOLINA																																																												
Miliolacea																																																												
Austrotrillina																																																												
howchini																																																							×			?		×
striata																																																												
Lacazinella																																																												
cf. *wichmanni*																					×																																							
Peneroplis																																																												
sp.													×	×																																														×
Spirolina																																																												
sp.																																																												
Sorites																																																												
sp.																		×																																										
Marginopora																																																												
vertebralis																																									×															×	×			×
Borelis																																																												
pygmaeus																								×																																				
Flosculinella																																																												
bontangensis bontangensis												×																																															×	×
bontangensis globulosa													×	×																																														
Miliolina undiff.			×				×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×						×											×		×		×	×		×	×		×	×	×	×	×	×	×	×		×
Textulariina undiff.								×				×	×	×	×			×				×	×	×								×	×								×	×			×	×			×			×	×	×						
ROTALIINA																																																												
Rotaliacea																																																												
Operculina																																																												
complanata	×		×	×	×	×	×	×		×	×							×	×	×	×	×		×		×	×	×	×	×	×	×	×	×	×		×			×	×	×					×	×	×	×	×	×	×	×	×					×
Operculinella																																																												
venosa				×																					×																														×					
Cycloclypeus (Cycloclypeus)																																																												
eidae	×	×	×	×																								×	×	×			×							×																				
cf. *eidae*																																										×	×	×		×	×			×	×	×		×						
carpenteri																									×		×							×	×				×		×																			
cf. *carpenteri*																																																×							×					×
Cycloclypeus (Katacycloclypeus)																																																												
cf. *annulatus*																																																												
Heterostegina																																																												
borneensis							×		×	×	×						×			×	×	×		×										×	×	×	×																							
suborbicularis																																																												
Spiroclypeus																																																												
cf. *margaritatus*																																																												

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Fig. 5a. Distribution charts for larger foraminifera—III.

LOCALITY	Learmonth 1						Learmonth 2		Exmouth 1			Exmouth 2											RRS 1		Ashmore Reef 1									New Zealand				GR 2	W Is 1	Badj. Creek	AR 1	Mandu Calr Type Section				Tulki Limestone Type Section									Mt LeFroy	Various Localities Cape Range				
TAXON / UWAGD / BMR Catalogue No.	70564	70565	70566	70567	70568	70569	70573	70574	70577	70578	70579	70586	70587	70588	70589	70590	70591	70592	70593	70594	70595	70596	70599	70600	70601	70602	70603	70604	70605	70606	70607	70608	70609	70611	70612	70613	70614	72223	72224	72225	72226	CR113	CR114	CR117	CR118	CR6	CR7	CR9	CRC3	CRC4	CRC5	CRC6	CRC7	CRC8	CR83	CR12	CR13	CR24	CR28	CR46
Miogypsina (Miogypsina)																																																													
globulina																																				x																								
intermedia																																					x																							
Miogypsina (Lepidosemicyclina)																																																												
thecideaeformis																										x	x	x											?	x	x																			
cf. *thecideaeformis*																																													x			x	x	x	x					x				x
Miogypsina (Miogypsinoides)																																																											
dehaarti	x		x	x	x	x																																																						
Orbitoidacea																																																												
Amphistegina																																																												
bikiniensis							x	x	x	x	x							x	x		x	x		x																																				
hauerina	x		x	x	x	x																	x		x	x	x	x	x	x	x		x	x	x	?	?			x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x				x
Borodinia																																																												
septentrionalis																																																												
Gypsina																																																												
globulus	x		x		x	x																		x	x	x	x	x		x			x	x	x						x	x	x		x	x		x	x	x	x	x		x	x	x	x			x
howchini			x							x									x	x	x	x		x																	x								x	x	x	x								x
mastaelensis																																									x				?															
sp.																																																												
Halkyardia																																																												
cf. *minima*																								x																																				
Victoriella																																																												
conoidea																																					x																							
Biarritzina																																																												
alternata	x		x	x		x																										x										x			x				x											
carpenteriaeformis																																																												
proteiformis																																																												
Lepidocyclina (Eulepidina)																																																												
badjirraensis				?																								juv		x	x	x	x																											
ephippioides									x	x	x							x			x	x		x												x	x																							
Lepidocyclina (Nephrolepidina)																																																												
howchini howchini																										x	x											x	x		x																			
howchini praehowchini		x	x	x																								x	x											x																				
howchini s.l.																																										x	x	x			x	x	x	x	x	x	x	x	x	x		x		x
japonica																														x	x																													
orakeiensis orakeiensis																																				x	x																							
orakeiensis waikukuensis																																		x	x																									
sumatrensis							x	x	x	x	x		?								x			x																																				
Discorbidae undiff.							x	x		x		x	x	x	x	x		x		x	x	x	x	x		x	x	x		x		x	x	x	x	x	x			x	x	x			x	x		x	x			x	x	x		x				
Elphidiidae undiff.	x		x	x	x		x	x	x			x	x	x	x	x		x	x		x	x	x			x		x		x	x	x	x	x	x	x	x			x						x									x					
Rotaliidae undiff.	x		x	x			x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x			x	x	x	x	x	x	x	x		x	x	x

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Fig. 5b. Distribution charts for larger foraminifera—III.

LOCALITY	Mandu ManduCr		Var. Loc. Cape Ra		Rough Ra 1		Various Localities Rough Range							Cape Range 1				Rough Range South 1									Muiron 1													Mandu Mandu Creek																	
TAXON / BMR Catalogue Number	CR53	CR54	CR55	CR103	80640986	80640987	80641354	80641355	80641356	80641357	80641358	80641359	80641360	80640565	80640566	80640567	80640570	80640521	80640522	80640523	80640524	80640525	80640526	80640527	80640528	80640530	80642000	80642001	80642005	80642006	80642007	80642008	80642009	80642010	80642011	80642012	80642013	80642015	80642016	71640345	71640342	71640343	71640344	71640346	71640347	71640348	71640349	71640350	71640351	71640352	71640353	71640354	71640355	71640356	71640357	71640358	71640359
MILIOLINA																																																									
Miliolacea																																																									
Austrotrillina																																																									
howchini							x		x		?							x																																							
striata																				x																																						
Lacazinella																																																									
cf. *wichmanni*																							x	x																																	
Peneroplis																																																									
sp.							x																																																		
Spirolina																																																									
sp.							x																																																		
Sorites																																																									
sp.																				x																																						
Marginopora																																																									
vertebralis					?		x	x	x																																																
Borelis																																																									
pygmaeus							x						x																																												
Flosculinella																																																									
bontangensis bontangensis				x			x	x				?																																													
bontangensis globulosa																																																									
Miliolina undiff.	x		x	x	x	x	x	x	x		x	x	x					x		x		x	x	x												x												x									
Textulariina undiff.	x	x		x			x	x	x			x				x											x									x	x				x	x				x			x								
ROTALIINA																																																									
Rotaliacea																																																									
Operculina																																																									
complanata	x			x								x	x	x		x	x			x	x	x	x	x	x		x	x	?	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x		x		x	x	x	x	x			
Operculinella																																																									
venosa			?	?																																					?																
Cycloclypeus (Cycloclypeus)																																																									
eidae														x	x																			x	x	x																					
cf. *eidae*																																																									
carpenteri																												x		x	x		x							x	x		x														
cf. *carpenteri*	x	x	x	x																																						x		x	x	x	x	x	x	x	x		x	x	?	?	
Cycloclypeus (Katacycloclypeus)																																																									
cf. *annulatus*																																																									
Heterostegina																																																									
borneensis																					x				x																																
suborbicularis																																																									
Spiroclypeus																																																									
cf. *margaritatus*							x	x	x	x	x	x	x																																												

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Fig. 6a. Distribution charts for larger foraminifera—IV.

LOCALITY	Mandu Mandu Cr		Var. Loc. Cape Ra		Rough Ra 1		Various Localities Rough Range							Cape Range 1				Rough Range South 1									Muiron 1													Mandu Mandu Creek																	
TAXON / BMR Catalogue Number	CR53	CR54	CR55	CR103	80640986	80640987	80641354	80641355	80641356	80641357	80641358	80641359	80641360	80640565	80640566	80640567	80640570	80640521	80640522	80640523	80640524	80640525	80640526	80640527	80640528	80640530	80642000	80642001	80642005	80642006	80642007	80642008	80642009	80642010	80642011	80642012	80642013	80642015	80642016	71640345	71640342	71640343	71640344	71640346	71640347	71640348	71640349	71640350	71640351	71640352	71640353	71640354	71640355	71640356	71640357	71640358	71640359
Miogypsina (Miogypsina)																																																									
globulina																																																									
intermedia																																																									
Miogypsina (Lepidosemicyclina)																																																									
thecideaeformis																																	×																								
cf. *thecideaeformis*																																														×											
Miogypsina (Miogypsinoides)																																																									
dehaarti																																																									
Orbitoidacea																																																									
Amphistegina																																																									
bikiniensis																			×	×	×	×	×	×	×																																
hauerina	×	×	×	×	×	?		×				×		×			×										×	×	×		×	×	×	×						×	×	×	×	×	×	×	×		×	×	×	×	×	×		?	?
Borodinia																																																									
septentrionalis				×																																																					
Gypsina																																																									
globulus		×		×					×												×									×	×	×			×								×					×	×	×	×	×	×				
howchini				×				×				×											×	×	×							×																									
mastaelensis																																																									
sp.																																																									
Halkyardia																																																									
cf. *minima*																																																									
Victoriella																																																									
conoidea																																																									
Biarritzina																																																									
alternata																							×														?	?			?			×													
carpenteriaeformis																							×																		×																
proteiformis																																																									
Lepidocyclina (Eulepidina)																																																									
badjirraensis													×																																											
ephippioides								×	×	×		×	×						×	×	×																																				
Lepidocyclina (Nephrolepidina)																																																									
howchini howchini																														×	×	×	×							×	×		×														
howchini praehowchini																																		×	×	×																					
howchini s.l.	×	×	×	×	×	×	?		?		?	?	?																													×		×	×	×	×	×	×	×	×	×	×	×	×		×	
japonica																																																									
orakeiensis orakeiensis																																																									
orakeiensis waikukuensis																																																									
sumatrensis							?	?	?		?	?	?							×	×																																				
Discorbidae undiff.	×		×			?								×		×		×	×	×	×									×	×	×	×		×	×	×						×							×							
Elphidiidae undiff.																		×						×	×			×		×	×	×	×	×																							
Rotaliidae undiff.	×	×	×	×			×	×	×	×	×	×				×	×	×	×		×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			

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Fig. 6b. Distribution charts for larger foraminifera—IV.

been used synonomously with 'larger foraminiferids', but because it has a systematic connotation (with the Superfamily Orbitoidacea) it is not a desirable term.

STRATIGRAPHY

NORTH WEST CAPE AREA

Condon & others (1955, 1956) formalised the stratigraphic nomenclature that had been previously used informally by Clapp (1925), Raggatt (1936), Singleton (1941), and Condon (1954), and recognised several new units. McWhae & others (1958), Condon (1968), and Quilty (1974a) presented a synthesis of the lithostratigraphy for the area, based on the work of all the earlier writers; Chaproniere (1976) described a new subsurface unit. The scheme of Condon & others (1955), as modified by Condon (1968), has been used in this study. However, because of additional subsurface information available to me from the many wells drilled in the area, this scheme has been modified and expanded (Fig. 8).

The ages of the units (see Appendix 4) are expressed in terms of the planktic foraminiferal zonal scheme of Blow (1969) and the East Indian Letter Classification as modified by Adams (1970) and Chaproniere (1981b), and in conventional epoch nomenclature (Fig. 7). The boundaries between the units in the subsurface have been located by using changes in geophysical log character, together with information based on rock samples from ditch-cuttings and cores, as well as faunal evidence. The stratigraphic relations for all sections studied in the North West Cape area are illustrated diagrammatically in Figures 8, 9, and 10.

Giralia Calcarenite lateral equivalent

The name Giralia Calcarenite was initially adopted by Singleton (1941) and was formally defined by Condon & others (1956) for friable to hard, commonly recrystallised limestone containing glauconite and limonite ooliths exposed in the Giralia Anticline. The limestone contains a rich marine fauna, including the larger foraminiferids *Nummulites, Discocyclina, Asterocyclina*, and *Assilina* (Condon, 1968). Ludbrook (1967) considered the age to be Late Eocene, but based on this fauna it is Middle to Late Eocene; Quilty (1974a) reached the same conclusion. To date no work has been published on the planktic foraminiferal faunas, so that the position of the Giralia Calcarenite in the zonal scheme of Blow (1969) or Berggren (1971) is not known. On the basis of the larger foraminiferids listed above, the limestone can be correlated to either Tertiary a_3 or *b* stages.

In the subsurface of Cape Range, friable glauconitic calcarenite and calcilutite containing moderate amounts of terrigenous material unconformably underlie the Cape Range Group; the well-preserved planktic foraminiferal fauna suggests a variety of dates from Middle to Late Eocene. A coarser-grained calcarenite in the subsurface of Rough Range is in a similar stratigraphic position and contains a similar planktic foraminiferal fauna to that at Cape Range: in addition to the planktic foraminifera, it contains rare *Discocylina* and *Asterocyclina* similar to those found in the Giralia Calcarenite. Because of their age and stratigraphic position, it is considered that these rocks are lateral equivalents of the Giralia Calcarenite, but their lithologic differences preclude them from that unit. These rocks fall outside the limits of this study, and will not be discussed further.

Cape Range Group

This name was first used by Clapp (1925) for Cretaceous and Tertiary rocks that crop out in Cape Range, Rough Range, and Giralia Range. Condon & others (1955) restricted the use of this name to include the Oligocene to Lower Miocene Mandu Calcarenite and Tulki and Trealla Limestones that crop out mainly in the Cape Range area. Condon (1968, p. 38) further restricted the unit to include only the Mandu Calcarenite and Tulki Limestone, because he considered that '... the wide regional extent of the Trealla [Limestone] compared with the very restricted occurrence of the Tulki [Limestone] and Mandu [Calcarenite] indicates a very significant change in palaeogeography'; this is obviously a reference to the change in depositional regime between the Trealla Limestone and the older Mandu Calcarenite and Tulki Limestone. As will be shown later, the Mandu Calcarenite and Tulki Limestone are both diachronous and were deposited in a regressive cycle, whereas the Trealla Limestone was deposited in a transgressive cycle. The Bullara Limestone is a name that Chaproniere (1976) introduced for a lateral equivalent of the Mandu Calcarenite.

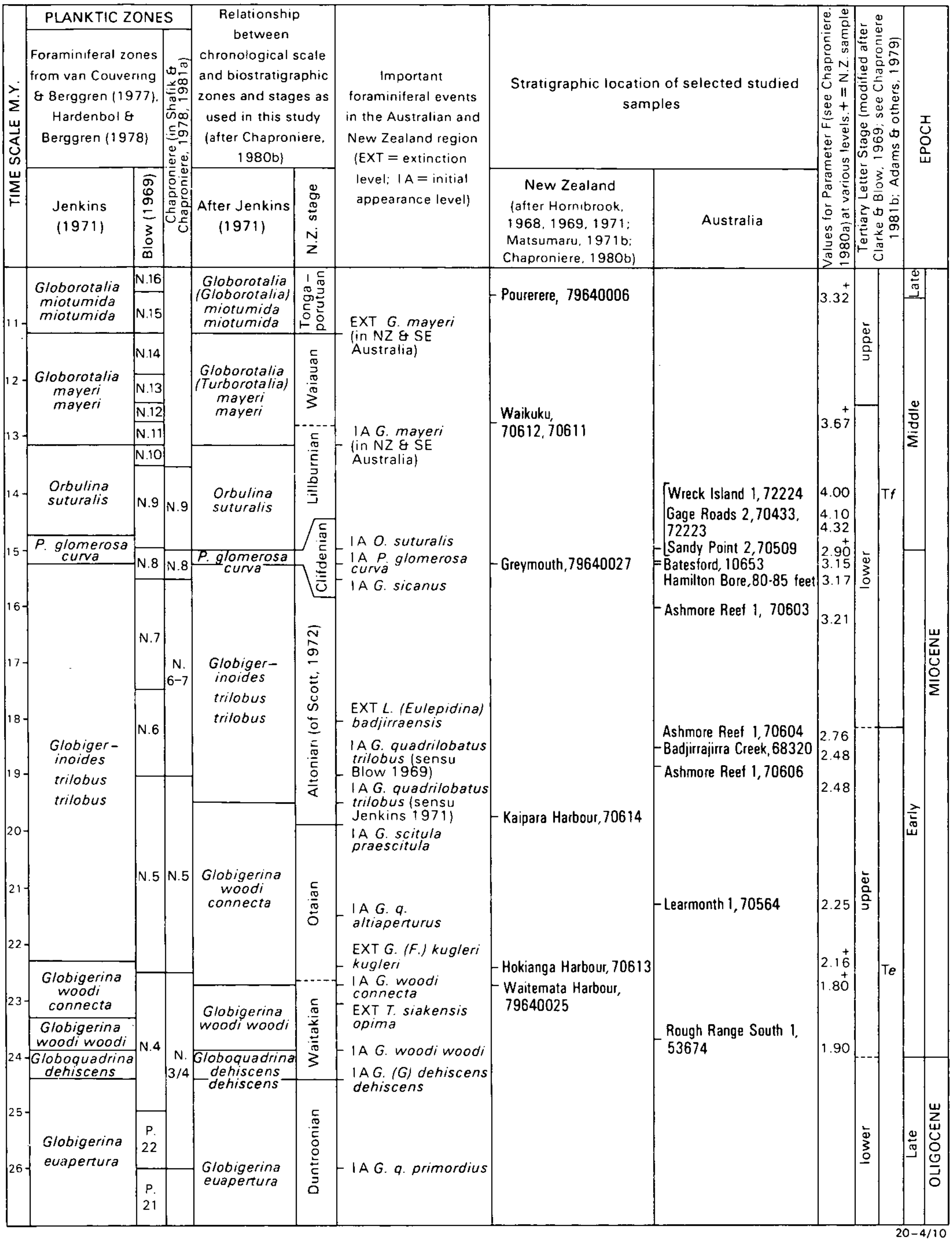

Fig. 7. Relations between the planktic zones of Blow (1969, 1970) and Jenkins (1971), New Zealand chronostratigraphic stages, and the East Indian Letter Classification of the Tertiary (modified after Chaproniere, 1980b).

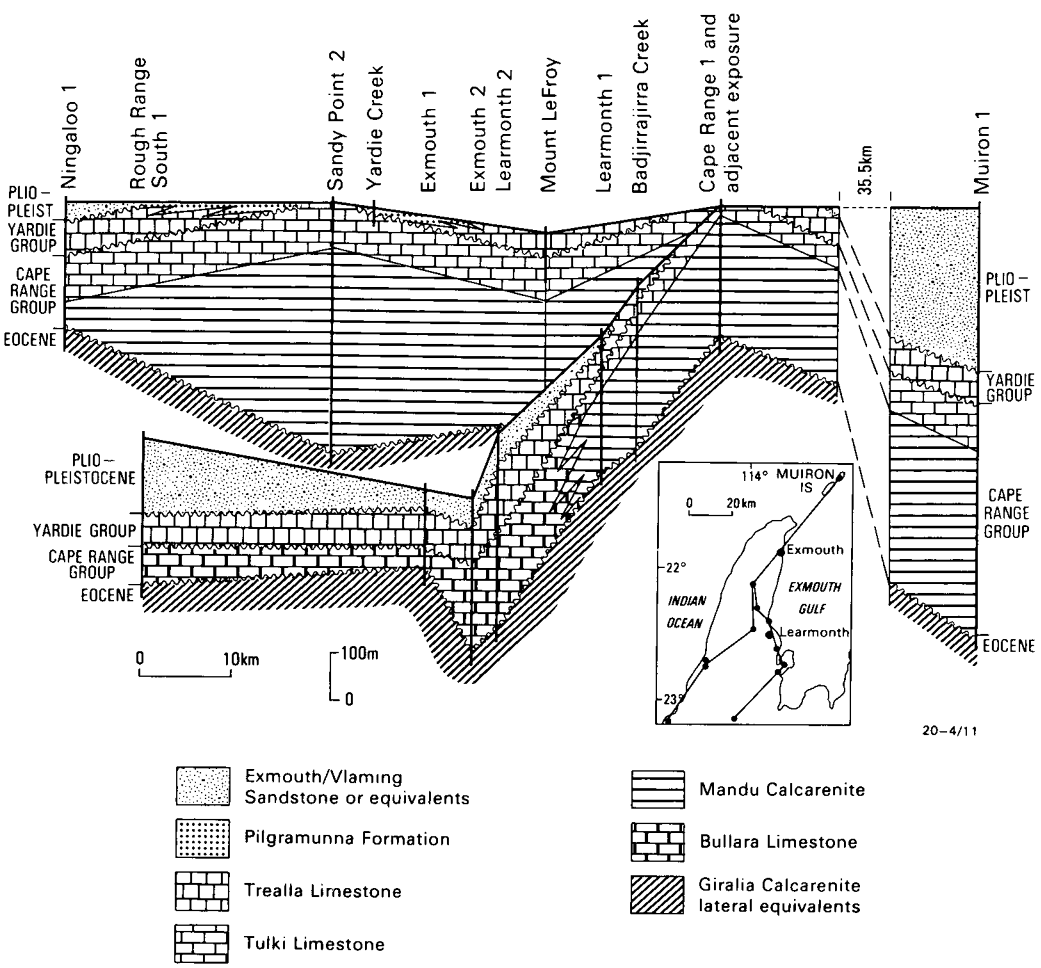

Fig. 8. Fence diagram of the relations between post-Eocene lithostratigraphic units in the North West Cape.

Mandu Calcarenite

The Mandu Calcarenite was defined by Condon & others (1955, p. 24) for well-bedded creamy 'friable chalky calcarenites at the bottom of the exposed Tertiary section in the Cape Range'. The type section, in Badjirrajirra Creek, is the thickest surface section (81 m) exposed. The upper contact was defined as the base of the hard crystalline Tulki Limestone. The lower contact was not defined. At the type section, the Mandu Calcarenite may be divided into two subunits: a lower part (lower 50 m) of fine-grained calcarenite which commonly contains chert nodules and in which larger foraminiferids are rare or absent; and an upper part (top 30 m) of medium to coarse-grained, poorly sorted calcarenite containing abundant larger foraminiferids, commonly concentrated into coquinas (Plate 1, fig. 6; Chaproniere, 1975, fig. 8B); the degree of cementation increases towards the top. The upper Mandu Calcarenite grades into the overlying Tulki Limestone (Plate 2, fig. 2) with at least one (probably more) minor disconformity (Plate 2, fig. 6; Chaproniere, 1975, fig. 9A). The two subunits are present in all the wells studied within the Cape Range area.

The upper part of the Mandu Calcarenite (and of the overlying Tulki Limestone) in the subsurface is intensely recrystallised; as a result the rocks have a light cream colour and sugary appearance. The fossils have been altered, and usually all that is found of the

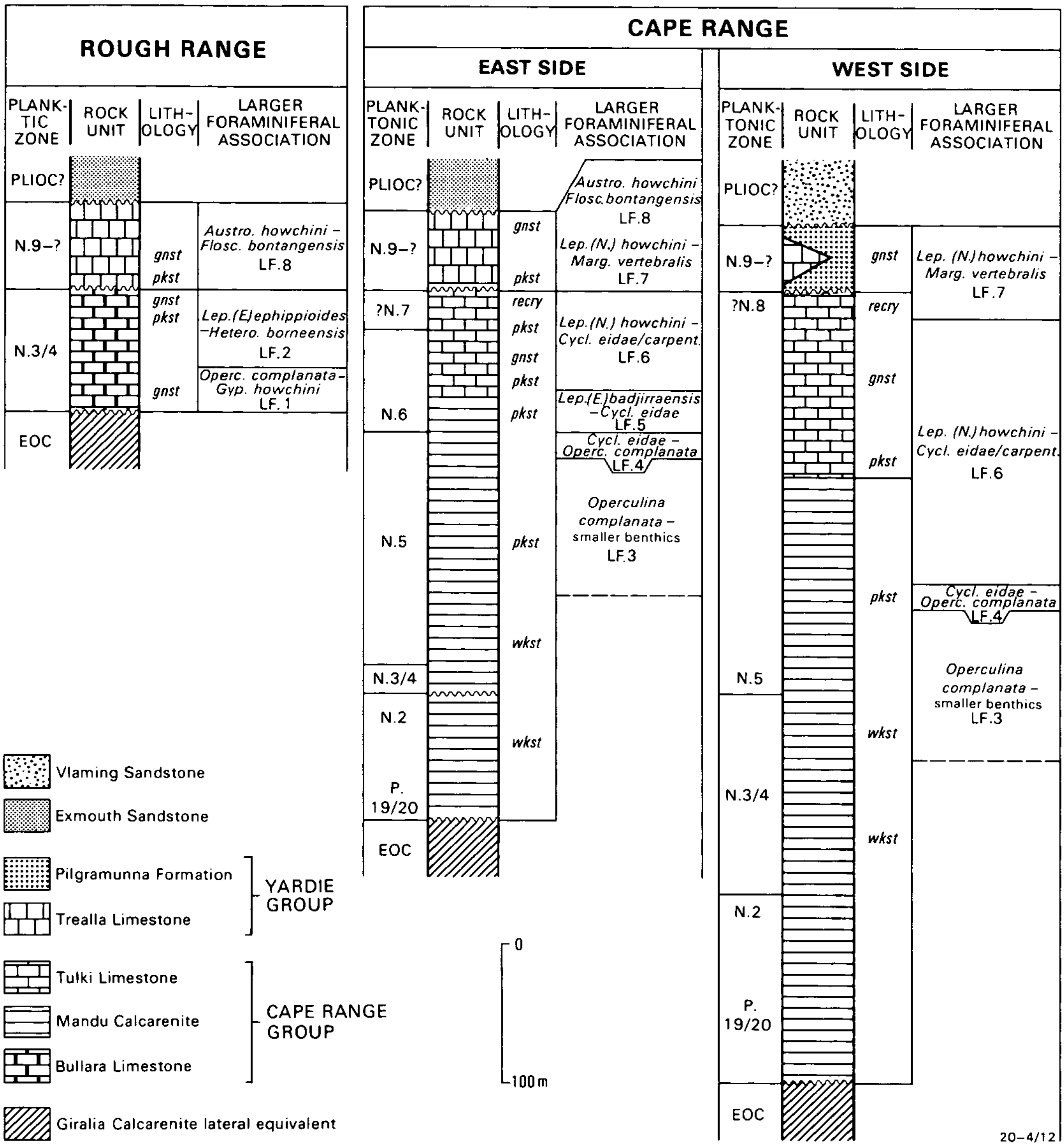

Fig. 9. Composite Oligo-Miocene stratigraphic sections from three localities in the North West Cape (modified after Chaproniere, 1975, 1981b).

miliolines and other high-magnesium calcitic forms are internal casts. In thin section the larger foraminiferids have lost, at least to some extent, their shell microstructure. The base of this altered zone gives way gradually to fairly unaltered rocks below, with no obvious faunal or lithologic change. In Muiron No. 1 well (and also Ashmore Reef No. 1 well, which is discussed below) the recrystallised zone is well marked on the spontaneous potential log (showing an increase in resistivity), but only slightly marked on the resistivity logs. In other wells in the Cape Range area, logs were not run until below this interval. Apart from there being no faunal or other lithologic change within this zone or immediately below it, there is little or no evidence for a disconformity within this altered part of the Mandu Calcarenite. I consider that the recrystallisation is best explained as secondary diagenesis result-

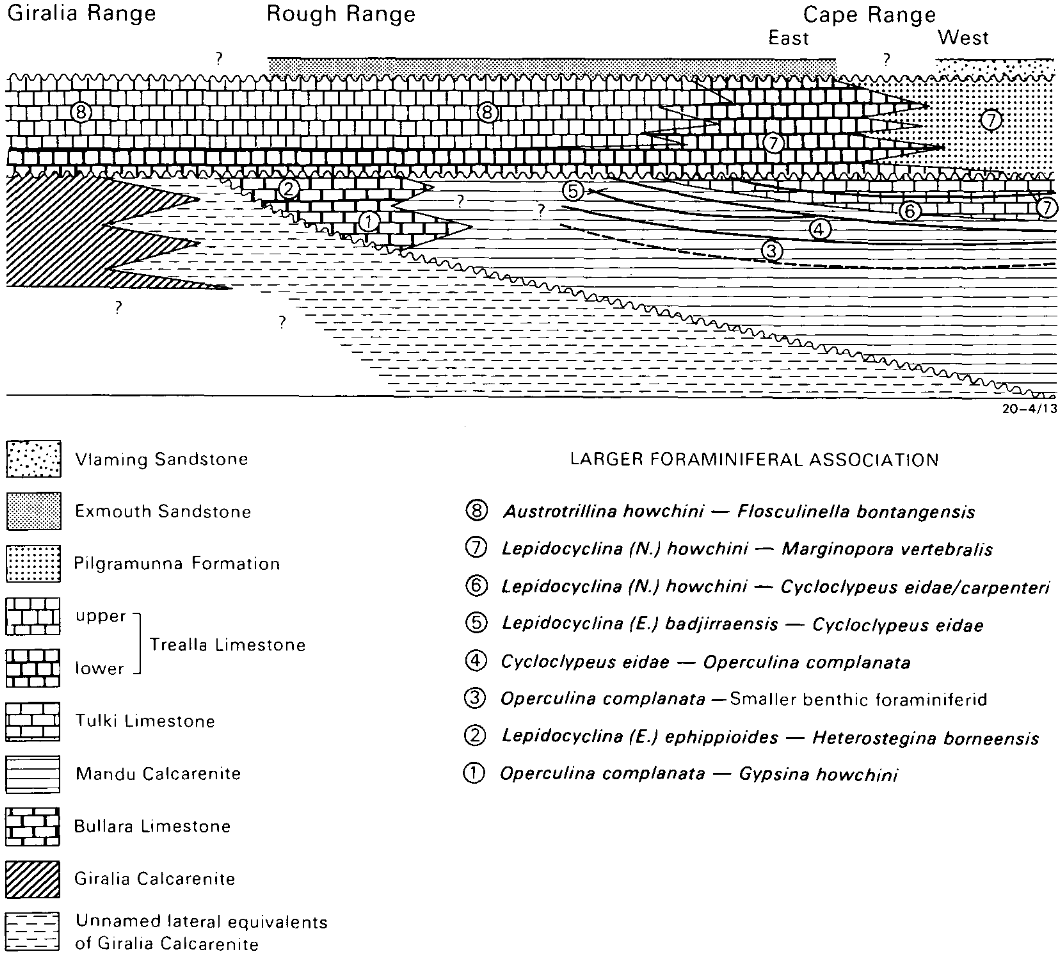

Fig. 10. Diagrammatic east-west cross-section through Oligo-Miocene lithostratigraphic units in the North West Cape (after Chaproniere, 1975).

ing from percolating waters associated with the unconformity marking the top of the Cape Range Group (top of the Tulki Limestone).

As noted earlier, Condon & others (1955) did not define the lower contact of the Mandu Calcarenite. McWhae & others (1958, table IX, p. 124), however, showed that this unit overlies the Giralia Calcarenite; although they did not indicate the nature of the contact, they showed the thickness of the Mandu Calcarenite as 800 feet (244 m). This formation unconformably overlies sediments that are considered to be lateral equivalents of the Giralia Calcarenite in all the wells that I studied. In Cape Range No. 1 well (Fig. 1), which is the nearest to the type section, this contact is placed at 264 m (Appendix 4, Fig. A9).

The thickness of the Mandu Calcarenite ranges from 37 m in Ningaloo No. 1 well (Figs. 1, 8) to 434 m in Sandy Point No. 2 well (Figs. 1, 8). In Cape Range No. 1 well a thickness of 264 m was encountered; this figure represents the lower part of the Mandu Calcarenite, and a further 42 m (the upper part) is exposed in the canyon walls surrounding the well site, giving a total of 306 m for the Mandu Calcarenite in this area. The unit thickens northwards and westwards in Cape Range (Figs. 8, 9, 10).

Condon & others (1955) recorded the Mandu Calcarenite only from Cape Range, but according to McWhae & others (1958) and Condon (1968) it also crops out in Rough Range. I have recognised this unit only within the Cape Range Anticline and its northward extension to the Muiron Islands; the Rough Range 'Mandu Calcarenite' recorded by McWhae & others (1958) and Condon (1968) is here considered to be a different lithologic unit (probably the Bullara Limestone) which was discussed by Chaproniere (1976).

Crespin (1952, 1955a) has studied the foraminiferal faunas from the surface sections of the Mandu Calcarenite. With the additional data now available a more complete picture can be given. The lower part of this unit contains a large and diverse fauna dominated by smaller benthic and planktic forms; larger foraminiferids, which are rare but increase in numbers towards the top, are represented by *Operculina complanata, Cycloclypeus eidae*, and *Lepidocyclina* (*Eulepidina*) *badjirraensis*. The upper part contains a fauna that is dominated by the same species of larger foraminiferids as the lower part and also includes *Lepidocyclina* (*Nephrolepidina*) *howchini, Miogypsina* (*Lepidosemicyclina*) *thecideaeformis*, and *Gypsina globulus*; the smaller benthic and planktic foraminiferids are subordinate, the latter becoming increasingly rare.

The planktic foraminiferids correlate to Zones P.19/20-N.6 of Blow (1969). The upper Mandu Calcarenite on the eastern side of Cape Range contains a typical Tertiary upper *e* stage fauna, but the uppermost 5 m contains a larger foraminiferal fauna typical of the Tertiary lower *f* stage. The same Tertiary lower *f* fauna occurs in the same rocks on the western side of Cape Range.

Bullara Limestone

Chaproniere (1976) defined and discussed this unit, and no further discussion is necessary here, except to note that it represents a lateral equivalent of the Mandu Calcarenite. It correlates to Zone N.3/4 and to the Tertiary lower *e* stage.

Tulki Limestone

Condon & others (1955, p. 25) defined the Tulki Limestone as '. . . hard, thick-bedded crystalline limestone . . . which conformably overlies the Mandu Calcarenite'. The type section is in Badjirrajirra Creek, where a thickness of 66 m is exposed (Condon & others, 1955). The upper contact, with the Pilgramunna Formation or Trealla Limestone, is an unconformity. The lower contact, with the Mandu Calcarenite, appears to be gradational over an interval of 3 m, but within this zone there is at least one minor disconformity. The rocks immediately below the disconformity have features similar to those described by Purdy (1968) as having been formed by subaerial diagenetic processes: for example, *Halimeda* plates and some larger foraminiferal tests have been truncated (Plate 2, fig. 6; Chaproniere, 1975, fig. 9A), suggesting that the rock was lithified and then eroded; solution channels connect *Halimeda* plates with one another and with other fossils; and those fossils which have an aragonitic or high-magnesium calcite content have been recrystallised. The almost total absence of low-magnesium calcite that has recrystallised to micrite—typical of the upper parts of the Tulki Limestone (see below)—and the similarity of the foraminiferal fauna on either side of the break, suggest that the period of emergence was quite brief.

The Tulki Limestone can be divided into two parts: a lower pinkish red muddy limestone whose weathered surface is brown and nodular (Plate 2, fig. 2); and an upper creamy massive limestone which forms shear cliffs (Plate 2, fig. 4), and on microscopic examination is always intensely recrystallised (Chaproniere, 1975, figs. 9C,E,F). In thin section the low-magnesium calcite (including echinoid fragments near the unconformity) is replaced by micrite, so that only faint outlines remain. I believe that processes similar to those described by Purdy (1968) for his subaerial diagenesis model can be invoked to explain this phenomenon. Indeed, Condon & others (1955) noted that the top of the Tulki Limestone is often marked by a pisolitic horizon; furthermore, two of their samples from this zone (CR30 and CR65) appear to be calcretes. The evidence, therefore, suggests that the Tulki Limestone was emergent for some time before the Trealla Limestone was deposited, a conclusion already put forward by Condon & others (1955). The intense alteration which marks the top of the Tulki Limestone is also found in the subsurface in wells such as Muiron No. 1 and Ningaloo No. 1.

The Tulki Limestone was originally mapped as extending throughout the Cape Range and eastwards into Rough Range (Condon & others, 1955). However, as noted by Chaproniere (1976), the limestone underlying the Trealla Limestone in Rough Range is considered to be the Bullara Limestone. The Tulki Limestone is, therefore, restricted to the Cape Range area including the northwards extension to the Muiron Islands. The thickest section is at Mandu Mandu Creek, where Condon & others (1955) recorded 127 m; the thinnest is at the type section (66 m). As can be seen from Figure 4, the limestone thickens in a southwesterly direction; this feature may be an apparent thickening related to the amount of material removed during erosion before the Trealla Limestone was deposited. In the subsurface the thickness is similar to that measured at the surface.

The fauna of the Tulki Limestone is identical with that from the top of the Mandu Calcarenite and correlates to the Tertiary lower *f* stage. Planktic foraminiferids are present in most thin sections of the limestone, but accurate identification is difficult; however, by referring to the plates in Postuma (1971), I have made some identifications. Forms which are referable to either *Globigerinoides quadrilobatus immaturus* or *G. quadrilobatus trilobus* are present in the limestones from the eastern side of Cape Range; I was not able to find *Praeorbulina* or *Orbulina*, even though Crespin (1955a) recorded the latter. The thin sections from which *Orbulina* was identified have been re-examined, and the specimens are regarded as sections through the ultimate chambers of other globigerines. The Tulki Limestone from the western side of Cape Range contains forms very close to *Praeorbulina glomerosa* and *Globigerinoides sicanus*, as well as the *Globigerinoides* species noted above. The planktic faunas suggest a correlation to within Zone N.6-7 for the Tulki Limestone on the eastern side, and to Zone N.8 for the limestone on the western side of Cape Range. Thus the faunal evidence indicates that the Tulki Limestone is Early Miocene in age, becoming younger westwards.

Yardie Group

This name was originally defined by Condon & others (1953, p. 27) for '. . . the calcareous sandstone and sandy limestone which interfingers with the Trealla Limestone'; the Yardie Group was divided into upper and lower parts. Later, Condon & others (1955) proposed the name Pilgramunna Formation for the lower part, which was considered to be a lateral equivalent of the Trealla Limestone, and the Vlaming Sandstone for the upper, which was considered to disconformably overlie the Pilgramunna Formation. Condon (1968, p. 39) considered the name Yardie Group to be invalid because 'it contains an important disconformity', referring to the contact between the Pilgramunna Formation and the Vlaming Sandstone. However, the name can still be used validly to encompass both the Pilgramunna Formation and the Trealla Limestone, because both are the result of a single transgressive event over an erosion surface developed on the Cape Range Group. This seems preferable, rather than to complicate the nomenclature by the addition of another name.

Trealla Limestone

The Trealla Limestone was defined by Condon & others (1955, p. 28) for '. . . hard white to cream, thin-bedded foraminiferal crystalline limestone . . . which overlies the Tulki Limestone'. Condon (1968, p. 39) redefined the unit as '. . . resting disconformably or unconformably on Tulki Limestone, Mandu Calcarenite, Giralia Calcarenite, or older formations . . .'. The Trealla Limestone has a very wide distribution, especially when compared with that of the Cape Range Group, and ranges from Barrow Island in the north (McWhae & others, 1958) to Yaringa in the south (Condon, 1968). It is unconformably overlain by the Exmouth Sandstone and other younger deposits. It appears to show little lateral variation, except to the west where it grades laterally into the Pilgramunna Formation (Condon & others, 1955; Condon, 1968). Its thickness ranges from 56 m at the type section to 83 m in Exmouth No. 2 well; it may reach 100 m in Exmouth No. 1 well.

Microscopic and faunal studies have enabled the Trealla Limestone to be divided into two parts: a lower part dominated by bioclastic packstone (Chaproniere, 1975, fig. 9G) containing a similar fauna to that of the Tulki Limestone, but distinguished by the presence of common *Marginopora vertebralis* and *Austrotrillina howchini*, and by a reduction in the frequency of *Lepidocyclina* (*Nephrolepidina*); and an upper part dominated by bioclastic grainstone with a foraminiferal fauna dominated by milioline forms, such as *Marginopora vertebralis*, *Austrotrillina howchini*, *Flosculinella bontangensis*, *Borelis pygmaeus*, and numerous smaller forms. In the upper part, *Lepidocyclina* and other rotaline forms are rare or absent and often fragmentary. The lower unit has been found only in the Cape Range area, whereas the upper unit is widespread throughout the southern part of the Carnavon Basin.

The larger foraminiferal fauna of the Trealla Limestone is typical of the Tertiary lower *f* stage. Planktic foraminiferids, though rare, are confined to the lower subunit. The presence of *Orbulina* indicates that it correlates to a zone no older than N.9; the absence of other forms prevents a more accurate correlation. The age of the limestone is Middle Miocene.

Pilgramunna Formation

The Pilgramunna Formation was described by Condon & others (1955, p. 30) for a sequence of '... coarse-grained to medium-grained quartz sandstone, sandy limestone, and limestone, resting disconformably on the Tulki Limestone, or conformably on the Trealla Limestone ...' (see Chaproniere, 1975, fig. 10A,B). The unit is disconformably overlain by the Exmouth Sandstone, and grades laterally into the Trealla Limestone (Condon, 1968).

The fauna of the Pilgramunna Formation is similar to that of the Trealla Limestone, but most fossils are fragmentary and often rounded. Both *Marginopora* and *Lepidocyclina* are present with rare smaller miliolines; no planktic foraminiferids have been recorded. Because of the scarcity of fossils and their fragmentary nature, no detailed study of the fauna has been attempted. The age is similar to that of the Trealla Limestone—that is, Middle Miocene.

The Pilgramunna Formation is restricted to the western side of Cape Range and has not been seen in any of the wells studied.

Younger units

Those units that disconformably or unconformably overlie the Cape Range or Yardie Groups lie outside the scope of this study. All these younger units have been described by Condon & others (1955) and Condon (1968).

OTHER AREAS IN AUSTRALIA

As noted earlier, samples from three wells and one quarry in Australia outside the North West Cape area have been incorporated in the study. A brief resume of the stratigraphic locations of these samples is presented below.

Ashmore Reef No. 1 well

Ashmore Reef No. 1 well is situated on the Sahul Shelf, in the northwest of Western Australia (Fig. 1), within the Bonaparte Gulf Basin. It penetrated one of the thickest Oligo-Miocene sections known from Western Australia (898 m) at the time of drilling, and has proved to be a very valuable reference section.

The stratigraphy, which has been discussed by Craig (1968), Shafik & Chaproniere (1978), and Chaproniere (1981a), is summarised in Figure 11. The Oligocene to Early Miocene Cartier beds disconformably overlie the recrystallised Eocene Hibernia beds. This disconformity is placed at 1222 m; it is well marked on geophysical logs and as a lithologic change. The Cartier beds are characterised by friable calcilutite and green calcarenite (Chaproniere, 1975, fig. 10C); the top is gradational (indicated by lithologic and geophysical log characteristics), and is placed at about 933 m. An unnamed, friable, light grey calcarenite, containing larger foraminiferids which are rare low in the formation but abundant higher up, and corals, bryozoa, and molluscs at the top, directly overlies the Cartier beds (Plate 2, figs. 1,3,5; Chaproniere, 1975, fig. 10D–G). There is an abrupt change in the geophysical log character at 803 m, coinciding with the lithology becoming highly recrystallised and leached. Craig (1968) and

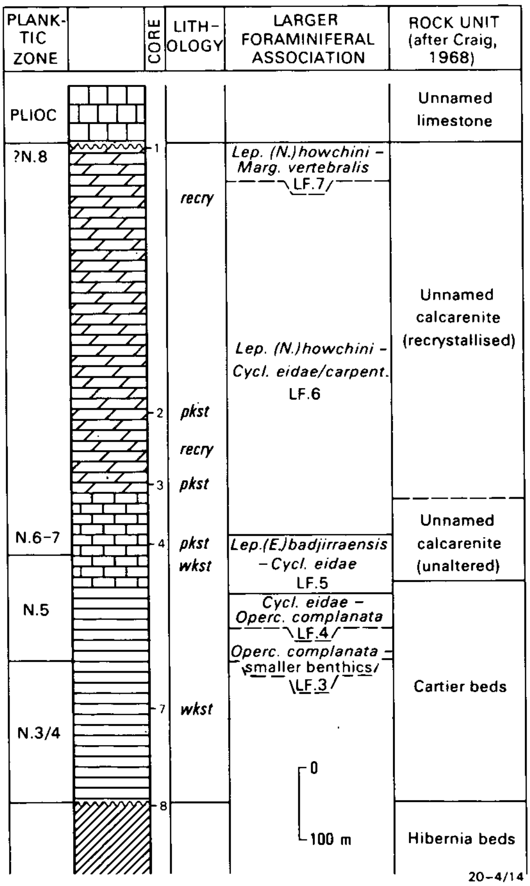

Fig. 11. Stratigraphic summary of the Oligo-Miocene section in Ashmore Reef No. 1 well (modified after Chaproniere, 1975, 1981a,b).

Coleman (1968) both placed a disconformity at this level. I do not consider this to be a disconformity, because the lithologic change is not accompanied by a faunal change; I conclude, therefore, that the change in geophysical log character marks the base of the zone of recrystallisation. The recrystallisation features are best explained in terms of a secondary diagenetic event related to the unconformity marking the top of the Miocene section, a similar explanation to that advanced earlier to account for changes within the Mandu Calcarenite. The top of the unnamed calcarenite is placed at 321 m, coinciding with a marked change in fauna, lithology, and geophysical log character.

The planktic foraminiferal fauna from the lower Cartier beds contains an assemblage typical of Zone N.3/4. The base of Zone N.5 is placed at about 960 m, within the upper Cartier beds, by Chaproniere (1981a). *Operculina complanata* first appears within the upper half of the Cartier beds, and *Cycloclypeus eidae* and then *Lepidocyclina* (*Eulepidina*) *badjirraensis* appear successively near the top; this fauna is typical of the Tertiary upper *e* stage. The age of the Cartier beds ranges from the Late Oligocene to Early Miocene.

The poor planktic fauna from the lower part of the unnamed calcarenite is typical of Zone N.6–7 (Chaproniere, 1981a); planktic foraminiferids have not been found above 797 m. Larger foraminiferids become increasingly abundant upwards throughout this unit. *L.* (*Eulepidina*) *badjirraensis* becomes extinct in the lower part and is replaced by *L.* (*Nephrolepidina*) *howchini*; *Miogypsina* (*Lepidosemicyclina*) *thecideaeformis* appears at a similar level. Throughout this section, the evolving embryonic characters of the larger foraminiferids become more advanced phylogenetically, and follow the same trends observed in the North West Cape area; these are discussed below. *Marginopora vertebralis* and *Flosculinella bontangensis* appear at the top of this calcarenite. The last appearance of *L.* (*Eulepidina*) *badjirraensis* marks the upper limit of the Tertiary upper *e* stage (Adams, 1970), and this event occurs at about 812 m. The evolutionary level for the *L.* (*Nephrolepidina*) *howchini* populations in the lower part is similar to that of faunas from the Mandu Calcarenite on the eastern side of Cape Range; those populations from the middle part are the same as those from the Mandu Calcarenite on the western side of Cape Range. No biometric data are available for the larger foraminiferids from the top of the unit, because it is not possible to extract specimens from the well-cemented limestone; they appear to be similar to those from the topmost part of the Tulki Limestone or the lower part of the Trealla Limestone, and so may correlate to within Zones N.8 or N.9.

The Cartier beds are considered to be of a similar age to the upper Mandu Calcarenite, and the unnamed calcarenite to the uppermost part of the Mandu Calcarenite and the Tulki Limestone. The lithologies and faunas from this part of Ashmore Reef No. 1 well suggest that the Cartier beds and the unnamed calcarenite were deposited in the same regressive cycle as that of the Cape Range Group; hence, the unconformity at the top of both sequences was probably formed by the same event.

Gage Roads No. 2 well

Larger foraminiferids have been studied from Gage Roads No. 2 well in the Perth Basin (Fig. 1). The fauna studied is from the Stark Bay Formation, which contains a planktic foraminiferal fauna typical of Zone N.9 and is Middle Miocene in age (Quilty, 1974b).

Batesford

The larger foraminiferids from one sample of the Batesford Limestone (Fig. 1) have been incorporated in this study. The stratigraphic setting for this unit has been discussed by Carter (1964) and is summarised in Figure 12.

Carter (1964, fig. 15, p. 40) identified the following planktic species from the Batesford Limestone: *Globigerinoides bisphericus* (=*sicanus*), *G. rubra*, and *G. triloba*. Matsumaru (1971a) identified *Globigerina ciperoensis*, *Globigerinoides bisphericus*, and *G. triloba*. In addition, I have identified *Globigerina praebulloides* s.l., *G. woodi woodi*, *Globigerinoides quadrilobatus immaturus*, *G. quadrilobatus subquadratus*, *G. quadrilobatus trilobus*, *G. sicanus*, *Globoquadrina dehiscens dehiscens*, and *Praeorbulina transitoria*. The taxon *Globigerinoides triloba*, as used by both Carter and Matsumaru, contains forms which would be better identified as *G. quadrilobatus immaturus* and *G. quadrilobatus trilobus*. Furthermore, the form identified as *G. rubra* by Carter (1964) is probably *G. quadrilobatus subquadratus*.

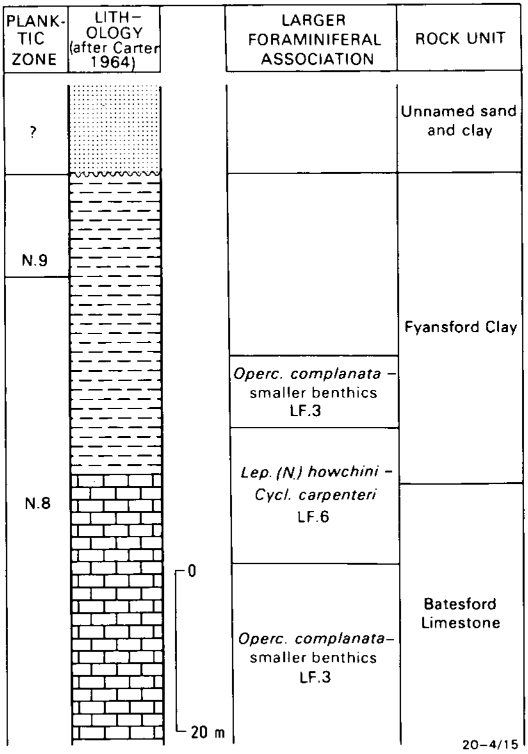

Fig. 12. Stratigraphic summary of the Batesford Limestone at Batesford, Victoria (modified after Carter, 1964; after Chaproniere, 1975, 1981b).

Carter (1964) noted that *Orbulina* first appears within the upper part of the Fyansford Clay (Fig. 12), the unit which apparently conformably overlies the Batesford Limestone. This evidence suggests that the fauna of the Batesford Limestone is typical of Zone N.8 of Blow (1969), and therefore is slightly older than the Trealla Limestone, but of similar age to the youngest parts of the Tulki Limestone.

The evolutionary stage of *Cycloclypeus carpenteri* and *Lepidocyclina* (*Nephrolepidina*) *howchini howchini* is characteristic of the Tertiary lower *f* stage. *Gypsina howchini, G. globula, Operculina complanata,* and *Amphistegina hauerina* are also present.

Wreck Island No. 1 well

The only available sample, UWA72226, from Wreck Island No. 1 well (Fig. 1) in the Capricorn Basin, Queensland, was studied from core 8 (358–361 m). This sample is from Derrington's (1960) unit M3, from which Crespin (1960) recorded *Cycloclypeus, Miogypsina,* and *Lepidocyclina.*

I have not recorded planktic foraminiferids from core 8, but Palmieri (1971) considered that the interval belonged to his cenozone V. He placed the *Orbulina* first-appearance datum (=base of Zone N.9 of Blow, 1969) at 411 m, which is about 50 m below core 8. Palmieri (1973) noted that the Lepidocyclinae occurring at this level are associated with *Orbulina suturalis, Globorotalia* (*Turborotalia*) *mayeri,* and *Globigerinoides trilobus.* This fauna is typical of the biostratigraphic interval from the middle of Zone N.9 to the middle of Zone N.13 of Blow (1969).

I have examined core 8 and found it to be intensely recrystallised, and in thin section to be devoid of planktic forms. Furthermore, biometric evidence suggests that the sample correlates to Zone N.8 (Chaproniere, 1980a). Palmieri's (1973) records seem to have been from ditch-cuttings, and so the planktic species that he recorded may be contaminants from higher levels.

Because the sample available to me contained only *Lepidocyclina* (*Nephrolepidina*) *howchini howchini,* the other taxa recorded from this level by Crespin (1960) have not been studied. On biometric evidence this level correlates with the Tertiary lower *f* stage.

Hamilton Bore

One sample (77640413) was studied from Hamilton Bore. This is a ditch-cutting sample from 24.4–25.9 m (80–85 feet), and is from the same level that Chapman & Crespin (1932) recovered the holotype for *Lepidocyclina* (*Nephrolepidina*) *howchini.* It is from the Bochara Limestone, a unit which correlates with the Batesfordian Stage (Abele & others, 1976); this is equivalent to Zone N.8. The biometric studies on *L.* (*N.*) *howchini* support this correlation.

SUMMARY OF STRATIGRAPHY, NEW ZEALAND

As for the Australian sections, the planktic foraminiferal biostratigraphic scheme of Blow (1969) has been used wherever possible for correlating the New Zealand sections studied. However, because of the difficulty in accurate correlation between cool and warm-water sequences, it has been necessary to use the zonal scheme of Jenkins (1965, 1967) for the cooler-water samples from New Zealand. An attempt to correlate the schemes of Blow (1969) and Jenkins (1965, 1967, 1971) has been made in Figure 7. For the larger foraminiferids, the East Indian Letter Classification (Adams 1970; Adams & others, 1979; Chaproniere, 1981b) and the environmental associations (LF) of Chaproniere (1975, 1981b) have been used. Furthermore, use has been made of the New Zealand stage nomenclature.

Samples from six localities (Fig. 2) and various stratigraphic levels have been studied.

Pourerere

Sample 79640006 is from the Tutamoe Formation at Poanui Beach (see Appendix 2). This was taken from a similar level to Lillie's (1953) microfaunal sample AL114 (= NZGS No. F5958).

The planktic fauna is dominated by *Globorotalia* (*Globorotalia*) *miotumida miotumida*, *Globoquadrina dehiscens dehiscens*, and *Orbulina universa*, with rare *Turborotalia continuosa*, *Sphaeroidinellopsis* cf. *grimsdali*, and *S. seminulina*. *Globorotalia* (*Fohsella*) *mayeri mayeri* has not been recorded. The last-appearance level of *G.* (*F.*) *mayeri mayeri* defines the base of the *G.* (*G.*) *miotumida miotumida* Zone (Jenkins, 1967). The presence of *S.* cf. *grimsdali* (which is not known above the Waiauan Stage according to Jenkins, 1967) suggests that the Tutamoe Formation at this level may correlate with the *G.* (*F.*) *mayeri mayeri* Zone, but the absence of *G.* (*F.*) *mayeri mayeri*, the rarity of *S. seminulina*, and the presence of *G. dehiscens dehiscens*, may suggest a level near the base of the *G.* (*G.*) *miotumida miotumida* Zone. The *G.* (*F.*) *mayeri mayeri* Zone correlates with Zones N.11 to N.14, but the presence of *G.* (*G.*) *miotumida*, which appears within the zone, suggests a correlation with N.13 or younger. The G. (*G.*) *miotumida miotumida* Zone correlates with Zones N.15 to the lower part of N.17 (van Couvering & Berggren, 1977). The presence of *T. continuosa* without *G.* (*F.*) *mayeri mayeri* suggests a correlation with Zones N.15 or N.16.

Previously, this level within the Tutamoe Formation was considered to be within the Waiauan Stage (Lillie, 1953; Hornibrook, 1971; Matsumaru, 1971b), but because the *G.* (*G.*) *miotumida miotumida* Zone correlates to the whole of the Tongaporutuan Stage (Jenkins, 1967), this part of the Tutamoe Formation seems to be best regarded as within the uppermost Waiauan or the lowermost Tongaporutuan.

The larger foraminiferal fauna from 79640006 consists of *Lepidocyclina* (*Nephrolepidina*) *orakeiensis waikukuensis*, *Cycloclypeus carpenteri*, *Heterostegina borneensis*, *Operculina complanata*, *Amphistegina hauerina*, *Gypsina globulus*, and *Planorbulinella zelandica*. This fauna is similar to that from samples 79640027 and UWA70612. On the values of parameter F for *L.* (*N.*) *orakeiensis waikukuensis*, and parameter pc in *Cycloclypeus carpenteri*, it correlates with the Tertiary lower *f* stage.

Waikuku Beach

Two samples, UWA70611 and UWA70612, are from the Waikuku Limestone, North Cape. Leitch & others (1969) considered that the age of this unit ranges from late Lillburnian to Waiauan (late Middle Miocene), based on the presence of *Orbulina universa*, *Globorotalia* (*Fohsella*) *mayeri mayeri*, and *G.* (*F.*) *peripheroronda*; this correlates to the *Globorotalia mayeri mayeri* Zone of Jenkins (1967), which is probably equivalent to Zones N.11–14. However, *G.* (*F.*) *peripheroronda* appears to become extinct within the Waikuku Limestone (Leitch & others, 1969), suggesting that the unit may straddle the N.11–12 zonal boundary and correlate with the basal part of the *G. mayeri mayeri* Zone; this would be close to the Lillburnian-Waiauan Stage boundary.

The larger foraminiferal fauna of the two samples contains *Lepidocyclina* (*Nephrolepidina*) *orakeiensis waikukuensis*, *Cycloclypeus carpenteri*, *Operculina complanata*, and *Heterostegina borneensis*. The presence of *H. borneensis* suggests that this fauna correlates to the Tertiary lower *e* stage; however, *Cycloclypeus carpenteri* and the evolutionary stage of the embryonic parts of *L.* (*N.*) *orakeiensis waikukuensis* indicate the Tertiary lower *f* stage. On the basis of the age of the Pourerere sample and a comparison of the values for parameter pc for *Cycloclypeus carpenteri* in the Pourerere and Waikuku samples, the Waikuku Limestone is older than the sampled level within the Tutamoe Formation. However, the values for parameter F in *L.* (*Nephrolepidina*) in the same samples suggests the converse.

Greymouth

Sample 79640027 is from the NZGS locality S44/559, from the Stillwater Mudstone in the Alexander Street cutting. This unit correlates with the Clifdenian Stage at this locality (Nathan, 1974).

The planktic fauna contains *Praeorbulina glomerosa* without *Orbulina*. This indicates the *Praeorbulina glomerosa curva* Zone of Jenkins (1967) and the upper part of Zone N.8 of Blow (1969).

The larger foraminiferal assemblage consists of *Lepidocyclina* (*Nephrolepidina*) *orakeiensis hornibrooki*, *Cycloclypeus carpenteri*, *Heterostegina borneensis*, *Gypsina globulus*, *Amphistegina hauerina*, and *Planorbulinella zelandica*. This fauna is similar to that from the Waikuku Beach and Pourerere localities, differing only on the evolutionary stage of *L.* (*Nephrolepidina*) and *Cycloclypeus*. This, too, correlates with the Tertiary lower *f* stage.

Kaipara Harbour

Sample UWA70614 (=NZGS locality N28/631) is from the Orbitoid bed, which is part of the Puketi Formation (Waitakere Group).

The planktic fauna from this sample contains *Globigerina woodi connecta*, *G. woodi woodi*, *Globigerinoides quadrilobatus immaturus*, *G. quadrilobatus quadrilobatus*, and *Globoquadrina dehiscens dehiscens*. This fauna is typical of the latest part of the *Globigerina woodi connecta* Zone of Jenkins (1967). The presence of *Globigerinoides quadrilobatus quadrilobatus* without *G. quadrilobatus trilobus* and the absence of *Globorotalia* (*Fohsella*) *kugleri kugleri* (which may be the result of environmental factors, but considered unlikely in view of the presence of *Globigerinoides quadrilobatus immaturus*) indicate a correlation with Zone N.5 of Blow (1969). This evidence suggests that the Orbitoid bed in Kaipara Harbour is slightly younger than the Orbitolite bed in Hokianga Harbour.

The larger foraminiferal fauna contains *Lepidocyclina* (*Nephrolepidina*) *orakeiensis orakeiensis*, *L.* (*Eulepidina*) *ephippioides*, *Heterostegina borneensis*, and *Miogypsina* (*Miogypsina*) *intermedia*. The presence of *Miogypsina* (*Miogypsina*) with *L.* (*Eulepidina*) is typical of the Tertiary upper *e* stage, yet the presence of *Heterostegina borneensis* suggests a Tertiary lower *e* stage correlation. However, because *H. borneensis* ranges into the Tertiary lower *f* stage (Waikuku Limestone and Tutamoe Formation—see above) in New Zealand, and because *Miogypsina* (*Miogypsina*) first appears at the base of Tertiary upper *e* stage, a correlation with Tertiary upper *e* is accepted here.

According to Hornibrook (*in* Arlidge, 1955) the Orbitoid bed is from the Altonian Stage. The presence of *Globigerinoides* may indicate a correlation with the upper part of the *G. woodi connecta* Zone, which is placed in the present concept of the Altonian Stage of Scott (1972).

Hokianga South Head

Sample UWA70613 is from the Orbitolite bed (NZGS locality N18/569), which is probably part of the Waitiiti Formation of Ballance & others (1977).

Jenkins (1971) has listed the planktic foraminiferal species in the Orbitolite bed, and concluded that the fauna belongs to the *Globigerina woodi connecta* Zone, which he correlated earlier (1965, 1967) with the interval from the late part of the *G. ciperoensis ciperoensis* Zone to the early part of the *Catapsydrax dissimilis* Zone of Bolli (1957). Blow (1969) correlated these to his Zones N.3 to N.5. I consider that the forms identified by Jenkins (1971) as *Globigerinoides altiaperturus* are early members of the *G. quadrilobatus* plexus and so are more typical of Zone N.3/4 of Chaproniere (*in* Shafik & Chaproniere, 1978). The presence of *Globorotalia* (*Fohsella*) *kugleri kugleri* lends support to this conclusion.

The larger foraminiferal assemblage from the Orbitolite bed at Hokianga is nearly identical with that from the Orbitoid bed at Kaipara Harbour (sample UWA70614); it differs only in the presence of *Miogypsina* (*Miogypsina*) *globulina* rather than *M.* (*M.*) *intermedia*. As with sample UWA70614, the fauna from the Hokianga Orbitolite bed is typical of the Tertiary upper *e* stage, based on the presence of *Miogypsina* (*Miogypsina*). The occurrence of *M.* (*Miogypsina*) in Zone N.3/4 indicates that the Tertiary upper *e*–lower *e* stage boundary occurs below the top of Zone N.3/4; previously the boundary between these two stages had been equated with the N.4–N.5 zonal boundary (Adams, 1970).

Jenkins (1967) considered that *Globorotalia* (*Fohsella*) *kugleri* was restricted to the lower part of the *Globigerina woodi connecta* Zone, and to the Otaian Stage.

Waitemata Harbour

Sample 79640025 is from the basal part of the Orakei Greensand Member of the East Coast Bays Formation (Ballance, 1976) at

Takaparawha Point. This is about 1.25 km northeast of the type locality for *L.* (*N.*) *orakeiensis orakeiensis*.

Hornibrook (1971) recorded the following planktic fauna from this level: *Globoquadrina dehiscens*, *Catapsydrax dissimilis*, *Globigerina woodi*, and *Globorotalia semivera*. In addition, I have found *Globigerina praebulloides*, *G. woodi connecta*, *G. woodi woodi*, and *Turborotalia euapertura*. This assemblage is dominated by *G. woodi woodi* and *C. dissimilis*. Only one specimen of *G. woodi connecta* was recovered; the rarity of this subspecies and its overlap with *T. euapertura* suggests a correlation with the base of the *Globigerina woodi connecta* Zone. The fauna from Waitemata Harbour is therefore older than the fauna from Hokianga South Head, and correlates to Zone N.3/4 of Chaproniere (*in* Shafik & Chaproniere, 1978).

The larger foraminiferal fauna is poor. I have recorded *Lepidocyclina* (*Nephrolepidina*) *orakeiensis orakeiensis*, *Gypsina globulus*, *Amphistegina aucklandica*, *Carpenteria* sp., and a single fragment of *Heterostegina* sp. In addition, Hornibrook (1971) recorded *Cycloclypeus* sp., *Planorbulinella plana*, and *Amphistegina campbelli*. This fauna is nondiagnostic for correlation with the Letter Stage Classification. However, the evolutionary development of *L.* (*N.*) *orakeiensis orakeiensis* in the sample is typical of that for the Tertiary lower *e* stage, confirming the planktic evidence that the sample is the oldest one from New Zealand in the study.

Hornibrook (1971) and Ballance (1976) considered that the Orakei Greensand was from the lower part of the Otaian Stage. However, Jenkins (1965) noted that *Turborotalia euapertura* did not range into the Otaian, and is last recorded in the lowermost part of the *G. woodi connecta* Zone, which is in the upper part of the Waitakian Stage. *T. euapertura* is known to range to higher levels outside New Zealand (e.g., Chaproniere, 1981a), and so its extinction level should not be relied on for exact correlation. For this reason, the sample must be from very close to the Waitakian-Otaian boundary.

BIOMETRIC STUDIES

The populations of *Cycloclypeus carpenteri*, *Heterostegina borneensis*, and *Lepidocyclina* (*Nephrolepidina*) which have been studied biometrically in this work are in addition to those from the Australasian region previously studied by Chaproniere (1980a); the new data are discussed below.

Cycloclypeus

Values for the four parameters used by Chaproniere (1980a) are listed in Table 1, but only parameters pc and Spc_{4+5} are discussed here. The values obtained for these two parameters for the three New Zealand populations (two in Table 1, the third in Chaproniere, 1980a) fit the planktic biostratigraphic data. The population from 79640006 is by far the most advanced and is statistically significantly different (based on the t-test at the 95% confidence level) from those from 79640027 and UWA706111. In contrast, there is no significant difference between the populations from 79640027 and UWA70611 (see Fig. 13). Comparison between the New Zealand and Australian populations shows that *Cycloclypeus* evolved at a slower rate in New Zealand, and that Zone N.8 populations in the two regions do not correlate biostratigraphically. Part of this inconsistency may be due to the very small sample ($N=2$) available from Zone N.8 in New Zealand (79640027), but, even so, the values for pc and Spc_{4+5} from UWA70611 are typical of levels below Zone N.8 in Australia (Chaproniere, 1980a). The additional data presented here are consistent with the conclusions made by Chaproniere (1980a): that the biostratigraphic usefulness of *Cycloclypeus* falls off above Zone N.8, and that the larger foraminiferids evolved at different rates in the two regions.

Heterostegina borneensis

Table 2 summarises the results for all populations of this species that I have studied. The t-test indicates that there is no significant difference between the populations based on parameter N_0 (this is the one used to define the species). For S_{4+5}, only the population from 79640006 (the youngest) differs significantly from the others, suggesting that parameter S_{4+5} either may be controlled by non-genetic factors, or suddenly started to evolve, so making it a potential biostratigraphic tool; more data are necessary to resolve this problem. The results for parameter N_0 show that one species is present, and that this is *H. borneensis*. Furthermore, the new data suggest that this species ranged to considerably

TABLE 1. STATISTICAL RESULTS FOR *CYCLOCLYPEUS*

Pop. No.	*pc*				Spc_{4+5}				D_I				*Log* D_I				Sc_1				
	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	N
79640006	8.39	0.94	11.20	7–10	9.26	2.68	28.94	7–19	188.91	20.11	10.65	150–230	2.27	0.05	2.02	2.18–2.36	25.92	4.97	19.17	19–35	13
79640027	11.00	1.41	—	10–12	9.50	0.71	—	9–10	175.50	17.68	—	163–188	2.24	0.04	—	2.21–2.27	26.00	2.83	—	24–38	2

TABLE 2. STATISTICAL RESULTS FOR *HETEROSTEGINA BORNEENSIS*

	N_0				S_{4+5}				D_I				D_{II}				
Pop. No.	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	N
7964006	3.14	0.35	11.15	3–4	5.32	1.25	23.50	3–8	163.41	32.31	19.77	95–210	105.45	33.31	31.59	45–155	22
79640027	3.38	0.72	21.30	3–5	4.75	1.69	35.58	2–7	163.81	44.18	26.97	80–250	117.50	24.14	20.54	75–138	16
UWA70611	3.38	0.71	51.44	2–5	4.47	1.27	28.41	2–7	90.31	13.28	14.70	73–118	68.91	12.43	18.04	45– 91	32
UWA53674	3.29	0.46	36.65	3–4	4.77	1.11	23.27	3–7	140.14	25.74	18.37	95–191	88.80	14.44	16.26	59–127	35

TABLE 3. STATISTICAL RESULTS FOR *LEPIDOCYCLINA (NEPHROLEPIDINA)*

	A				*dc*				*E*				*B*				
Pop. No.	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	N
77640413	51.92	6.88	13.25	39.66–67.39	46.42	13.08	28.18	21.62–76.67	50.09	10.05	20.06	27.27–70.77	60.16	8.92	14.83	35.71–76.02	35
79640006	52.73	9.68	18.36	29.41–74.16	47.69	16.32	34.22	15.38–83.87	53.07	14.53	27.38	15.22–83.61	62.82	9.89	15.74	44.04–83.33	38
79640025	43.20	5.34	12.36	35.71–52.33	30.73	11.06	35.99	19.61–51.43	36.32	9.07	24.97	27.03–52.94	49.03	8.55	17.44	40.51–62.50	8
79640027	52.83	5.15	9.75	41.67–63.41	43.34	9.97	23.00	22.50–65.22	50.79	8.60	16.93	31.03–67.39	62.84	10.07	16.02	34.59–80.00	29

	A + *B*				*C*				*F*				
Pop. No.	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	N
77640413	112.08	11.70	10.44	82.38–128.25	4.09	1.22	29.83	2– 8	3.17	0.57	17.98	2–4	35
79640006	115.53	16.13	13.96	86.25–143.25	5.53	1.78	32.19	3–10	3.32	0.62	18.67	2–4	38
79640025	92.23	12.16	13.18	77.84–110.33	3.13	1.13	36.10	2– 5	1.81	0.35	18.62	1–2	8
79640027	115.67	12.06	10.43	80.47–142.30	4.34	1.08	24.88	2– 6	2.90	0.62	21.38	2–4	29

	D				D_I				D_{II}				
Pop. No.	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	$\bar{x}$	s	V	R	N
77640413	1.63	0.17	10.44	1.27–2.00	215.46	39.39	18.28	133–300	347.97	62.14	17.86	253–500	35
79640006	1.68	0.27	16.07	1.27–2.44	283.58	59.57	21.01	173–513	472.82	93.10	19.69	220–720	38
79640025	1.58	0.08	5.06	1.48–1.75	274.13	42.76	15.60	233–353	430.88	57.94	13.45	387–533	8
79640027	1.66	0.16	9.64	1.41–1.93	224.86	51.38	22.85	153–380	368.03	70.50	19.16	287–567	29

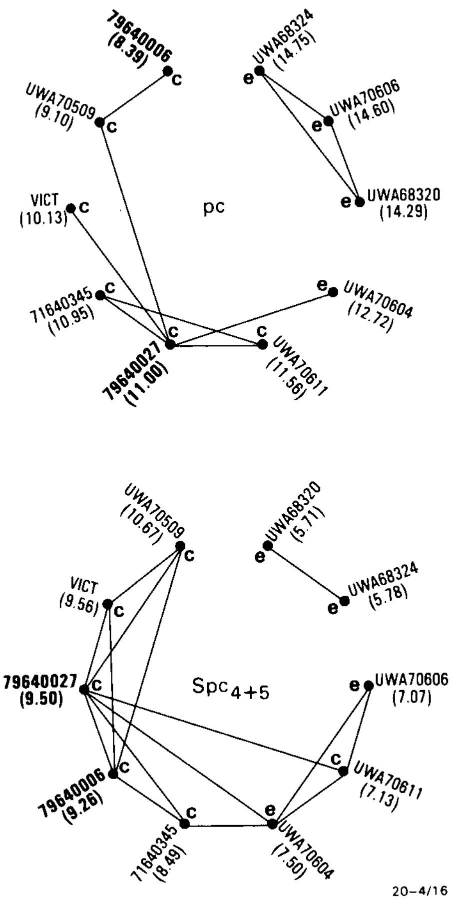

Fig. 13. Results of the t-test for parameters pc and Spc_{4+5} in populations of *Cycloclypeus (Cycloclypeus) eidae* and *C. (C.) carpenteri* from Australia and New Zealand. Lines drawn between populations indicate that the differences between them are not significant at the 95% level of confidence. A bold face indicates those populations whose biometric results are incorporated in this study; biometric results for the other populations are published by Chaproniere (1980a).

higher levels in New Zealand long after its extinction elsewhere in the Indo-Pacific region. Chaproniere (1980a) suggested that the presence of this species in the Middle Miocene in New Zealand (UWA70611) was probably due to reworking, but the presence of *H. borneensis* in 79640006 and 79640027, from widely spaced areas where it would be difficult to derive it from Late Oligocene or Early Miocene sediments, gives greater credence to its longer survival in this region.

Lepidocyclina (Nephrolepidina).

Table 3 summarises, for four new samples (77640413, 79640006, 79640025, and 79640027), the values obtained for all parameters used by Chaproniere (1980a). Parameter F was the most useful for taxonomic and biostratigraphic discrimination (Chaproniere (1980a), and is the only one discussed here. Figures 14 and 15 illustrate the results of the t-test; these are modifications of those given by Chaproniere (1980a, microfiche attachment), where the Australian and New Zealand data are presented together; in this study they are separated and the new populations added. Figures 14a and b clearly show the differences between *sumatrensis*, *praehowchini*, and *howchini* from Australia, and Figures 15a and b the differences between *orakeiensis*, *hornibrooki*, and *waikukuensis* from New Zealand. The population from 79640006 is the only one to be ranked out of biostratigraphic order; this is the youngest population that I have studied from Australia and New Zealand, and, though it falls within the range proposed for *waikukuensis*, the values obtained for parameter F are lower than expected; this suggests that the biostratigraphic usefulness of this parameter may lessen above the early Middle Miocene. This is not unexpected because at higher levels the peculiar multilepidine embryoconchs become more common in the populations shortly before the extinction of this genus. Thus, the new data reinforce the conclusions reached by Chaproniere (1980a) on the value of parameter F and on the existence of two separate lineages of *L. (Nephrolepidina)* in the Australia–New Zealand region: the *orakeiensis–hornibrooki–waikukuensis* lineage in New Zealand, and the *sumatrensis–praehowchini–howchini* lineage in Australia.

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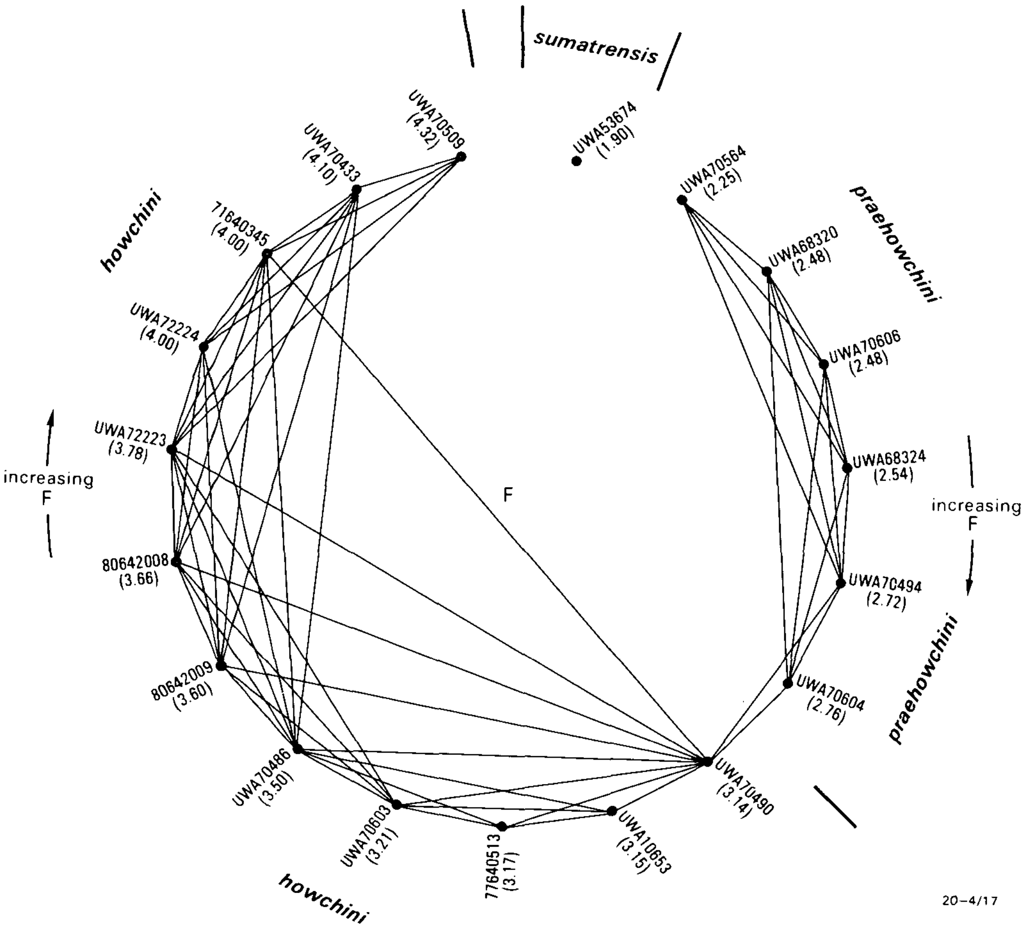

Fig. 14a. Results of the t-test for parameter F in populations of *Lepidocyclina (Nephrolepidina)* from Australia; diagram with equidistant populations (cf. Fig. 14b). Lines drawn between populations indicate that the differences between them are not significant at the 95% level of confidence. A bold face indicates those populations whose biometric results are incorporated in this study; biometric results for the other populations are published in Chaproniere (1980a). Note that population 77640513 should be 77640413.

who suggested and supervised the study, read earlier manuscripts, and introduced me to the larger foraminiferids; to Dr D. J. Belford (Bureau of Mineral Resources) for advice and reading the manuscript; to Mr C. Hughes (University of Western Australia) and Mr P. Davis (BMR) for help with photography; to Mrs H. Apps for drawing most of the illustrations; and to Drs P. Quilty (WAPET) and C. A. Wright (Burmah Oil Company of Australia Ltd—BOCAL) for numerous discussions on foraminiferids from the offshore parts of the Carnarvon Basin and the North West Shelf.

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Finally, I wish to thank my wife, Angela, without whose help, understanding, and moral support this study would never have been completed.

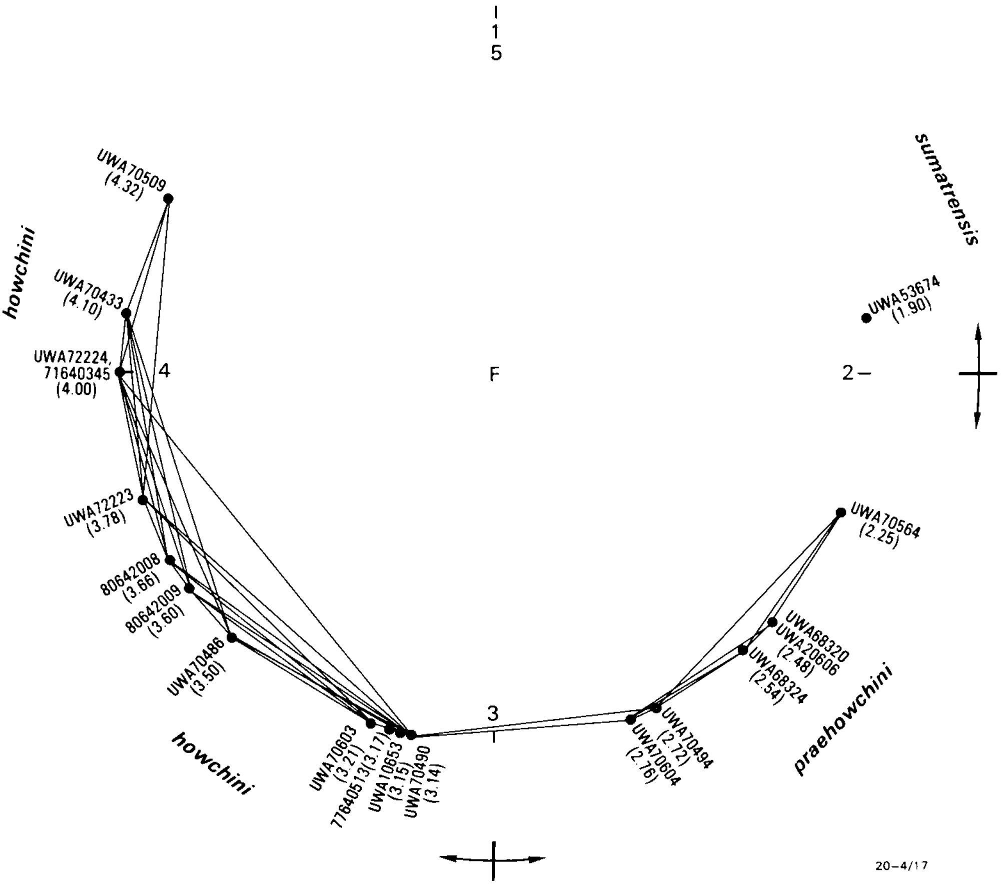

Fig. 14b. Results of the t-test for parameter F in populations of *Lepidocyclina (Nephrolepidina)* from Australia; diagram scaled according to mean values of F (cf. Fig. 14a). Note that population 77640513 should be 77640413.

SYSTEMATIC PALAEONTOLOGY

Suborder **MILIOLINA** Delage & Hérouard
Superfamily **MILIOLACEA** Ehrenberg
Family **MILIOLINIDAE** Ehrenberg
Subfamily **FABULARIINAE** Ehrenberg

Genus **Austrotrillina** Parr, 1942

Type species: *Trillina howchini* Schlumberger, 1893; original designation.

Austrotrillina howchini (Schlumberger, 1893)
Plate 14, figures 1, 2

1893 *Trillina howchini* Schlumberger, p. 119, text-fig. 1; pl. 3, fig. 6.
1942 *Austrotrillina howchini* (Schlumberger); Parr, pp. 361-362.
1943b *Austrotrillina howchini* (Schlumberger); Crespin, p. 77 (list).
1951 *Austrotrillina howchini* (Schlumberger); Glaessner, pp. 273-274 (list).
1954 *Austrotrillina howchini* (Schlumberger); Singleton, p. 62 (list).
1954 *Austrotrillina howchini* (Schlumberger); Crespin, p. 40, pl. 7, fig. 14.
1955a *Austrotrillina howchini* (Schlumberger); Crespin, p. 76 (list), pl. 9, fig. 4.
1956 *Austrotrillina howchini* (Schlumberger); Condon & others, p. 55 (list).
1958 *Austrotrillina howchini* (Schlumberger); Glaessner & Parkin, pp. 110, 133 (list).
1961 *Austrotrillina howchini* (Schlumberger); Ludbrook, p. 87 (list), pl. IV, fig. 5.
1964 *Austrotrillina howchini* (Schlumberger); Carter, p. 62, pl. 1, figs. 12-17.
1968 *Austrotrillina howchini* (Schlumberger); Adams, pp. 86-89, pl. 2, figs. 1-7; pl. 6, figs. 1-5, 7.

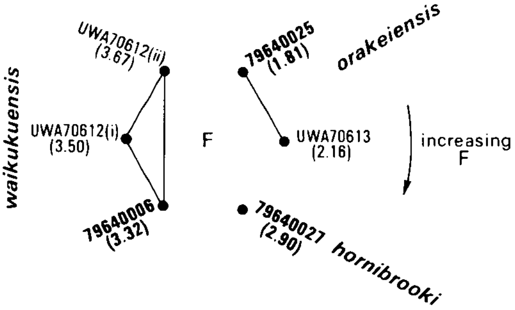

Fig. 15a. Results of the t-test for parameter F in populations of *Lepidocyclina (Nephrolepidina)* from New Zealand; diagram with equidistant populations (cf. Fig. 15b). Lines drawn between populations indicate that the differences between them are not significant at the 95% level of confidence. A bold face indicates those populations whose biometric results are incorporated in this study; biometric results for the other populations are published in Chaproniere (1980a).

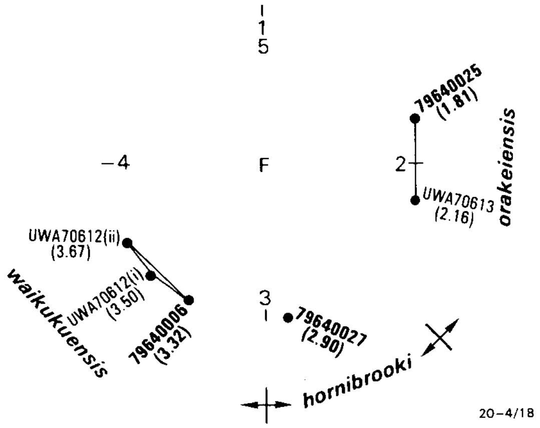

Fig. 15b. Results of the t-test for parameter F in populations of *Lepidocyclina (Nephrolepidina)* from New Zealand; diagram scaled according to mean values of F (cf. Fig. 15a).

1969 *Austrotrillina howchini* (Schlumberger); Lindsay, p. 23 (list).
1970 *Austrotrillina howchini* (Schlumberger); Lowry, pp. 94, 107 (list).
1973 *Austrotrillina howchini* (Schlumberger); Binnekamp, p. 9, pl. 1, figs. 1-4.
1974 *Austrotrillina howchini* (Schlumberger); Adams & Belford, p. 487, pl. 73, fig. 7.

Remarks. Typical specimens from the North West Cape area have alveoli that bifurcate, but not as pronouncedly as in specimens from Victoria. It must be concluded, therefore, that these specimens from the North West Cape area are primitive *A. howchini*, similar to those discussed and figured by Adams (1968).

Dimensions of figured specimens.	Maximum diameter (mm)
UWA75006	1.15
UWA75007	1.10

Distribution. This species ranges from within the topmost parts of the Tulki Limestone and throughout the Trealla Limestone. It is also present in core 1 from Ashmore Reef No. 1 well. It is confined to the LF.7 and LF.8 associations. The figured specimens are from sample UWA51524, from the Trealla Limestone.

Austrotrillina striata Todd & Post, 1954
Plate 3, figures 1a–e

1954 *Austrotrillina striata* Todd & Post, p. 555, pl. 198, fig. 9.
1956 *Austrotrillina howchini* (Schlumberger); Crespin & Belford, p. 2 (list).
1968 *Austrotrillina striata* Todd & Post; Adams pp. 92-93, pl. 4, figs. 1-13; pl. 6, fig. 9.

Remarks. Several specimens have been recorded from one sample from the Bullara Limestone. They are free and highly recrystallised, and most are decorticated. This decortication has revealed coarse, simple alveoli, indicating that they are *A. striata*; thin sections support this. A network of tubules ramifies the test wall (see Plate 3, fig. 1d); these have been interpreted as resulting from the burrowing activity of blue-green algae, similar to that recorded by Kendall & Skipworth (1969).

Dimensions of figured specimen.	Maximum length (mm)	Maximum width (mm)
UWA75008	0.55	0.45

Distribution. This species has been recorded from samples UWA53674 and 80640523 from the Bullara Limestone. It is restricted to the LF.2 association.

Genus **Lacazinella** Crespin, 1962

Type species: *Lacazina wichmanni* Schlumberger, 1894.

Lacazinella sp. cf. **L. wichmanni** (Schlumberger, 1894)
Plate 3, figures 4a–b; Plate 14, figures 3,4

1894 *Lacazina wichmanni* Schlumberger, p. 296, pl. 12, figs. 2-5.
1956 aff. *Lacazina* sp.; Crespin & Belford, p. 3 (list).
1962 *Lacazinella wichmanni* (Schlumberger); Crespin, pp. 338-339, pl. 1, figs. 1-9; pl. 2, figs. 1-15; text-fig. 2A-B.

Remarks. Recrystallised and decorticated specimens with internal characters close to those of *L. wichmanni* have been found in the lower part of the Bullara Limestone. They differ from the types only by being more elongate, and in this respect resemble *L. reicheli* (Bursch). Because of their poor preservation, they have been placed in open nomenclature.

Dimensions of figured specimens.	Maximum length (mm)	Maximum width(mm)
UWA75009	0.75	0.45
UWA75010	—	1.05
UWA75011	—	0.75

Distribution. This form is found only in the lower part of the Bullara Limestone and is restricted to the LF.1 association. As noted by Chaproniere (1976) this species has probably been reworked from the Giralia Calcarenite. The figured specimens are from sample UWA53676.

Family **SORITIDAE** Ehrenberg

Genus **Peneroplis** de Montfort

Type species: *Nautilus planatus* Fichtel & Moll, 1798; original designation.

Peneroplis sp.

Plate 14, figures 6, 7

Remarks. Because *Peneroplis* sp. has been recorded only from random thin sections, no attempt has been made to refer specimens of this genus to any described species.

Dimensions of figured specimens.	Maximum diameter (mm)
UWA75012	0.80
UWA75014	1.10

Distribution. Peneroplis sp. has been recorded only from grainstone lithologies of the upper parts of both the Bullara and Trealla Limestones, and is restricted to the LF.2 and LF.8 associations. The figured specimens are from samples UWA51524 and UWA68347 from the Trealla Limestone.

Genus **Spirolina** Lamarck

Type species: *Spirolina indracea* Lamarck; subsequent designation of Cushman (1927a).

Spirolina sp.

Plate 14, figure 5

Remarks. Forms with a simple spiral coil becoming uncoiled and rectilinear have been recorded as *Spirolina* sp.

Dimensions of figured specimen.	Maximum diameter (mm)
CPC15686	0.80

Distribution. This genus has been recorded from the grainstones of the upper parts of both the Bullara and Trealla Limestones, and is restricted to the LF.2 and LF.8 associations. The figured specimen is from sample 80641354 from the Trealla Limestone.

Genus **Sorites** Ehrenberg

Type species: *Sorites dominicensis* Ehrenberg (=*Nautilus marginalis* Lamarck); subsequent designation of Cushman (1927b).

Sorites sp.

Plate 14, figures 8–10

Remarks. Cole (1954, pp. 582–583) concluded that '*Sorites* is a valid genus' and can be distinguished from *Marginopora* by the planispirally coiled embryonic chambers. He also noted that in vertical section *Sorites* has a single layer of chambers, while *Marginopora* is more complicated, generally having two or more layers. However, Cole found that some specimens of *Marginopora* have only a single layer (see Cole, 1954, pl. 211, figs. 6, 10, 11, 13, 17). In vertical section alone, such forms could not be distinguished from *Sorites*, and so in random thin section the two genera cannot be distinguished from one another with certainty. For this reason I have identified specimens with only a single layer of chambers throughout their ontogeny as *Sorites* sp., even though some of these may be simple forms of *Marginopora*.

Dimensions of figured specimens.	Maximum diameter (mm)
UWA75013	1.45
UWA75015	3.05
UWA75016	0.50

Distribution. Sorites sp. has been recorded only from the upper parts of the Bullara and Trealla Limestones and is restricted to the LF.2 and LF.8 associations. The figured specimens are from sample UWA53674 from the Bullara Limestone, and from samples UWA 51524 and UWA51509 from the Trealla Limestone.

Genus **Marginopora** de Blainville

Type species: *Marginopora vertebralis* de Blainville, 1830; original designation.

Marginopora vertebralis de Blainville, 1830

Plate 14, figures 11–15

1830 *Marginopora vertebralis* de Blainville, p. 377.
1954 *Marginopora vertebralis* Quoy & Gaimard; Cole, pp. 582-583, pl. 210, figs. 10-13; pl. 211, figs. 3-29.

1965 *Marginopora vertebralis* Quoy & Gaimard; Cole, pp. 22-24, pl. 7, fig. 9; pl. 8, figs. 1-6; pl. 9, figs. 1-12; pl. 10, figs. 1-8.
1974 *Marginopora vertebralis* Blainville; Adams & Belford, p. 488, pl. 74, fig. 11.

Remarks. As noted above, *Sorites* cannot be distinguished in random thin sections from specimens of *Marginopora* with a single layer of chambers unless the embryonic chambers are present. Forms with more than one layer are readily identified as *Marginopora.* Cole (1965) considered *Marginopora vertebralis* as a senior synonym for *Amphisorus hemprichii.* Ross (1972) apparently considered the two forms to belong to the same genus (*Marginopora*) but suggested that they could be distinguished by the following: *M. vertebralis* has a trilaminate arrangement of chambers after 2-mm diameter of growth, and *M. hemprichii* has a bilaminate arrangement; the two forms have different numbers of apertural pores per chamberlet. Ross & Ross (1978) noted that the two forms differ in the degree of perforation of the lateral chamberlets. In the main, such differences are difficult to observe in random thin section, making distinction between the two species difficult, but the rarity of trilaminate specimens suggests that the North West Cape specimens may be more closely related to *A. hemprichii.* However, trilaminate types are always associated with bilaminate specimens, implying a close relationship.

Because *Marginopora* was studied from random thin sections only, the number of apertural pores per chamber could not be identified. Until more is known about the relationship of the two forms in modern seas, I prefer to follow Cole (1965) and place them within the same taxon.

Dimensions of figured specimens.	Maximum diameter (mm)
UWA75017	2.60
UWA75018	2.00
UWA75019	2.30
UWA75020	2.65
UWA75021	2.90

Distribution. Rare specimens of *Marginopora* range from within the upper part of the Tulki Limestone and throughout the Trealla Limestone in the North West Cape area. The taxon is also present in the uppermost part of the unnamed calcarenite (core 1) in Ashmore Reef No. 1 well. It is restricted to the LF.7 and LF.8 associations. The figured specimens are from samples UWA51908 and UWA51909 from the Trealla Limestone.

Family **ALVEOLINIDAE** Ehrenberg

Genus **Borelis** de Montfort

Type species: *Nautilus melo* var. B Fichtel & Moll, 1798; original designation.

Borelis pygmaeus Hanzawa, 1930

Plate 14, figures 16, 17

1930 *Borelis pygmaeus* Hanzawa, p. 94, pl. 26, figs. 14, 15.
1956 *Neoalveolina pygmaea* (Hanzawa); Crespin & Belford, p. 2 (list).
1974 *Borelis pygmaeus* Hanzawa; Adams & Belford, pp. 488-490, pl. 71, figs. 9-14.

Remarks. Rare, poorly preserved specimens similar to those figured by Adams & Belford (1974) have been referred to this taxon.

Dimensions of figured specimens.	Maximum length (mm)	Maximum width (mm)
UWA75022	0.85	0.40
CPC15688	—	0.60

Distribution. This species is found in the upper Bullara Limestone and throughout the Trealla Limestone. It is restricted to the LF.2, LF.7, and LF.8 associations. The figured specimens are from samples UWA70600 from the Bullara Limestone and 80641354 from the Trealla Limestone.

Genus **Flosculinella** Schubert

Type species: *Alveolinella bontangensis* Rutten, 1913; subsequent designation of Galloway (1933).

Flosculinella bontangensis (Rutten, 1913)

Mohler (1949) and Adams (1970) considered that *Flosculinella globulosa* gave rise to *F. bontangensis* and that both intergrade. For this reason, and also because specimens referable to both forms are present in the same samples, they are treated here as subspecies. *F. bontangensis* is the senior synonym and so has priority.

Crespin (1955a, list) recorded *F. cucumoides* (Chapman) from the Trealla Limestone. Subsequently, Adams (1970, p. 115) stated that this name is a junior synonym for *F. bontangensis.* However, *F. cucumoides* has priority because it was described at an earlier date, 1908. *F. cucumoides* is based on poor figures and description, and the types should be restudied. However, C. G. Adams (personal communication—letters, May, July 1974) noted that the type locality for this species cannot be located, so restudy of this form from topotypic material is impossible. Consequently the relationship between *F. bontangensis* and *F. cucumoides* must remain uncertain. For this reason the name *F. bontangensis* is retained in this study.

Flosculinella bontangensis bontangensis
(Rutten, 1913)

Plate 14, figures 18–21

1913 *Alveolinella bontangensis* Rutten, p. 221, pl. 14, figs. 1-3.
1954 *Flosculinella bontangensis* (Rutten); Singleton, p. 61 (list).
1955a *Flosculinella bontangensis* (Rutten); Crespin, p. 74, pl. 9, fig. 5, p. 77 (list).
1956 *Flosculinella bontangensis* (Rutten); Condon & others, p. 55 (list).
1958 *Flosculinella bontangensis* (Rutten); McWhae & others, p. 126 (list).
1969 *Flosculinella bontangensis* (Rutten); Lindsay, p. 23 (list), pl. 2, fig. 3.
1970 *Flosculinella bontangensis* (Rutten); Lindsay, p. 5 (list).
1970 *Flosculinella bontangensis* (Rutten); Lowry, p. 94 (list).
1974 *Flosculinella bontangensis* (Rutten); Adams & Belford, p. 490, pl. 74, fig. 3.

Remarks. Mohler (1949) noted that three species of *Flosculinella* could be distinguished: *F. reicheli*, of which specimens are small and have a maximum-length-to-maximum-diameter ratio (l/w) ranging between 0.9 and 1.2; *F. globulosa–bontangensis*, of which specimens are larger—and globular initially—but become increasingly fusiform with time and have an l/w ratio between 1.0 and 1.8; and *F. borneensis*, which are the largest and most fusiform and have an l/w ratio between 1.7 and 3.2.

Even though Mohler (1949) did not distinguish between *F. globulosa* and *F. bontangensis*, the type figures clearly show that Rutten (1913) regarded *F. bontangensis* as distinctly fusiform. For this reason, specimens in which the l/w ratio exceeds 1.2 have been referred to *F. bontangensis bontangensis*. These are associated, in some samples, with less common, more globular forms which have been placed into *F. bontangensis globulosa*.

Dimensions of figured specimens.	Maximum length (mm)	Maximum width (mm)
UWA75023	2.20	0.60
UWA75024	—	0.85
UWA75025	2.40	1.60
CPC15689	1.50	0.85

Distribution. This taxon is found in the grainstone lithology of the Trealla Limestone, and the packstone lithology from the uppermost part of the unnamed calcarenite in Ashmore Reef No. 1 (core 1); it is restricted to the LF.8 association. The figured specimens are from samples UWA51908, UWA68346, UWA 70586, and CR28.

Flosculinella bontangensis globulosa
(Rutten, 1917)

Plate 3, figures 2a–b; Plate 14, figure 22

1917 *Alveolinella (Flosculinella) globulosa* Rutten, p. 277, pl. 5, figs. 140-141.
1957b *Flosculinella globulosa* (Rutten); Cole, p. 767, pl. 240, fig. 1.
1969 *Flosculinella globulosa* (Rutten); Cole, p. C7, pl. 4, figs. 24, 26.
1973 *Flosculinella globulosa* (Rutten); Binnekamp, p. 9, pl. 24, figs. 1-2.

Remarks. Globular forms which have an l/w ratio between 1 and 1.2 have been referred to *F. bontangensis globulosa.* Two free specimens (one of which is illustrated in Pl.3, figs. 2a–b) have been found in ditch-cuttings from Exmouth No. 2 well at levels within the Trealla Limestone.

Flosculinella bontangensis is associated with a typical Tertiary lower *f* stage fauna. Planktic species at levels below the initial appearance of this genus in the Trealla Limestone indicate a correlation to Zone N.9 or younger of Blow (1969). This implies that the gradation between *globulosa* and *bontangensis* (sensu stricto) occurred within the Tertiary lower *f* stage, above the base of Zone N.9. Adams (1970) questioned the occurrence of *globulosa* at this level, and expressed uncertainty regarding the level at which this transition occurred, but, in the North West Cape area at least, the position of the transition is now known.

Dimensions of figured specimens.	Maximum length (mm)	Maximum width (mm)
UWA75026	—	1.05
UWA75027	0.90	0.90

Distribution. This taxon is found only in the grainstone lithologies of the Trealla Limestone, where it occurs with *F. bontangensis bontangensis*. It is restricted to the LF.8 association. The figured specimens are from sample UWA 70587.

Suborder **ROTALIINA** Delage & Hérouard
Superfamily **ROTALIACEA** Ehrenberg
Family **NUMMULITIDAE** de Blainville
Subfamily **NUMMULITINAE** de Blainville

Genus **Operculina** d'Orbigny

Type species: *Lenticulites complanatus* Defrance, 1822; subsequent designation of Cushman (1914).

The genus *Operculina* has been critically reviewed by several workers since it was proposed by d'Orbigny (1826). Yabe (1918) described *Operculinella*, and Hanzawa (1935) *Operculinoides*, for forms which Cole (1959) considered to be junior synonyms for *Operculina*. Earlier, Bannink (1948) concluded that *Operculinella* is synonymous with *Operculina*; he mentioned *Operculinoides*, but made no comment on its relationship to *Operculina*, except to note that it is 'an American branch of the *Operculina*-type' (Bannink, 1948, p. 111). Cole (1959) failed to mention Bannink's work, even though it supported his own conclusions. Smout & Eames (1960) criticised Cole's (1959) paper, and considered that *Operculinella* is a valid genus and that *Operculinoides* is its junior synonym. Subsequently, Cole (1960a, p. 190) stated that 'there are only two valid genera of all those that have been proposed for camerinids with undivided chambers. They are *Camerina* and *Miscellanea*'. Thus, he included *Operculina*, *Operculinoides*, *Operculinella*, and others in *Camerina*. Cole (1961a, p. 113), in reply to criticism by Smout & Eames (1960), supported his earlier conclusions by noting that 'differences in a given species . . . are influenced . . . by external or environmental controls', justifying these remarks by reference to Jennings (1916, cited *in* Vaughan, 1933, p. 7) and Heron-Allen (1915), who reported on variations in cultural populations of foraminiferids. As the result of a decision by the International Commission on Zoological Nomenclature (opinion 192, 1945) by which *Nummulites* was validated, effectively suppressing *Camerina*, Cole (*in* Loeblich & Tappan, 1964) transferred his concept of *Camerina* to *Nummulites*. Coleman (1963, p.26) stated that 'that part of Cole's arguments which rejects *Operculinella* is convincing', but he considered it wise to continue to use *Operculina* until agreement on the use of the contested names was reached. Hanzawa & Urata (1964) and Hanzawa (1965) retained the usage of the generic names previously rejected by Cole (1959, 1960a, 1961a,b). However, Cole (1966) reiterated his opinions, and urged the usage of *Camerina* instead of *Nummulites*, despite the decision of the International Commission on Zoological Nomenclature.

Cole's concept of *Operculina* has found general acceptance, but that regarding *Camerina* as the name for all camerinids with undivided chambers has not. The validity of *Camerina* is doubted, since the decision of the International Commission to suppress that name in favour of *Nummulites*. Most recent authors (e.g., Adams, 1965, 1970; Adams & Belford, 1974; van der Vlerk & Bannink, 1969) have maintained the use of *Operculina* and *Nummulites*. Barnett (1974) made a quantitative taxonomic study of the Nummulitidae; from this he concluded that *Operculinoides*, *Neooperculinoides*, *Nummulitoides*, and *Palaeonummulites* are junior synonyms for *Nummulites*, and that *Assilina*, *Nummulites*, *Operculina*, and *Operculinella* are morphologically distinct, valid genera. These views are followed in this study.

Operculina complanata (Defrance, 1822)

Plate 5, figures 2, 3; Plate 15, figures 1, 2, 11;
Plate 25, figures 1–6

1822 *Lenticulites complanata* Defrance, p. 453.
1826 *Operculina complanata* (Defrance); d'Orbigny, p. 281.
1921 *Operculina bartschi* Cushman, p. 376, text-fig. 13.
1927 *Operculina complanata* (Defrance); Chapman, p. 143.
1936 *Operculina bartschi* Cushman; Crespin, pl. 1, fig. 12.
1938 *Operculina victoriensis* Chapman & Parr, p. 84, pl. 16, figs. 3-8; text-fig. 2.
1938 *Operculina matapauensis* Chapman & Parr, pp. 288-290, pl. 17, figs. 10, 11; text-fig. 4.
1948 *Operculina complanata* (Defrance); Bannink, pp. 86, 88, pl. X, figs. 78-81; pl. XI, figs. 89-91.
1954 *Operculina victoriensis* Chapman & Parr; Crespin, p. 43, pl. 7, fig. 22.
1954 *Operculina complanata complanata* (Defrance); Papp & Küpper, p. 116, pl. 2, figs. 1-3, 5-8.
1955a *Operculina victoriensis* Chapman & Parr; Crespin, pp. 74, 79 (list).
1956 *Operculina* cf. *victoriensis* Chapman & Parr; Crespin & Belford, p. 2 (list).
1961 *Operculina victoriensis* Chapman & Parr; Ludbrook, p. 80 (list), pl. V, fig. 3.
1963 *Operculina complanata* (Defrance) subsp. *japonica* Hanzawa; Coleman, p. 26, pl. 7, figs. 14-16; pl. 9, fig. 13.
1963 *Operculina complanata* (Defrance); Souaya, p. 444, pl. 53, figs. 1-2.
1964 *Operculina victoriensis* Chapman & Parr; Carter, pp. 128-129, pl. 13, figs. 266, 267; text-fig. 26.
1965 *Camerina complanata* (Defrance); Reed, pp. 80-81, pl. 12, figs. 2, 5, 9, 10, 12.
1966 *Operculina complanata* (Defrance); Butt, pp. 88-90, pl. 8, figs. 9-12.
1969 *Operculina victoriensis* Chapman & Parr; Lindsay, p. 23 (list).

Remarks. Papp & Küpper (1954) noted that most populations of *Operculina complanata* from the type area near Dax, France, were associated with forms which they referred to *Heterostegina heterostegina*; these species can be separated only by the presence or absence of secondary septa in the last few chambers of adult specimens. Butt (1966, p.89) stated that *O. complanata* from Escornebeou, France, 'shows a great variation in the diameter of the proloculus . . . in the surface sculpture from smooth to highly ornamented forms. For these reasons the distinction between *O. complanata* and *O. gaimardi* mainly on the basis of a difference in the protoconchal diameter as shown by Smout & Eames (1960) would be unnecessary'. Butt (1966, p.90) also suggested that *O. complanata* occurs in several Recent deposits.

Chapman & Parr (1938) described *Operculina victoriensis* from Victoria, and *O. matapauensis* from New Guinea. They considered that both were distinct from *O. complanata* because they lacked the incipient secondary septa which were present in specimens that they identified as *O. complanata* from Dax, France. However, specimens with secondary septa must be referred to *Heterostegina heterostegina* and not *Operculina complanata* (cf. Papp & Küpper, 1954, 1966). I have examined specimens from samples collected from the type localities of both *O. matapauensis* and *O. victoriensis* and stored in the collections of the Bureau of Mineral Resources, Canberra; these forms have a similar variation in size and ornamentation to that observed by Butt (1966). Therefore, the Australian and New Guinean complanate forms of *Operculina* cannot be distinguished from their European counterparts and so must be considered synonymous, a conclusion which has already been reached by Bannink (1948) and Reed (1965).

Chapman & Parr (1938, p.287) considered that the species 'showing the closest affinity with *O. victoriensis* is probably the Recent *O. bartschi* Cushman, described from the Philippines. The latter species is considerably larger, attaining a diameter of 8 mm and it has 20 to 25 chambers to the whorl, as compared with a maximum of 20 in *O. victoriensis*. The central portion of the shell is often much thickened and strongly biconvex, while this is never seen in *O. victoriensis*'. In populations of Recent forms identified by Chapman & Parr (1938) as *O. bartschi* stored in the collections of the Bureau of Mineral Resources in Canberra, the variation in size, the number of chambers in the final whorl, the secondary deposits over the earlier parts of the test, and the external ornament are all similar to those observed in fossil populations of *O. victoriensis* from Victoria and North West Cape; this indicates that the two forms belong to the same species.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75028	2.15	0.45
UWA75029	2.95	0.50
UWA75030	3.60	0.60
UWA75031	5.40	0.50
UWA75032	3.40	0.35
UWA75033	4.25	0.40
UWA75034	4.70	0.70
UWA75035	2.50	—
UWA75036	2.70	0.70
UWA75037	1.40	0.70

Distribution. In the North West Cape area, *O. complanata* is wide-ranging and is present through most of the Cape Range Group. It is rare in the Trealla Limestone. This species is found in all the larger foraminiferal associations. In Ashmore Reef No. 1 well, this form ranges from near the top of the Cartier beds and throughout the unnamed calcarenite; it also occurs in the samples from the Batesford Limestone, Waitakere Group, and Waikuku Limestone. The figured specimens are from samples UWA10653 (LF.6) from the Batesford Limestone, UWA53674 (LF.2) from the Bullara Limestone, and UWA68316 (LF.5), UWA68324, UWA70470, and UWA 70504 (LF.6) from the Mandu Calcarenite.

Genus **Operculinella** Yabe

Type species: *Amphistegina cumingii* Carpenter, 1860; original designation.

Operculinella venosa (Fichtel & Moll, 1798)
Plate 15, figures 3, 4; Plate 25, figure 7

1798 *Nautilus venosus* Fichtel & Moll, p. 59, pl. 8, figs. e-h.
1948 *Operculina venosa* (Fichtel & Moll); Bannink, pp. 87, 91, pl. XIV, figs. 123-125, 129-132.
1955a *Operculinella venosus* (Fichtel & Moll); Crespin, p. 79 (list).
1959 *Operculina venosa* (Fichtel & Moll); Cole, pp. 361-363, pl. 28, figs. 12-14, 17, 18; pl. 29, figs. 1, 2, 11, 13, 14; pl. 30, figs. 1, 9, 10; pl. 31, fig. 31.
1963 *Operculina venosa* (Fichtel & Moll); Coleman, p. 28, pl. 8, figs. 1-2.

Remarks. Cole (1959) has discussed this species in detail, and nothing new can be added.

This is only the second fossil record of this species from Australia, the first having been by Crespin (1955a) from the Trealla Limestone.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75038	1.45	0.46
UWA75039	1.85	0.85
UWA75040	1.70	—

Distribution. O. venosa is rare in the North West Cape area. It is recorded from two samples from the Mandu Calcarenite and from several samples from the Tulki and Trealla Limestones. It is restricted to the LF.6, LF.7, and LF.8 associations. The figured specimens are from samples UWA70490 and UWA70493 from the Mandu Calcarenite.

Subfamily **CYCLOCLYPEINAE** Bütschli
Genus **Cycloclypeus** Carpenter
Subgenus **Cycloclypeus** Carpenter

Type species: *Cycloclypeus mammilatus* Carter, 1861; subsequent designation of Carter (1861).

Tan (1932) divided *Cycloclypeus* into three subgenera, noting (p.40) that 'it will not always be possible to distinguish the representatives of the subgenus *Cycloclypeus* from that of *Katacycloclypeus*, as the former sometimes possesses an annulus'. He concluded that the folds of *Cycloclypeus* 'are faint or developed as irregular folds', and that those of *Katacycloclypeus* 'as a rule are very distinct and regular'. Cole (1961b) questioned the subgeneric division of *Cycloclypeus*, stating that he 'had difficulty in attempting to separate certain specimens on the presence or absence of the annular folds into subgenera', and suggested that the presence or absence of the annular folds should be so constant that specimens could be identified subgenerically without the difficulties encountered.

Both *Cycloclypeus* and *Katacycloclypeus* have been found only in random thin sections, and the range of variation between the two forms cannot be evaluated; for uniformity, the two subgenera have been retained for this study.

Cycloclypeus (Cycloclypeus) eidae Tan, 1932

Plate 5, figures 6a,b; Plate 16, figures 1–5; Plate 25, figures 8–10

1927 *Cycloclypeus pustulosus* Chapman, pp. 143-144.

1932 *Cycloclypeus eidae* Tan, pp. 59-62, pl. 13, fig. 3; pl. 14, figs. 1-6; pl. 15, figs. 1-4; pl. 18, figs. 2, 7; pl. 22, figs. 3, 4, 8.

1955a *Cycloclypeus eidae* Tan; Crespin, pp. 74, 77 (list), pl. 9, fig. 1.

1955a *Cycloclypeus posteidae* Tan; Crespin, pp. 74, 77 (list).

Description. The adult test is moderately large, ranging from 1.75 to 4.30 mm in diameter and from 0.40 to 0.55 mm in thickness. It is biumbonate, and has a thickened central area and a wide peripheral flange. The exterior of the test is covered on both sides by concentrically arranged rows of small round or cuneiform pustules, which commonly coalesce to form weak concentric ridges (as in *C. carpenteri*, Plate 6, figs. 2, 3). Microspheric and megalospheric forms are commonly of similar size and sculpturing.

Internally, in megalospheric individuals, the nepionic stage (pc) is made up of nine to 21 chambers, and has mean values for the different populations ranging from 12.72 to 15.63. The number of chamberlets of the fourth and fifth precyclic chambers (Spc_{4+5}; *sensu* MacGillavry, 1962) ranges from three to 13, and the population means range from 5.13 to 7.50. The number of chamberlets in the first cyclic chamber (Sc_1) ranges from 22 to 44, and the population means range from 24.50 to 33.80. In most individuals (95%) the third nepionic chamber is undivided, but in some (2%) it is divided into two chamberlets, and in others (3%) both the third and fourth are undivided. The diameter of the protoconch (D_I) ranges from 65 μm to 222 μm, and the population means range from 101.88 μm to 140.33 μm. In microspheric individuals (which form less than 5% of the populations), the protoconch is followed by an average of 30 precyclic chambers, of which eight on average are undivided. The diameter of the protoconch ranges from 20 μm to 51 μm, with a mean of 34.60 μm.

Remarks. Tan (1932) mainly based his description of both *C. eidae* and *C. posteidae* on external characters, although he noted that the range of variation in the number of nepionic chambers was from four to 21 for the former and from four to 18 for the latter; he did not count the first two chambers. The distinction between these two species was based on the character of the microspheric generation, which in *C. eidae* was similar both in size and external sculpture to the megalospheric generation, whereas in *C. posteidae* it was distinctly larger than the megalospheric.

Tan (1932) also noted that *C. eidae* tended to have a smaller protoconch; his figures certainly bear this out, but there is a distinct rapid gradation to a larger protoconch through his *eidae–posteidae* series. Tan stated (1932, p.50) that 'the criterium drawn from the differences in the microspheric generation for the differentiation of *Cycl. eidae* from *Cycl. posteidae* (sic) will be difficult in its application. Namely the micropheric generation . . . is very rare, so that there is a great chance that they are not found in the populations'. He considered that both *C. eidae* and *C. posteidae* had a constant sculpturing over the test, a feature that served to distinguish them from *C. carpenteri*, *C. indopacificus*, and *C. postindopacificus*, in which this feature is most variable. The microspheric form of the three last-named species is much larger than the megalospheric, a factor that is also characteristic of *C. posteidae*. Tan considered that the larger number of nepionic chambers in *C. eidae* and *C. posteidae* would distinguish them from *C. carpenteri*, *C. indopacificus, and C. postindopacificus*, but there is a distinct morphological gradation between all of these species.

MacGillavry (1962) concluded that the first two chambers should be taken into account in counting the nepionic chambers; subsequently other workers (e.g., O'Herne & van der Vlerk, 1971; O'Herne, 1972) have followed this concept, and it has been maintained in this work. A figure of two must be added to the values obtained by Tan (1932), in order to compare them with those of MacGillavry (1962) and later workers. MacGillavry has also suggested that those specimens of *Cycloclypeus* with 12 or more nepionic chambers be referred to *C. eidae*, and those with less than 12 be assigned to *C. carpenteri*, an idea which makes the name *posteidae* unnecessary. He made no mention of *C. indopacificus* or *C. postindopacificus*, both of which are made similarly unnecessary if MacGillavry's suggestion is biologically valid; if so these names must now be considered junior synonyms for *C. carpenteri*, and their use should be discontinued, especially in view of the biometric results given by Chaproniere (1980a) which show no evidence for further subdivision of either *C. eidae* or *C. carpenteri*; the distinction between these two species is, in any case, only arbitrary.

Drooger (1955) found that fossil populations of *Cycloclypeus* from eastern Borneo have a bimodal frequency distribution for the counts of nepionic chambers; he concluded that this was due to the presence of both microspheric and megalospheric generations. However, MacGillavry (1962) suggested that this bimodality was the result of mixing of two separate groups, one a less advanced constituent regarded as *C. eidae*, and the other a more advanced constituent referred to *C. carpenteri*. Neither opinion can be sustained on the evidence presented by Chaproniere (1980a).

In the North West Cape area the succession from *C. eidae* to *C. carpenteri* is gradational, and is not marked by the bimodal distribution of nepionic chamber values found by Drooger (1955) and MacGillavry (1962). Some populations show a polymodal distribution, but this can be explained by the relatively small number of specimens studied. Because of this gradation, Tan's (1932) nomenclature is unnecessary and the simpler concept proposed by MacGillavry (1962) is retained. However, because MacGillavry's concept results in the artificial division of a single population into two species, that concept has been modified: those populations where the mean value for the number of nepionic chambers exceeds 12 are referred to *C. eidae*, and those with values of less than 12 are assigned to *C. carpenteri*.

Small specimens of *Heterostegina*-like forms (see Plate 5, figs. 6a,b) have been found in the upper parts of the LF.3 and lower parts of the LF.4 associations. Chapman (1927) recorded *Heterostegina depressa* from faunas collected from the Cape Range; these faunas are similar to those of the LF.4 association. As these small forms are associated with adult *C. eidae* and have similar internal characters, they are considered to be juveniles which have been transported into water depths in which they could not survive.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75044	0.53	0.10
UWA75046	4.20	0.40
UWA75047	4.05	0.55
UWA75048	3.85	0.45
UWA75049	1.75	—
UWA75050	2.40	—
UWA75051	2.40	—
UWA75052	2.05	—
UWA75053	2.00	—

Distribution. *C. eidae* first appears within the upper part of the Mandu Calcarenite, and it may range into the Tulki Limestone, but only on the eastern side of Cape Range. Within the upper part of the Mandu Calcarenite on the western side of Cape Range this species grades into *C. carpenteri.* A similar distribution is found in Ashmore Reef No. 1 well, where *C. eidae* first appears near the base of the unnamed calcarenite. Adult forms of this species range from the LF.4 to the LF.6 association. The figured specimens are from samples UWA68312, UWA68318, UWA70564 (LF.5), and UWA68324 (LF.6) from the Mandu Calcarenite, and UWA70606 (LF.5) and UWA70604 (LF.6) from the unnamed calcarenite in Ashmore Reef No. 1 well.

Cycloclypeus (Cycloclypeus) sp. cf. **C. eidae** Tan, 1932

Plate 15, figures 12, 13, 15, 16

1932 *Cycloclypeus eidae* Tan, pp. 50-59, pl. 5, fig. 6; pl. 12, figs. 2, 3; pl. 13, figs. 1, 2, 4-6.

Remarks. Specimens of *Cycloclypeus* found in random thin sections of rocks from the uppermost Mandu Calcarenite and Tulki Limestone could not be adequately treated statistically, and therefore could not be identified with certainty. Most of the specimens which show diagnostic characters fall within the range of *C. eidae* and have been referred to this species, but in open nomenclature.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75054	5.40	0.55
UWA75055	5.50	0.60
CPC15690	1.30	—
CPC15691	6.05	—

Distribution. C. sp. cf. *C. eidae* is confined to the uppermost Mandu Calcarenite and Tulki Limestone from the eastern side of Cape Range, where it is restricted to the LF.6 association. The figured specimens are from samples UWA51889, CRC4, and CR113 from the Tulki Limestone.

Cycloclypeus (Cycloclypeus) carpenteri Brady, 1881

Plate 6, figures 1a–d,2,3; Plate 16, figures 6–11

1862 *Cycloclypeus* sp., Carpenter, p. 292, pl. 9, figs. 2-7.

1881 *Cycloclypeus carpenteri* Brady, p. 67.

1932 *Cycloclypeus* cf. *carpenteri* Brady; Tan, pp. 75-77, pl. 5, fig. 4; pl. 2, figs. 1, 2, 9; pl. 23, fig. 8; pl. 24, figs. 1-7, 12, 13.

1932 *Cycloclypeus indopacificus* Tan, pp. 66-67, pl. 15, fig. 7; pl. 18, fig. 3; pl. 19, fig. 1; pl. 22, fig. 10; pl. 23, figs. 1, 2.

1932 *Cycloclypeus postindopacificus* Tan, pp. 66-67.

1941 *Cycloclypeus victoriensis* Crespin, pp. 305-309, pl. 12, figs. 1-3, 4, 8; pl. 13, figs. 9, 17; pl. 14, figs. 20-23; pl. 15, figs. 26-28, 31-32.

1941 *Cycloclypeus victoriensis* var. *gippslandica* Crespin, pp. 309-311; pl. 12, fig. 4; pl. 13, figs. 10-16, 18; pl. 14, figs. 19, 24; pl. 15, figs. 25, 29, 30.

1955a *Cycloclypeus victoriensis* Crespin; Crespin, p. 72 (list).

1955a *Cycloclypeus indopacificus* Tan; Crespin, pp. 72 (list), 74, 77 (list), pl. 9, figs. 2, 3.

1964 *Cycloclypeus victoriensis* Crespin; Carter, pp. 131-136, text-fig. 29; pl. 17, fig. 293.

1969 *Cycloclypeus indopacificus* Tan; Leitch & others, p. 30 (list).

1979 *Cycloclypeus carpenteri* Brady, 1881; Adams & Frame, pp. 6-10, figs. 2, 4-11.

Description. The test is moderately large, ranging from 1.65 to 3.95 mm in diameter and from 0.40 to 0.75 mm in thickness. It is biumbonate, and has a thickened central area and a wide thin peripheral flange. It is covered on both sides with small round or cuneiform pustules arranged spirally on the central area and concentrically over the remainder of the test. Microspheric individuals are rare, but are commonly larger than the megalospheric forms.

Internally in megalospheric forms, the nepionic stage (pc) is made up of six to 16 chambers, and has mean values for the different populations ranging from 8.39 to 11.56. The number of chamberlets of the fourth and fifth precyclic chambers (Spc_{4+5}) ranges from three to 19, and the population means range from 7.13 to 10.67. The number of chamberlets in the first cyclic chamber (Sc_1) ranges from 13 to 36, and the population means range from 25.12 to 28.92. In most individuals (86%) the third nepionic chamber is undivided, but in some (12%) it is divided into two chamberlets, and in others (2%) both the third and fourth are undivided. The diameter of the protoconch (D_I) ranges from 83 to 341 μm, and the population means range from 131.77 to 198.97 μm. In microspheric individuals (which form less than 5% of the populations) the protoconch is followed by an average of 31 precyclic chambers, of which 11 on average are undivided. The diameter of the protoconch ranges from 18 to 46 μm, with a mean of 32.00 μm.

Remarks. The past and present concepts of *C. carpenteri* have already been discussed above. There it was suggested that those populations of *Cycloclypeus* with a mean value for pc of less than 12 be referred to *C. carpenteri.* It was also suggested that both *C. indopacificus* and *C. postindopacificus* are junior synonyms for *C. carpenteri.*

Recently Adams & Frame (1979) have redescribed syntypic material of *C. carpenteri* and *C. guembelianus*, and considered the latter to be a subjective senior synonym of the former. Furthermore, the numbers of nepionic chambers in both species (including the protoconchs and deuteroconchs) range from four to nine, and the diameter of the protoconch ranges from 150 to 230 μm. These figures overlap with the specimens encountered in this study, giving some support for the concept of *C. carpenteri* argued above.

Crespin (1941) assigned to *Cycloclypeus victoriensis* and *C. victoriensis* var. *gippslandica* forms which she regarded as being closely related to *C. indopacificus.* She considered that the smaller size and greater number of nepionic chambers (7–13) of *C. victoriensis* distinguish it from *C. indopacificus* (4–6). She noted that the Victorian forms show a similar variation in external characters and a distinct difference in size between the megalospheric and microspheric generations, in common with *C. indopacificus.*

Carter (1964, p. 132) considered that the differences between *C. victoriensis* and *C. victoriensis* var. *gippslandica* 'are of a minor nature' and did not warrant a separate name. His statistical study of *C. victoriensis* from Gippsland gave similar results to that of Crespin (1941); he considered that the range of variation of the numbers of nepionic chambers was within that for *C. eidae* and not *C. indopacificus.* However, the difference in size between the two generations suggests that the Victorian forms are closest to *C. posteidae* in Tan's (1932) terminology.

As noted by Chaproniere (1980a) the statistical data presented by Carter (1964) suggest that the Victorian forms are not distinctly different from those of the North West Cape area. According to the concept of *C. carpenteri* of MacGillavry (1962) as modified above, the populations from Victoria then fall within the range of that species and not *C. eidae. C. victoriensis* so becomes a junior synonym of *C. carpenteri.*

The New Zealand specimens from sample UWA70611 just fall within the range of *C. carpenteri* on parameter pc ($\overline{pc}$ = 11.56). However, they differ from the Australian forms on the values for parameter Spc$_{4+5}$ ($\overline{Spc}_{4+5}$ = 7.13), which falls within the range for *C. eidae.* In contrast, those from 79640006 are the most advanced encountered in this study for pc ($\overline{pc}$ = 8.39), but, in common with UWA70611, the values of Spc$_{4+5}$ ($\overline{Spc}_{4+5}$ = 9.26) are lower than would be expected from such advanced forms.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75041	—	—
UWA75042	—	—
UWA75043	1.85	—
UWA75250	2.10	—
CPC15692	2.30	—
CPC15693	2.50	—
CPC15694	2.70	—
F76	3.95	0.75
F77	1.65	—

Distribution. In the North West Cape area, populations referred to *C. carpenteri* occur only in the upper part of the Mandu Calcarenite on the western side of Cape Range. They also are found in the upper parts of the unnamed calcarenite in Ashmore Reef No. 1 well. In both areas they have evolved from *C. eidae. C. carpenteri* is present in the Batesford Limestone in Victoria, and in New Zealand it occurs in the Waikuku Limestone, the Tutamoe Formation at Pourerere, and the Stillwater Mudstone at Greymouth. The species occurs in the upper parts of the LF.6 association and may extend into the LF.7 association. The figured specimens are from samples 71640345 and UWA70509 (LF.6) from the Mandu Calcarenite, and UWA70611 (=N2/528; LF.6) from the Waikuku Limestone.

Cycloclypeus (Cycloclypeus) sp. cf. **C. carpenteri** Brady, 1881

1881 *Cycloclypeus carpenteri* Brady, p. 67.

Remarks. Specimens of *Cycloclypeus* which occur in random thin sections of rocks from the Tulki and Trealla Limestones from the North West Cape area could not be treated statistically, and, therefore, were not able to be identified with certainty. In those specimens where the diagnostic characters could be observed the values fell within the range of *C. carpenteri*, and they have been referred to that species, but in open nomenclature.

Distribution. C. sp. cf. *C. carpenteri* is confined to the Tulki and Trealla Limestones, and ranges from the LF.6 to within the LF.8 association.

Subgenus **Katacycloclypeus** Tan

Type species: *Cycloclypeus annulatus* Martin, 1880; original designation.

Cycloclypeus (Katacycloclypeus) sp. cf. **C. annulatus** Martin, 1880

Plate 15, figure 14

1880 *Cycloclypeus annulatus* Martin, p. 157, pl. 28, fig. 1.
1932 *Cycloclypeus (Katacycloclypeus) annulatus* Martin; Tan, pp. 39-40.
1955a *Katacycloclypeus annulatus* (Martin); Crespin, pp. 74, 78 (list).

Remarks. Specimens with a marked annular thickening in vertical section have tentatively been referred to this species. The arguments for and against the recognition of this subgenus are discussed above. Because these specimens are found only in random thin sections, no statistical studies could be made; they are associated with *C.* sp. cf. *C. eidae* and *C.* sp. cf. *C. carpenteri.* Adams & Frame (1979) considered that only one species of *Katacycloclypeus* can be recognised at present.

Dimensions of figured specimen.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75056	3.75	0.55

Distribution. This species is rare, and occurs in the topmost Mandu Calcarenite and in the Tulki and lower Trealla Limestones; it is restricted to the LF.6 and LF.7 associations. The figured specimen is from sample UWA 51886 from the Mandu Calcarenite.

Genus **Heterostegina** d'Orbigny

Type species: *Heterostegina depressa* d'Orbigny, 1826; subsequent designation of Parker, Jones, & Brady (1865).

Heterostegina borneensis van der Vlerk, 1929

Plate 5, figures 4a–5c; Plate 15, figure 5a–8; Plate 25, figures 11, 12

1929 *Heterostegina borneensis* van der Vlerk, p. 16, figs. 6a-c, 25a-b.
1956 *Heterostegina borneensis* van der Vlerk; Crespin & Belford, p. 2 (list).
1957a *Heterostegina borneensis* van der Vlerk; Cole, pp. 757-759, pl. 237, figs. 1-23; with synonymy.
1963 *Heterostegina borneensis* van der Vlerk; Coleman, pp. 28-30, pl. 8, figs. 3, 4.
1969 *Heterostegina borneensis* van der Vlerk; Leitch & others, p. 30 (list).

Remarks. Moderately large specimens with fairly thick, robust, smooth to weakly sculptured tests have been treated statistically (Chaproniere, 1980a); additional studies have been included here. The maximum diameter of megalospheric forms ranges from 1.46 to 3.26 mm, and of the microspheric generation from 3.08 to 3.77 mm. The number of undivided chambers (N_0, including the protoconch and deuteroconch), the number of chamberlets in the fourth and fifth chambers (S_{4+5}), and the diameters of the protoconch (D_I) and deuteroconch (D_{II}), for both generations, are given in Chaproniere (1980a) and in Table 2. Chaproniere (1980a) suggested that parameters N_0 and S_{4+5} appear to be the most useful for correlation. However, the results from the two populations discussed by Chaproniere (1980a), and the two additional ones from New Zealand (79640006 and 79640027), suggest that there is no evolutionary change from the Late Oligocene to the Middle Miocene. There is some indication from population 79640006 (the youngest studied) that values for parameter S_{4+5} seem to increase with time, but, until more populations from this level are studied, the significance of this change cannot be evaluated. Even though there is a statistically significant difference for $\overline{D}_I$ and $\overline{D}_{II}$ between the populations from North West Cape and New Zealand, it is considered to be of little importance and may reflect differences in environmental rather than genetic factors.

There is little published statistical information, with the exception of Cole (1958a), for this species. Van der Vlerk (1929, in his original description of this species, stated that the first three chambers are undivided, but he failed to mention the number of specimens examined. Cole (1957a) referred specimens with a single operculine chamber ($N_0 = 3$) to *H. borneensis*, and those with two such chambers ($N_0 = 4$) to a new species, *H. duplicamera.* Both groups, apparently, are constant for these characters and have different stratigraphic occurrences.

In the North West Cape and New Zealand populations there is a mixture of values for parameter N_0, ranging from 2 to 5, but 3 is the mode. The frequency distribution is unimodal, suggesting that little or no mixing of faunas has taken place. For these reasons it is considered that the North West Cape and New Zealand forms belong to the same species.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75057	2.25	0.75
UWA75058	3.00	0.75
UWA75059	3.15	0.55
UWA75060 (microspheric)	3.65	—
UWA75061	1.65	—
UWA75062	2.75	—
UWA75063	1.75	0.60
F78	2.90	—

Distribution. This species has been recorded only from the Bullara Limestone, where it is restricted to the LF.2 association, in the North West Cape area. In New Zealand, this species is present in all but one sample, and so has a much longer biostratigraphic range than elsewhere. Chaproniere (1980a) suggested that the record of this species in the Waikuku Limestone may have been the result of reworking from older sediments. In view of its wide distribution in New Zealand above its extinction level elsewhere, it seems that this species survived to at least the Late Miocene (N.15 or N.16) in New Zealand. The figured specimens are from samples UWA 53674, UWA70577, UWA70594, and UWA 70600 from the Bullara Limestone, and UWA 70612 (=N2/584) from the Waikuku Limestone.

Heterostegina suborbicularis d'Orbigny, 1826

Plate 25, figure 13

1826 *Heterostegina suborbicularis* d'Orbigny, p. 305.
1903 *Heterostegina suborbicularis* d'Orbigny; Fornasini, p. 396, pl. 14, fig. 6.
1921 *Heterostegina suborbicularis* d'Orbigny; Cushman, p. 385.
1927 *Heterostegina suborbicularis* d'Orbigny; Hofker, p. 70, pls. 35, 36, figs. 3, 6-12.
1933 *Heterostegina suborbicularis* d'Orbigny; Hofker, p. 153.
1960 *Heterostegina depressa* d'Orbigny; Barker, p. 232, pl. 112, figs. 14-16.

Remarks. Hofker (1927) suggested that *H. suborbicularis* is a senior synonym for *H. depressa*, a conclusion that has been disputed by Barker (1960). Barker considered that *H. suborbicularis* is a *nomen nudem* that had been validated by Fornasini (1903), and suggested that the name should not be used. Earlier, Cushman (1921, p. 385) had concluded that *H. suborbicularis* can be distinguished from *H. depressa*, the former 'being much thicker'. The forms recorded in this study are similar to those described by Cushman (1921). Until the two species are restudied and their relationships described, it is convenient to recognise both.

The specimens recorded here have N_0 values of 12 and 13; a single specimen in a random thin section has a minimum value of eight.

Dimensions of figured specimen.	Maximum diameter (mm)
CPC15695	1.35

Distribution. H. suborbicularis has been recorded from one sample from the upper Mandu Calcarenite (UWA51888) and from a single level from the unnamed calcarenite from Ashmore Reef No. 1 well (UWA70604, 80647032). In all three samples the species is associated with an LF.6 fauna.

Genus **Spiroclypeus** Douvillé

Type species: *Spiroclypeus orbitoideus* Douvillé, 1905; original designation.

Spiroclypeus sp. cf. **S. margaritatus**

(Schlumberger, 1902)

Plate 15, figures 9, 10

1902 *Heterostegina margaritata* Schlumberger, pp. 252, 253, pl. 7, fig. 4.
1955b *Spiroclypeus margaritatus* (Schlumberger); Crespin, pp. 2 (list), 3 (list), 4 (list).

Remarks. Cole (1969) concluded that seven of the 11 different species of post-Eocene *Spiroclypeus* are junior synonyms for *S. margaritatus.* Although Adams (1970) sounded a note of caution, Adams & Belford (1974, p. 492) supported Cole (1969), and concluded 'that only one species is present despite the wide range of morphologic variation' in faunas from Christmas Island.

All specimens of *Spiroclypeus* found in the North West Cape area are derived forms occurring in conjunction with a fauna typical of the LF.8 association. All of them, as well as those of *Lepidocyclina* (*Eulepidina*) and *L.* (*Nephrolepidina*), are abraded and well rounded, and probably have been reworked from the underlying Bullara Limestone. *Spiroclypeus* has not been found in that unit, but *Heterostegina borneensis* is abundant. Even though the equatorial chambers have not been studied statistically, there are many similarities between *S. margaritatus* and *H. borneensis*, the two being differentiated only on the presence or absence of lateral chambers. Cole (1957b, p. 747) noted that *Spiroclypeus* did not occur with, and always was present at higher stratigraphic levels than, *H. borneensis* in drillholes at Eniwetok Atoll. Adams (1970) stated that

H. borneensis appears before *S. margaritatus* in Sarawak and East Borneo. This stratigraphic occurrence and the similarity of the equatorial chamber arrangement of the two species suggests a close relationship. It is concluded, therefore, that the specimens of *S.* sp. cf. *S. margaritatus* were derived from a part of the Bullara Limestone at a higher stratigraphic level than that which has yielded *H. borneensis*; this younger part of the unit was removed by erosion after the regression of the sea in the Rough Range area before the Trealla Limestone was deposited.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
CPC15687	1.20	—
CPC15696	2.75	0.90

Distribution. Spiroclypeus sp. cf. *S. margaritatus* is restricted to the basal Trealla Limestone in the Rough Range area, where it is associated with a derived LF.2 assemblage, accompanied by a fauna typical of the LF.8 association. The figured specimens are from samples 80641354 and 80641359.

Family **MIOGYPSINIDAE** Vaughan

Drooger (1963, p. 315) stated that the miogypsinids 'underwent rapid and varied evolution in many of the shallow and warm marine environments all over the world'. Different groups have evolved along separate lineages, each of which has been distinguished at the subgeneric level by Drooger (1952, 1963). Three of these (*Miogypsina, Miogypsinoides,* and *Lepidosemicyclina*) have been recognised in this study, and it is believed that they are sufficiently distinct for Drooger's scheme to be followed.

The presence of lateral chambers in *Miogypsinoides* differentiates it from *Miogypsina* s.s. and *Lepidosemicyclina*; the peripheral position of the embryoconch in these three subgenera distinguishes them from other subgenera (Drooger, 1952, 1963). The distinction between *Miogypsina* s.s. and *Lepidosemicyclina* is less clear; the main distinction, though, is the presence of hexagonal chambers in *Lepidosemicyclina.* Specimens of *Miogypsina* s.s. may also have hexagonal chambers, but these are confined to the frontal margins of larger specimens (Drooger, 1963), whereas they are well developed in the other subgenus.

Among the New Zealand and Australian specimens the two subgenera can be distinguished by other criteria. Comparison of Figures 16 and 17 shows that the chamber arrangement in the spirals surrounding the protoconchs and deuteroconchs is important. In *Miogypsina* s.s. there are two symmetrical sets of spiral chambers, one set larger and one smaller; in the larger there is no difference between the primary spiral and one of the secondary spirals. In *Lepidosemicyclina,* the primary spiral is the largest, and the three secondary spirals are of unequal size, leading to a distinct asymmetrical arrangement. A further distinction between the two subgenera is evident in advanced specimens: in *Miogypsina* s.s. the equatorial chambers are spatulate and in a circular concentric arrangement; such an arrangement is not evident in *Lepidosemicyclina,* in which the chambers are arranged in an intersecting curve (see Plate 17, figs. 1–8). In addition, the two subgenera can be readily distinguished on external characters. Those from New Zealand (*Miogypsina* s.s.) are subcircular in outline, and have a flat, narrow, delicate flange along the frontal margin; the apical area, containing the embryoconch, is difficult to discern, but is marked by a weak triangular region; and the surface is covered by numerous, small rounded papillae. The Western Australian forms (*Lepidosemicyclina*) have a distinctly triangular outline, and a prominent, protruding apical area; the frontal margin is wide and commonly undulating; and the test is thin and, in common with the New Zealand forms, covered by papillae.

It is concluded, therefore, that the differences between the two groups are sufficient to warrant separation at the subgeneric level, and the division of *Miogypsina* by Drooger (1952, 1963) into the subgenera *Lepidosemicyclina, Miogypsina,* and *Miogypsinoides* is retained.

Subgenus **Miogypsina** Sacco

Type species: *Nummulina globulina* Michelotti, 1841; original designation.

Barker (1965) has discussed this subgenus in detail. Drooger (1952, 1953, 1963) used the statistical parameters V and X (see Chaproniere, 1980a) to distinguish between species forming each lineage. He specified the arbitrary range of values for $\overline{V}$ from 10 to 45 for *M.* (*Miogypsina*) *globulina* (= *M. irregularis*), and from 45 to 70 for *M.* (*M.*) *intermedia* (Drooger, 1952, p. 54). These values are used in this study.

There is no difference in external morphology between the two species. The outer surface is covered by small, stout pustules, which have a fairly constant size for each individual. The test wall between the pustules is delicate and thin. The walls of both the lateral and equatorial chambers are perforated by numerous small pores (see Plate 6, fig. 5b; Plate 7, figs. 1b,c). In some specimens (Plate 7, fig. 1b) larger pores which are visible at the sutures between lateral chambers have been interpreted as foramina. The pustules appear to be formed by localised thickening of the lateral wall of each equatorial chamber; the lateral chambers appear to overlie the suture between each equatorial chamber. The distribution of the pustules provides a strengthening of the test and test walls while maintaining thin lateral chamber walls. Haynes (1965) has reported similar features in modern larger foraminiferids which have a symbiotic relationship with green algae; I conclude that the miogypsinids maintained a similar relationship (see Chaproniere, 1975).

The data presented by Chaproniere (1980a) define the internal characteristics of the coiled embryonic part; the range of variation is illustrated in Figure 16. In both species there are two unequal nepionic spirals; the second spiral is much weaker in *M. globulina* than in *M. intermedia* and is expressed by the difference in values for parameter $\overline{V}$. The mean value for parameter γ in both species is positive, which is similar to the results of Drooger (1952) and Drooger & Socin (1959). Their equatorial chambers in median sections are ogival to spatulate. Vertical sections show that the floors and ceilings of their lateral chambers are thick, and are almost equal to the chamber height. Studies by SEM show that the walls are densely perforate, and that each equatorial chamber is connected to the next by a funnel-shaped stolon (see Plate 7, fig. 2b; Plate 12, fig. 6).

Miogypsina (Miogypsina) globulina (Michelotti, 1841)

Plate 6, figures 5a–b; Plate 16, figures 14,15; Figure 16

1841 *Nummulina globulina* Michelotti, p. 297, pl. 3, fig. 6.

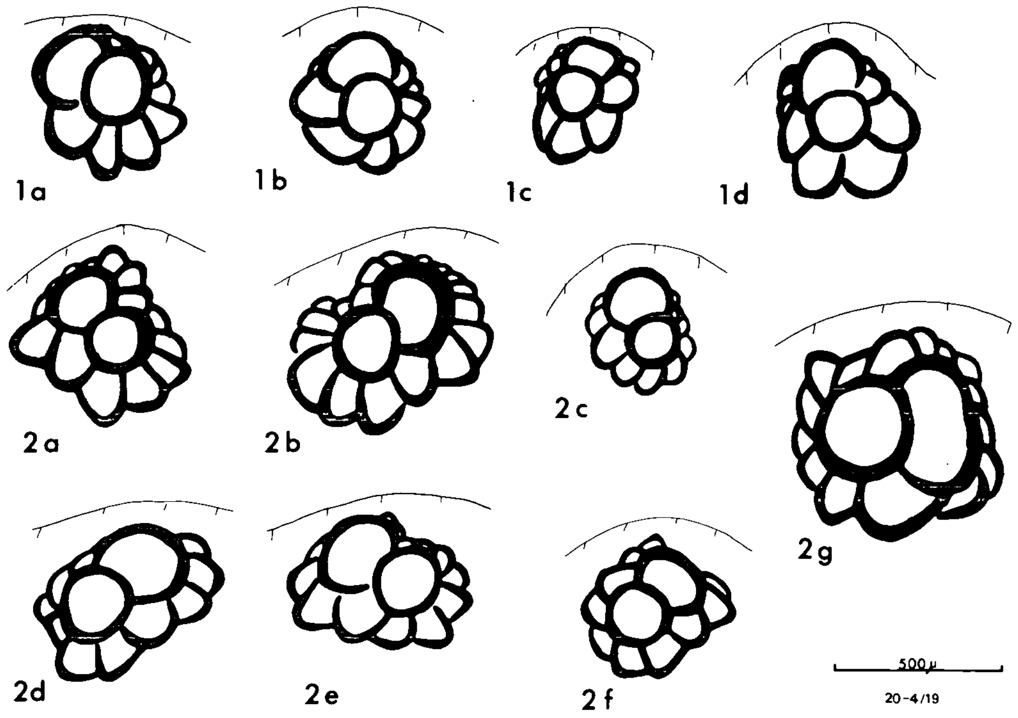

Fig. 16. Variations in embryoconchs of *Miogypsina* **from New Zealand: 1,** *Miogypsina (Miogypsina) globulina* **from UWA70613; 2,** *M. (M.) intermedia* **from UWA70614.**

1959 *Miogypsina (Miogypsina) globulina* (Michelotti); Drooger & Socin, pp. 420-422, pl. 1, figs. 5-6 (with synonymy).

1964 *Miogypsina (Miogypsina) globulina* (Michelotti); Drooger & Freudenthal, p. 522.

1965 *Miogypsina (Miogypsina) globulina* (Michelotti); Barker, pp. 321-322, pl. 3, figs. 4-6, 9, 11.

1966 *Miogypsina globulina* (Michelotti); Vervloet, p. 61, pl. 12, fig. 5, text-fig. 6.

Remarks. Drooger & Socin (1959) stated that *M. globulina* is the senior synonym of *M. irregularis*. Drooger (1952) considered that *M. irregularis* was typified by mean values of V falling within the range of 0 to 45. The mean value for V for the population from UWA 70613 is 28.26, well within the range given by Drooger (1952).

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
F65	2.25	0.60
F66	1.95	—
F67	2.35	—

Distribution. M. (*Miogypsina*) *globulina* is found only in sample UWA70613 (=N18/569) from the Otaua Group exposed in Hokianga Harbour, New Zealand. Here it is associated with a fauna typical of the LF.2 association.

Miogypsina (Miogypsina) intermedia Drooger, 1952

Plate 6, figures 4a–b; Plate 7, figures 1a–2b; Plate 12, figure 6; Plate 16, figures 12, 13, 16, 17; Figure 16

1952 *Miogypsina (Miogypsina) intermedia* Drooger, pp. 35-36, pl. 2, figs. 30-34; pl. 3, figs. 4a-b.

1965 *Miogypsina (Miogypsina) intermedia* Drooger; Barker, pp. 324-325, pl. 5, figs. 7, 8, 10.

Remarks. This species is very similar to *M. globulina*, differing only in the mean values for parameter V, which range from 45 to 70 for *M. intermedia* (Drooger, 1952, 1963). The values for the other parameters are tabulated in Chaproniere (1980a, table 3), and have been discussed above. The amount of variation of the embryoconch is illustrated in Figure 16.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
F69	2.65	0.75
F70	2.60	0.80
F71	2.30	—
F72	2.90	—
F73	2.60	—
F74	2.95	0.90
F75	2.15	0.80

Distribution. M. (*M.*) *intermedia* has been recorded from only one sample, UWA70614 (= N28/631) from the Waitakere Group exposed in Kaipara Harbour, New Zealand, where it is associated with a typical LF.2 fauna almost identical with that of *M.* (*M.*) *globulina.*

Subgenus **Lepidosemicyclina** Rutten

Type species: *Orbitoides* (*Lepidosemicyclina*) *thecideaeformis*, Rutten, 1911; subsequent designation of Cole *in* Loeblich & Tappan, 1964.

This subgenus can be differentiated from *Miogypsina* s.s. and *Miogypsinoides* by criteria discussed above.

Rutten (1911) originally introduced *Lepidosemicyclina*, as a subgenus of *Orbitoides*, to accommodate species that were differentiated from *Lepidocyclina* by the positioning of the embryoconch near the periphery of the test. Mohan (1958) used the name for forms in which hexagonal chambers were present in the equatorial layer, a move which was earlier partly anticipated by Drooger (1953). Coleman (1963, p. 12) objected to the revival of this name because 'the essential diagnostic feature, the predominance of hexagonal equatorial chambers, is not consistent in individuals of the type species but is dependent on the size and stage of development reached before death by particular specimens. The possibility that *Lepidosemicyclina* has a limiting condition in its type species is sufficient reason not to further its adoption'. As noted above, Rutten (1911) defined this subgenus only on the basis of the position of the embryonic apparatus, a feature which now determines the genus *Miogypsina.* Rutten's (1911) first description of *Lepidosemicyclina* for both *M. polymorpha* and *M. thecideaeformis*, was short, but was supplemented by a later version (Rutten, 1912) in which specimens of what is now the type species (as designated by Cole, *in* Loeblich & Tappan, 1964) were shown to have hexagonal equatorial chambers. Thus, the 'limiting condition' on the type species referred to by Coleman (1963) does not exist. Furthermore, a subgeneric name can be redefined, and there are numerous examples of this in the literature. Drooger (1963, p. 333) based his usage of *Lepidosemicyclina* upon a lineage including *M. thecideaeformis*, in which 'during ontogeny, the equatorial chambers attain hexagonal shape'.

Miogypsina (Lepidosemicyclina) thecideaeformis (Rutten, 1911)

Plate 7, figures 3–6; Plate 17, figures 1–11; Plate 25, figure 14; Figure 17

1911 *Orbitoides (Lepidosemicyclina) thecideaeformis* Rutten, pp. 1157-1158.
1911 *Orbitoides (Lepidosemicyclina) polymorpha* Rutten, pp. 1159-1160.
1912 *Miogypsina thecideaeformis* (Rutten); Rutten, p. 204, pl. 12, figs. 1-5.
1912 *Miogypsina polymorpha* (Rutten); Rutten, p. 207, pl. 12, figs. 6-9.
1927 *Miogypsina* cf. *irregularis* (Michelotti); Chapman, p. 144.
1955a *Miogypsina thecideaeformis* (Rutten); Crespin, p. 79 (list).
1958 *Miogypsina (Lepidosemicyclina) thecideaeformis* (Rutten); Mohan, pp. 382-384, pl. 2, figs. 8-13; text-figs. 1e, 4d-f (with synonymy).
1958 *Miogypsina (Lepidosemicyclina) polymorpha* (Rutten); Mohan, p. 386, pl. 3, figs. 1-8; text-figs. 1f, 5a-c.
1963 *Miogypsina thecideaeformis* (Rutten); Coleman, pp. 12-13, pl. 2, figs. 7-12 (with synonymy).
1963 *Miogypsina polymorpha* (Rutten); Coleman, p. 12, pl. 2, figs. 1-6.
1974 *Miogypsina (Lepidosemicyclina) thecideae*formis (Rutten); Raju, pp. 84-85, pl. 6, figs. 2-4.

Remarks. Drooger (1953) redescribed Rutten's (1911) type material for both *M. thecideaeformis* and *M. polymorpha*, incorporating values for some statistical parameters of the embryoconch. In two papers (1952, 1963), he considered that parameter V was the most useful to distinguish between the various species of *Miogypsina*. The mean values of V for *thecideaeformis* and *polymorpha* are similar (Drooger, 1953), making differentiation between them by this parameter impossible. Drooger (1953) suggested that the two species could be distinguished by the ontogenetic stage at which the hexagonal chambers first developed, and by the regular arrangement of the embryonic chambers. Mohan (1958, p. 384) continued this usage, but considered that *M. (L.) thecideaeformis* differed from *M. (L.) polymorpha* 'in not having a twisted, winged test, and in having non-elongate and hexagonal chambers'. Coleman (1963) followed Drooger (1953) and considered *M. thecideaeformis* to have fewer hexagonal chambers than *M. polymorpha.*

If the concepts outlined above were used on the populations of *M. (Lepidosemicyclina)* from the northern part of Western Australia, then each population could be split into two species, a distinctly artificial separation. Specimens with a flattened frontal margin occur with those having an undulating margin, and even with bifid forms. As both of Rutten's species cannot be readily separated on the mean values for parameter V, they are here regarded as a single taxonomic unit; as *M. (L.) thecideaeformis* has pagination preference, it is the senior synonym.

The mean values for V for specimiens from north Western Australia range from 15.03 to 47.50, and individual values range from 0 to 89.90 (Chaproniere, 1980a). This is a much larger variation than that recorded by Drooger (1953), and at some future date may form the basis for further subdivision of the lineage. Mohan (1958) suggested that forms with similar equatorial chambers to *M. (L.) polymorpha,* but with values for V greater than 70, be referred to a new species *M. (L.) droogeri.* However, because this would result in the needless subdivision of a single population, only populations with mean values for V greater than 70 should be assigned to *M. (L.) droogeri.* In the populations studied, there is a similar range or variation of equatorial chambers, as recorded by earlier workers.

With the exception of a few specimens of *Miogypsina (Miogypsinoides) dehaarti,* no other species of this genus have been recorded from Western Australia. Both subgenera do not occur together, for *M. (Miogypsinoides)* is found at lower biostratigraphic levels than *M. (Lepidosemicyclina).* From this distribution, it is concluded that *M. (Lepidosemicyclina)* probably originated directly from *M. (Miogypsinoides)*—not from *M. (Miogypsina)* as postulated by Drooger (1953, 1963) and Raju (1974).

Specimens from sample UWA70604, from the unnamed calcarenite in Ashmore Reef No. 1 well, are similar in external characters to those found in the Mandu Calcarenite, but those from sample UWA70603, from a higher biostratigraphic level in that well, are much more inflated and have more tiers of lateral chambers. Specimens of *Lepidocyclina (Nephrolepidina)* from the same younger sample are also much more inflated than those studied elsewhere; in both instances this inflation is thought to be environmentally produced (Chaproniere, 1980a).

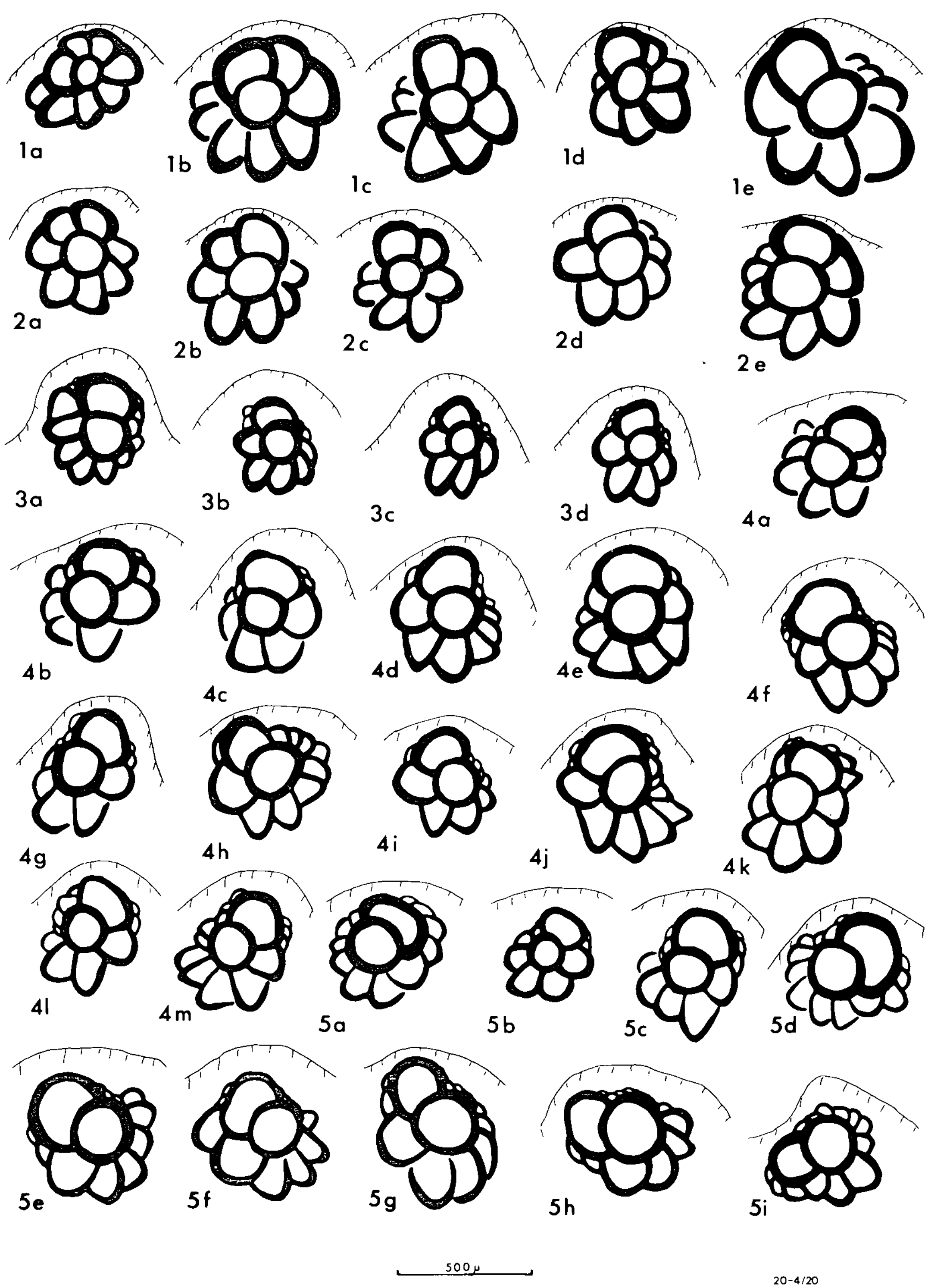

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Fig. 17. Variations in embryoconchs of *Miogypsina* **from Western Australia: 1–2,** *M. (Miogypsinoides) dehaarti*, **1 from UWA70564, 2 from UWA70495; 3–5,** *M. (Lepidosemicyclina) thecideaeformis*, **3 from UWA68324, 4 from UWA70604, 5 from UWA70603.**

The range of variation in the embryoconch is illustrated in Figure 17.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75064	2.85	0.45
UWA75065	1.80	—
UWA75066	2.15	0.55
UWA75067	2.20	0.45
UWA75068	2.80	0.95
UWA75069	1.95	—
UWA75070	2.80	1.05
UWA75071	2.35	—
UWA75072	2.55	—
UWA75073	1.50	—
UWA75074	1.85	—
UWA75075	1.60	—
UWA75076	2.15	—
UWA75077	2.10	0.45
UWA75078	1.85	—
UWA75079	1.80	0.50

Distribution. M. (*L.*) *thecideaeformis* is widespread throughout the upper Mandu Calcarenite in the Cape Range area, but is never abundant. It is present in greater numbers in the upper parts of the unnamed calcarenite in Ashmore Reef No. 1 well. It is restricted to the LF.6 association. The figured specimens are from samples UWA68324 and UWA72225 from the Mandu Calcarenite, and UWA70603 and UWA70604 from the unnamed calcarenite.

Miogypsina (Lepidosemicyclina) sp. cf. **M. thecideaeformis** (Rutten)

Plate 17, figures 12–14

1955a *Miogypsina polymorpha* (Rutten); Crespin, pp. 72 (list), 74, 79 (list).

1955a *Miogypsina excentrica* Tan; Crespin, pp. 72 (list), 74, 79 (list), pl. 9, fig. 6.

Remarks. Specimens with similar characteristics to those found as free individuals in the upper Mandu Calcarenite are present in random thin sections from the Tulki and lower Trealla Limestones. These specimens could not be treated statistically nor could the equatorial chambers be studied. For these reasons identification cannot be certain, and so the forms are placed in open nomenclature.

Crespin (1955a) identified seven species or subspecies of this genus from the Tulki and Trealla Limestones. Because the actual specimens were not labelled nor described, the identifications could not be verified. Most of Crespin's material has been examined during the course of this study, and the specimens observed seem to be no different from *M.* (*L.*) *thecideaeformis*; the absence of biometric data precludes definite identification. The form figured as *M. excentrica* by Crespin (1955a) does not show the subcentripetal development of the embryoconch which is characteristic of that species as described by Tan (1937); this specimen is here considered to be an anomalous growth form.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
CPC15697	4.20	0.75
CPC15698	3.65	0.50
CPC15699	2.65	0.20

Distribution. M. (*L.*) sp. cf. *M. thecideaeformis* is recorded from the Tulki and lower Trealla Limestones. It is restricted to the LF.6 and LF.7 associations. The figured specimens are from samples CR9 and CR46 from the Tulki Limestone.

Subgenus **Miogypsinoides** Yabe & Hanzawa

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

The lack of lateral chambers in *Miogypsinoides* distinguishes this subgenus from all other miogypsinids (Drooger, 1963; Cole *in* Loeblich & Tappan, 1964; Barker, 1965).

Miogypsina (Miogypsinoides) dehaarti van der Vlerk, 1924

Plate 7, figures 7a,b; Plate 8, figures 1–3; Plate 17, figures 15–17; Figure 17

1924 *Miogypsina dehaartii* van der Vlerk, pp. 429-431, text-figs. 1-3.

1957b *Miogypsinoides dehaarti* (van der Vlerk); Cole, pp. 339-440, pl. 111, figs. 5-16 (with synonymy).

1963 *Miogypsinoides dehaarti* (van der Vlerk); Coleman, p. 13, pl. 2, figs. 13-20.

1974 *Miogypsina (Miogypsinoides) dehaartii* van der Vlerk; Raju, pp. 80-81, pl. 1, figs. 19-25; pl. 3, fig. 8; pl. 4, figs. 2-4.

1974 *Miogypsina (Miogypsinoides) dehaarti* van der Vlerk; Adams & Belford, p. 497, pl. 73, figs. 12-14.

1976 *Miogypsina (Miogypsinoides) dehaartii* van der Vlerk; de Bock, p. 16, pls. 30, 39, 40, 42, 43.

Remarks. Drooger (1953) studied a fauna collected near the type locality of *M.* (*Miogypsinoides*) *dehaarti.* His external description closely matches the forms from Cape Range. The internal features of the Cape Range faunas have been summarised by Chaproniere (1980a, table 3) and the amount of variation of the embryoconch is illustrated in Figure 17.

Raju (1972) described a new species, *M.* (*Miogypsinoides*) *indica*, from the Early Miocene of India; it is differentiated from *M.* (*M.*) *dehaarti* by having positive mean values for γ and a larger protoconch.

The mean values for γ for the two populations from Cape Range are negative, and so these faunas are referred to *M.* (*M.*) *dehaarti*. In both populations, the mean values for D_I (Chaproniere, 1980a) are greater than those given by Drooger (1953) for *M.* (*M.*) *dehaarti*, but less than those given for *M. indica* by Raju (1972).

M. (*M.*) *dehaarti* from UWA70564 has higher negative values for $\bar{\gamma}$ ($\bar{\gamma} = -9.71 \pm 39.72$) than that from UWA70495 ($\bar{\gamma} = -3.40 \pm 20.75$), which suggests that UWA 70564 is older than UWA70495. This age difference is also supported by the populations of *Cycloclypeus eidae* and *Lepidocyclina* (*N.*) *howchini praehowchini* which occur in both samples.

A single microspheric specimen was found in sample UWA70495 (see Plate 8, figures 2a–c).

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75080	0.90	0.50
UWA75081	0.75	—
UWA75082	1.10	—
UWA75083	1.15	—
UWA75084	1.25	0.55
UWA75085	1.30	—

Distribution. M. (*Miogypsinoides*) *dehaarti* has been found only in ditch-cuttings from Ningaloo No. 1 well (244 to 253 m) and Learmonth No. 1 well (223 to 287 m). In both it is restricted to the LF.6 association. The figured specimens are from samples UWA 70495 and UWA70564.

Superfamily **ORBITOIDACEA** Schwager
Family **AMPHISTEGINIDAE** Cushman

Genus **Amphistegina** d'Orbigny

Type species: *Amphistegina vulgaris* d'Orbigny, 1826; subsequent designation of Parker, Jones, & Brady (1865).

Amphistegina bikiniensis Todd & Post, 1954
Plate 17, figure 18

1954 *Amphistegina bikiniensis* Todd & Post, p. 563, pl. 201, fig. 4.
1956 *Amphistegina bikiniensis* Todd & Post; Crespin & Belford, p. 2 (list).

Remarks. All specimens referred to this species have similar characteristics to those described by Todd & Post (1954).

Larsen (1976) suggested that *A. bikiniensis* may be a junior synonym of *A. floridana*, an American Miocene species, but any relationship between the two species seems remote on geographical grounds.

Dimensions of figured specimen.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75087	1.05	0.55

Distribution. This species is restricted to the Bullara Limestone in Rough Range, where it occurs in the LF.1 and LF.2 associations. The figured specimen is from sample UWA70600.

Amphistegina hauerina d'Orbigny, 1846
Plate 3; figures 3a–c,5; Plate 17, figures 19–22

1846 *Amphistegina hauerina* d'Orbigny, p. 207, pl. 12, figs. 3-5.
1927 *Amphistegina lessoni* d'Orbigny; Chapman, p. 143.
1955a *Amphistegina lessoni* d'Orbigny; Crespin, p. 75 (list).
1955a *Amphistegina radiata* (Fichtel & Moll); Crespin, p. 75 (list).
1961 *Amphistegina lessoni* d'Orbigny; Ludbrook, pp. 54 (list), 56 (list), pl. IV, fig. 1.
1964 *Amphistegina lessoni* d'Orbigny; Carter, pp. 115-116, pl. 11, figs. 223-225 (with synonymy).
1972 *Amphistegina lessoni* d'Orbigny; O'Herne, p 5, pl. 1, figs. 5-7; pls. 7-11.
1976 *Amphistegina hauerina* d'Orbigny; Larsen, p. 224, pl. 2, figs. 1, 4.

Remarks. There has been a great deal of confusion as to the identity of the various modern and fossil forms referred to *Amphistegina*; in the past it has been common practice to refer most forms from Australia to *A. lessoni*. O'Herne (1974) has reviewed the status of the various described species of *Amphistegina*, and, from this information, specimens from the samples studied may be referred to *A. quoyi*. Recently, Larsen (1976) has also studied the *Amphistegina* species; according to this analysis, forms encountered in this study seem best referred to *A. hauerina*. This is followed here.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75088	1.30	0.35
UWA75089	0.45	0.20
UWA75090	1.20	0.70
UWA75091	1.05	0.60
UWA75092	1.75	0.60
UWA75093	1.70	0.70

Distribution. This species is widespread in the area studied, suggesting a high environmental tolerance. It first appears within the upper part of the Mandu Calcarenite, and ranges up to the Trealla Limestone. The largest and best developed specimens are abundant from the uppermost Mandu Calcarenite and throughout the Tulki Limestone. It is also present in the unnamed calcarenite in Ashmore Reef No. 1 well, the Batesford Limestone, and in three samples from northern New Zealand. The species occurs in the LF.5 to LF.8 associations. The figured specimens are from samples UWA68315, UWA70504, UWA70507, and UWA70509 from the Mandu Calcarenite.

Family **ACERVULINIDAE** Schultze

Genus **Borodinia** Hanzawa

Type species: *Borodinia septentrionalis* Hanzawa, 1940; original designation.

Borodinia septentrionalis Hanzawa, 1940

Plate 18, figures 1,2

1940 *Borodinia septentrionalis* Hanzawa, pp. 790-791, pl. 42, figs. 10-12.
1957 *Borodinia septentrionalis* Hanzawa; Hanzawa, p. 65, pl. 26, figs. 1-6.
1970 *Borodinia septentrionalis* Hanzawa; Hanzawa & Hashimoto, p. 224, pl. 38, figs. 1-4.

Remarks. Specimens identical with those figured and described by Hanzawa (1940, 1957) have been found encrusting nodular coralline algae, echinoid spines, and molluscan fragments. Crespin (1955a) recorded *Acervulina inhaerens* Schultze from the Tulki and Trealla Limestones; this is certainly a misidentification of *Borodinia septentrionalis.*

Dimensions of figured specimens.	Maximum thickness (mm)
UWA75094	0.45
CPC15700	0.55

Distribution. This species has always been found encrusting skeletal fragments. It is never common and is recorded only from the Tulki and lower Trealla Limestones, where it occurs in the LF.6 and LF.7 associations. The figured specimens are from samples UWA68339 and CR103 from the lower part of the Trealla Limestone.

Genus **Gypsina** Carter

Type species: *Polytrema plana* Carter, 1876; subsequent designation of Carter (1880).

Gypsina globulus (Reuss, 1848)

Plate 4, figures 3a–4c; Plate 18, figure 7

1848 *Ceriopora globulus* Reuss, p. 33.
1900 *Gypsina globulus* (Reuss); Jones & Chapman, p. 229 et seq.
1927 *Gypsina globulus* (Reuss); Chapman, p. 142.
1933 *Sphaerogypsina globulus* (Reuss); Galloway, p. 309.
1955a *Gypsina globulus* Reuss [sic.]; Crespin, p. 78 (list), pl. 10, fig. 1.
1956 *Gypsina globulus* Reuss [sic.]; Crespin & Belford, p. 2 (list).
1963 *Gypsina globulus* (Reuss); Coleman, p. 10, pl. 1, fig. 2 (with synonymy).
1965 *Gypsina globula* (Reuss); Todd, pp. 55-56, pl. 22, fig. 5 (with synonymy).
1974 *Gypsina globula* (Reuss); Adams & Belford, p. 503.

Remarks. Todd (1965, p. 56) stated that 'the separation of specimens into two species or two genera on the basis of shape of test (globular in *Gypsina* (or *Sphaerogypsina*) *globula* and hemispherical in *Gypsina vesicularis*) and size of areolae . . . seems unjustified' and considered the two forms synonymous. Coleman (1963, p. 10) had earlier used both names, but noted that 'the indications are that there are intergrading specimens'.

Most specimens referred to *G. globulus* from the North West Cape area are spherical, the surface is covered in papillae; rare hemispherical forms (see Plate 4, figure 4) are present in some of the populations. Features that distinguish the hemispherical forms from typical specimens are their small size, a flattened face, and a surface covered by thickened protruding sutures instead of papillae. These differences are not considered sufficient to warrant separation, and both are referred to *G. globulus.* The lateral chamber walls are finely perforate, thin, and delicate, and appear to be protected by the thickened raised sutures or papillae.

Dimensions of figured specimens.	Maximum diameter (mm)
UWA75095	0.30
UWA75096	1.50
UWA75097	1.30

Distribution. G. globulus has been recorded from the Bullara Limestone and the upper Mandu Calcarenite and Tulki and Trealla Limestones from the North West Cape area, and the unnamed calcarenite in Ashmore Reef No. 1 well. It is present in all LF. associations except LF.1 and LF.3. The figured specimens are from samples UWA68314, UWA68324, and UWA70509 from the Mandu Calcarenite.

Gypsina howchini Chapman, 1910

Plate 4, figures 1a–2c; Plate 18, figures 3a–6

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

1955a *Gypsina howchini* Chapman; Crespin, p. 78 (list).

1955b *Gypsina howchini* Chapman; Crespin, p. 2 (list).

1961 *Gypsina howchini* Chapman; Ludbrook, pp. 51, 80, 87 (lists), pl. IV, fig. 3.

1964 *Gypsina howchini* Chapman; Carter, pp. 82, 83, pl. 4, figs. 82-85; pl. 15, fig. 283; text-fig. 24 (with synonymy).

1969 *Gypsina howchini* Chapman; Lindsay, p. 23 (list).

1970 *Gypsina howchini* Chapman; Lindsay, p. 5 (list).

Remarks. Specimens from the North West Cape area are identical with those from Victoria (see Plate 4, figures 1a–c, specimen from Cape Range; Plate 4, figures 2a–c, specimen from Victoria). SEM studies show that the exterior of the test is covered by elongate anastomosing thickenings produced by protruding thickened sutures. This is a further example in a larger foraminiferid of the strengthening of the test while maintaining thin perforate lateral chamber walls; as a structural type it suggests that this species may have had a symbiotic relationship with algae.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75098	1.85	0.50
UWA75099	2.15	0.90
UWA75100	2.30	—
UWA75101	2.05	0.75
UWA75102	1.60	0.55
UWA75103	1.15	—

Distribution. This species is never abundant, but is persistent throughout the Bullara Limestone, the upper Mandu Calcarenite, and the Tulki and Trealla Limestones in the North West Cape area, and is found in the unnamed calcarenite in Ashmore Reef No. 1 well. It occurs in the LF.1, LF.2, and LF.6 to LF.8 associations. The figured specimens are from samples UWA70600 from the Bullara Limestone, UWA68324 from the Mandu Calcarenite, UWA68345 from the Trealla Limestone, and UWA10653 from the Batesford Limestone.

Gypsina mastaelensis Bursch, 1947

Plate 18, figures 8,9

1947 *Gypsina mastaelensis* Bursch, pp. 37-40, pl. 3, figs. 15, 19; pl. 5, fig. 4; text-figs. 15, 17-19.

1952 *Hemigypsina mastaelensis* (Bursch); Bermudez, p. 124, pl. XXIV, fig. 16.

Remarks. Bursch (1947) described this species from the Moluccas, Indonesia, where it is associated with a typical Tertiary *c* stage fauna (Early Oligocene). Bermudez (1952) designated this taxon as the type species for a new genus, *Hemigypsina*, which was subsequently regarded as a junior synonym for *Gypsina* by Loeblich & Tappan (1964). Hanzawa & Hashimoto (1970, p. 225) stated that this species 'is nothing but an encrusting form of Foraminifera', and concluded that it is synonymous with *Acervulina inhaerens* and that the structural differentiation of the test is not sufficiently marked for it to be referred to *Gypsina*.

G. mastaelensis has a regular test construction and morphology, and so is distinctly different from *Acervulina*. Furthermore, its internal structural differentiation is just as marked as that in *G. howchini* (see Plate 4, figures 1a–2c). For these reasons, and because the test construction is similar to that for *Gypsina*, the species is retained in that genus.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75014	1.45	—
UWA75105	1.65	0.15

Distribution. G. mastaelensis appears to have had a restricted environmental range. In the North West Cape area it has been recorded only in bioclastic grainstone from the Tulki and Trealla Limestones, where it is associated with an assemblage interpreted as metahaline (Chaproniere, 1975). This species is found only in the LF.7 and LF.8 associations. The figured specimens are from sample UWA51909 from the Trealla Limestone.

Gypsina sp.

Plate 5, figures 1a–c

Remarks. A small conical form with a single flattened surface and external features typical of *Gypsina* has been recorded from some samples. The test form is indicative of an encrusting habit. Because of its rarity, no specimens were sectioned, and for this reason the internal characters are not known.

Dimensions of figured specimen.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75106	0.55	0.35

Distribution. This form has been recorded only from the upper Mandu Calcarenite in surface outcrops. It is restricted to the LF.5 and LF.6

associations. The figured specimen is from sample UWA68314.

Family **CYMBALOPORIDAE** Cushman
Subfamily **CYMBALOPORINAE** Cushman

Genus **Halkyardia** Heron-Allen & Earland

Type species: *Cymbalopora radiata* var. *minima* Leibus, 1911; subsequent designation of Cushman (1928).

Halkyardia sp. cf. **H. minima** (Leibus, 1911)

1911 *Cymbalopora radiata* Hagenow var. *minima* Leibus, p. 952, tf. 111, fig. 7.
1973 *Halkyardia minima* Leibus; Deloffre & Hamaoui, pp. 308-311, pl. 11, figs. 1-7.

Remarks. A single specimen with a large protruding plug, almost identical to the type figures, has been recorded from one sample. This specimen differs from *H. bikiniensis* Cole and *H. bartrumi* Parr in its possession of a large protruding plug; and from *H. minima* var. *indica* Tewari in having a concave ventral surface. Because only one specimen has been recorded, the range of variation is not known, and the form is placed in open nomenclature.

Distribution. This species has been recorded only from sample UWA70600, from the upper Bullara Limestone, and is restricted to the LF.2 association. Its presence in the Tertiary lower *e* stage Bullara Limestone is in agreement with the range specified by Adams (1970).

Family **HOMOTREMATIDAE** Cushman
Subfamily **VICTORIELLINAE** Chapman & Crespin

Genus **Victoriella** Chapman & Crespin

Type species: *Carpenteria proteiformis* var. *plecte* Chapman, 1921 (= *C. conoidea* Rutten, 1914); original designation.

Victoriella conoidea (Rutten, 1914)

Plate 13, figures 5a–b

1914 *Carpenteria conoidea* Rutten, p. 47, pl. 7, figs. 6-9.
1921 *Carpenteria proteiformis* Goës var. *plecte* Chapman, p. 320, pl. 51, fig. 3.
1930a *Victoriella plecte* (Chapman); Chapman & Crespin, p. 111.
1959 *Victoriella conoidea* (Rutten); Glaessner & Wade, p. 199, pl. 1, figs. 1-5; pl. 2, figs. 1-5, 7-10; pl. 3, fig. 3; text-figs. 1-4 (with synonymy).
1961 *Victoriella conoidea* (Rutten); Hornibrook, p. 168, pl. 26.

Remarks. Crespin (1955a) recorded *Carpenteria conoidea* from the Tulki Limestone after Chapman & Crespin (1930a) had defined *Victoriella.* I examined most of the material used by Crespin (1955a), but did not find *V. conoidea.* I conclude, therefore, that either Crespin's record is a misidentification or, more probably, the name was used for a species of *Carpenteria.*

Typical specimens of *V. conoidea* have been recorded from sample UWA70614 (= N28/631) from New Zealand.

Dimensions of figured specimen.	Maximum diameter (mm)	Maximum length (mm)
F82	1.40	2.50

Distribution. This species has been recorded only from the Waitakere Group (Puketi Formation) from Huketere Peninsula (Kaipara Harbour), New Zealand, where it is associated with a typical LF.2 assemblage.

Genus **Biarritzina** Loeblich & Tappan

Type species: *Columella carpenteriaeformis* Halkyard, 1918; original designation.

Biarritzina alternata (Chapman & Crespin, 1930b)

Plate 13, figures 4a–b

1930b *Carpenteria alternata* Chapman & Crespin, p. 99, pl. 5, figs. 9-10.
1955a *Carpenteria alternata* Chapman & Crespin; Crespin, p. 76 (list).

Remarks. I have examined the two type specimens for this species, which are housed in the Bureau of Mineral Resources (CPC21, CPC22). Both specimens are similar to those found in the North West Cape area.

This species is most variable in the test form; some specimens have two chambers in the final whorl, whereas others have three or four. The crescentic aperture is on the end of a long neck which commonly extends from the base of the final chamber.

B. alternata appears to differ from *B. carpenteriaeformis* by having a more compact mode of coiling and a crescentic to subcircular aperture. The range of variation of modern forms of *Biarritzina* needs to be studied before the status of *B. alternata* can be fully ascertained.

Dimensions of figured specimen.	Maximum diameter (mm)	Maximum length (mm)
UWA75108	1.65	2.15

Distribution. This species is never common, but is widespread throughout the upper Mandu Calcarenite and Tulki Limestone. It is present in all the larger foraminiferal associations except LF.1, LF.2, and LF.8. The figured specimen is from sample UWA70503 from the Mandu Calcarenite.

Biarritzina carpenteriaeformis (Halkyard, 1918)
Plate 13, figures 2a–3c; Plate 18, figure 10

1918 *Columella carpenteriaeformis* Halkyard, p. 28, pl. 2, figs. 1-5.
1964 *Biarritzina carpenteriaeformis* (Halkyard); Loeblich & Tappan, p. C628, fig. 499, 4a-c.

Remarks. Crespin (1955a) listed a number of species of *Carpenteria.* The status of these species is unknown, but *C. proteiformis* may be synonymous with *B. carpenteriaeformis.*

Specimens referred to as *B. carpenteriaeformis* seem to be similar to those illustrated by Loeblich & Tappan (1964). Unlike *B. alternata* their apertures are circular and present in earlier chambers (Plate 13, figs. 2b, 3a, 3b). Their finely perforate test wall and more compact mode of coiling differentiate them from specimens referred to *B. proteiformis.*

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum length (mm)
UWA75109	1.35	2.10
UWA75110	0.80	0.95
UWA75111	1.05	1.70

Distribution. Like *B. alternata, B. carpenteriaeformis* is never common, but is widespread throughout the upper Mandu Calcarenite and Tulki Limestone. It is present in all the larger foraminiferal associations except LF.1, LF.2, and LF.8. The figured specimens are from samples UWA70469 and UWA70509.

Biarritzina proteiformis (Goës, 1882)
Plate 13, figures 1a–c

1882 *Carpenteria balaniformis* var. *proteiformis* Goës, p. 94, pl. 6, figs. 208-214; pl. 7, figs. 215-219.
1915 *Carpenteria proteiformis* Goës; Cushman, p. 49, pl. 20, fig. 2; pl. 21, fig. 1 (with synonymy).
1957 *Carpenteria proteiformis* Goës; Hanzawa, p. 70, pl. 36, figs. 9, 11, 13; pl. 38, fig. 6.

Remarks. This form is similar to Recent specimens figured by Brady (1884) and Cushman (1915). Its coarsely perforate test wall and looser mode of coiling distinguish it from *B. alternata* and *B. carpenteriaeformis.*

Dimensions of figured specimen.	Maximum diameter (mm)	Maximum length (mm)
UWA75112	1.35	2.60

Distribution. This form is rare, and restricted to the upper Mandu Calcarenite in Sandy Point No. 2 well, where it is confined to the LF.6 association. The figured specimen is from sample UWA70503.

Family **LEPIDOCYCLINIDAE** Scheffen
Subfamily **LEPIDOCYCLININAE** Scheffen

Genus **Lepidocyclina** Gümbel

Type species: *Nummulites mantelli* Morton, 1833; subsequent designation of Douvillé (1898).

The supraspecific subdivision of the Lepidocyclinidae has been the subject of several papers since the late 1950s (e.g., Cole, 1960b, c, 1961b,c, 1962, 1963, 1968; Eames & others, 1962; Hanzawa, 1962, 1964), but no real unanimity has been reached on the status of the various supraspecific levels. To summarise, Cole (1963, 1968) concluded that there are only two valid subgenera of *Lepidocyclina*: *Polylepidina* and *Lepidocyclina* sensu stricto (including *Eulepidina*, *Multilepidina*, *Nephrolepidina*, and *Pliolepidina*). Hanzawa (1962, 1964) recognised *Lepidocyclina, Eulepidina, Multilepidina, Nephrolepidina, Pliolepidina,* and *Triplalelepidina* as valid genera. Eames & others (1962) regarded *Lepidocyclina, Eulepidina,* and *Pliolepidina* (including *Multilepidina*) as valid genera, and *Nephrolepidina* as a valid subgenus of *Lepidocyclina.* Cole (1963, 1968), Eames & others (1962) and Hanzawa (1962, 1964) appeared to be in general agreement in noting that there are distinct gradations between the different groups, but differed on the taxonomic value of the differences. To me, it appears that the arguments of all of these authors are legitimate to varying degrees.

Different evolutionary lineages can be recognised within the genus *Lepidocyclina* (Fig. 18); these commonly are geographically restricted and are conceptually similar to those found in *Miogypsina* (Drooger, 1952, 1963). In this study, I propose that each major lineage be recognised at the subgeneric level: (1) the American forms, in which the embryoconch varies from lepidocycline to nephrolepidine or pliolepidine types, fall within the concept of *Lepidocyclina* (*Lepidocyclina*); (2) a more widespread group which apparently arose as a branch from *L.* (*Lepidocyclina*) and rapidly spread to Europe and the Indo-Pacific, and in which the embryoconch rapidly became eulepidine associated with an increase in size of both the test and the embryoconch, falls

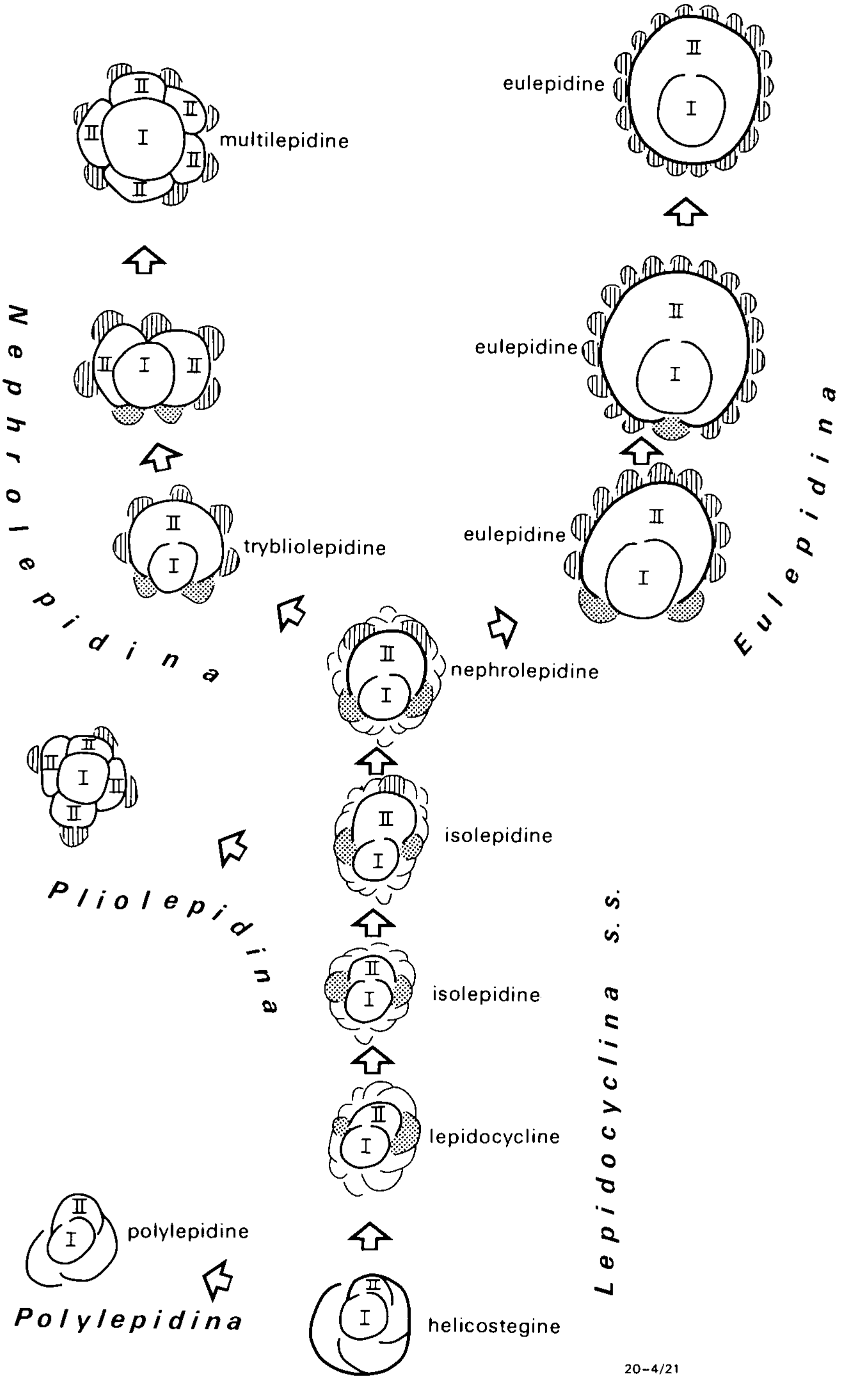

Fig. 18. Tentative phylogenetic scheme for the Lepidocyclinidae. Stippled chambers are the primary auxiliary chambers; those with vertical hatching are the adauxiliary chambers.

within the concept of *L.* (*Eulepidina*); and (3) a group which appears to have evolved as a late offshoot from *L.* (*Lepidocyclina*), and in which the rate of envelopment of the protoconch by the deuteroconch was slower than in *L.* (*Eulepidina*), and in which the embryoconch varies from isolepidine to nephrolepidine, trybliolepidine, and finally multilepidine types, falls within the concept of *L.* (*Nephrolepidina*). I realise that within each of these major lineages (the subgenera) local bioseries exist; each local bioseries can be recognised as a distinct species, and different levels within the series can be distinguished by a subspecific name. The type of embryoconch, the types of chambers making up the equatorial layer, and the arrangement of these chambers within that layer, are considered to have the greatest taxonomic significance (Chaproniere, 1980a); the test size, the number and shape of the lateral chambers, the development of pillars, and the general test shape, are considered to have little taxonomic importance, being controlled mainly by environmental pressures (Chaproniere, 1975, 1980a).

The subgeneric concepts presented above do not differ markedly from those discussed by other workers. Cole's (1960b,c, 1961b,c, 1963, 1968) arguments revolved around the fact that different levels within each of the three lineages may have the same types of embryoconchs, and for this reason he considered that only two subgenera were valid. Both Hanzawa (1962, 1964) and Eames & others (1962) realised that similar embryoconchs were present in each of the subgenera, but considered that other features of the test permitted the recognition of the different groups; although it was not mentioned, it is apparent from their publications that the lineage concept discussed above formed the basis for their understanding of *Lepidocyclina* (see Fig. 18).

Subgenus **Eulepidina** Douvillé

Type species: *Orbitoides dilatata* Michelotti, 1861; subsequent designation of Yabe (1919).

The definition given by Hanzawa (1962) is considered to be the most useful. This subgenus is most easily recognised by the following characteristics: (i) the numerous auxiliary chambers surrounding the embryoconch; (ii) the degree of envelopment of the protoconch by the deuteroconch (= parameters A and LA —see Chaproniere, 1980a); (iii) the large size of the embryoconch; (iv) the pectinations on the septa of the equatorial chambers; (v) the most common arrangement of the equatorial chambers is in a circular concentric pattern, rarely in a polygonal concentric, and never in a stellate pattern; and (vi) the rarity of hexagonal equatorial chambers. As Cole (1962) noted, some of these characters are found in other subgenera.

The distinction of early forms of *L.* (*Eulepidina*) from late forms of *L.* (*Lepidocyclina*) is difficult because many of the characters overlap. For this reason *L.* (*Eulepidina*) should not be recognised at the generic level. Late forms of *L.* (*Eulepidina*) are easily distinguished, as no other lineage has such an advanced type of embryoconch combined with a fairly primitive arrangement of equatorial chambers.

Lepidocyclina (Eulepidina) badjirraensis
Crespin, 1952

Plate 1, figure 6; Plate 12, figures 1a–3, 5a–b; Plate 18, figures 11–16; Plate 25, figures 15, 16; Figure 19.

1952 *Lepidocyclina (Eulepidina) badjirraensis* Crespin, pp. 29, 30, pl. 6, figs. 1, 2, 5; pl. 7, figs. 1, 2, 4; pl. 8, figs. 1-5.
1952 *Lepidocyclina (Eulepidina) manduensis* Crespin, pp. 30-31, pl. 6, figs. 3, 4; pl. 7, figs. 3, 5, 6; pl. 8, figs. 6, 7.
1955a *Lepidocyclina (Eulepidina) badjirraensis* Crespin; Crespin, pp. 72 (list), 73, 78 (list); pl. 7, figs. 2, 3; pl. 8, fig. 4; pl. 10, fig. 3.
1955a *Lepidocyclina (Eulepidina) manduensis* Crespin; Crespin, pp. 72 (list), 73, 78 (list); pl. 8, figs. 2, 3.
1957a *Lepidocyclina (Eulepidina) badjirraensis* Crespin; Cole, pp. 345-346, pl. 108, figs. 1-3; pl. 109, figs. 9, 10 (with synonymy).

Remarks. This species has been discussed in detail by Crespin (1952) and Cole (1957a), and Chaproniere (1980a) has provided statistical data. In my opinion, Cole (1957a) was correct in regarding *L.* (*E.*) *manduensis* as a junior synonym of *L.* (*E.*) *badjirraensis.* Crespin (1952) considered that the only difference between the two species was that of size—*L.* (*E.*) *manduensis* being the smaller. I have examined the faunas from the type section of the Mandu Calcarenite (which contains the type locality for the two species proposed by Crespin, 1952); as noted by Crespin (1952), the larger forms are found at a lower stratigraphic level than the smaller ones. I believe that this size difference was environmentally produced (Chaproniere, 1980a)—the larger forms resulting from deeper-water conditions. A similar relationship between size and environment has been observed for Recent specimens of *Marginopora vertebralis* (Ross, 1972).

A population of *L.* (*Eulepidina*) *badjirraensis* collected close to the type level for *L.* (*E.*) *manduensis*, near the top of the Mandu Calcarenite, has been studied statistically. The range of values for parameter A (Chaproniere, 1980a, table 4) is similar to that obtained for *L.* (*E.*) *dilatata dilatata* by Lange (1968) in the only other such study known to me on a species of this subgenus. It is noteworthy that in the North West Cape area no specimens were found with values for A of 100% (Chaproniere, 1980a); in contrast some specimens of *L.* (*E.*) *dilatata concentrica* have been recorded with values for A of 100% (Lange, 1968). Figure 19 illustrates the range of variation of the embryoconchs for this species.

The test microstructure for this subgenus has been studied by Eames & others (1962), and little can be added here. SEM microphotographs (Plate 16, figs. 2b, 2c, 4a, 4b, 5b) support the conclusions made by those authors, and clearly show the detailed microstructure. The pectinations on the tangential walls of the equatorial chambers are more weakly developed in *L.* (*Nephrolepidina*) (Plate 10, figs. 5a,b) and in *Miogypsina* (*Miogypsina*) (Plate 12, fig. 6) than in *L.* (*Eulepidina*) (Plate 12, figs. 2b,c).

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75114	5.05	0.65
UWA75115	2.25	0.50
UWA75116	2.45	0.30
UWA75117	0.85	—
UWA75118	23.78	—
UWA75119	5.09	0.53
UWA75120	3.15	—
UWA75121	2.75	—
UWA75122	3.45	—
UWA75123	4.85	—
UWA75124	4.80	—

Distribution. *L.* (*E.*) *badjirraensis* has been recorded from the upper part of the Mandu Calcarenite in the North West Cape area. The only other record is from the upper part of the Cartier beds and the lower parts of the unnamed calcarenite from Ashmore Reef No. 1 well. Adult specimens of this species are restricted to the LF.5 association, although some juveniles are recorded from the LF.4 association. The figured specimens are from samples UWA68316, UWA68318, UWA70469, and UWA70470 from the Mandu Calcarenite; and UWA70604 from the unnamed calcarenite and UWA70609 from the Cartier beds, both from Ashmore Reef No. 1 well.

Lepidocyclina (Eulepidina) ephippioides
Jones & Chapman, 1900

Plate 12, figures 4a,b; Plate 19, figures 1–7; Plate 25, figure 17; Plate 26, figures 1,2; Figure 19

1900 *Lepidocyclina ephippioides* Jones & Chapman, pp. 250-251, pl. 20, fig. 9.
1955b *Lepidocyclina (Eulepidina) insulaenatalis* Jones & Chapman; Crespin, p. 3 (list).
1955b *Lepidocyclina (Eulepidina) manduensis* Crespin; Crespin, p. 3 (list) (non-Crespin, 1952).
1956 *Lepidocyclina (Eulepidina) planata* Oppenoorth; Crespin & Belford, p. 2 (list).
1971b *Eulepidina dilatata dilatata* (Michelotti); Matsumaru, pp. 184-185, pl. 22, figs. 28-38.
1973 *Lepidocyclina (Eulepidina) ephippioides* (Jones & Chapman); Binnekamp, pp. 20-21, pl. 12, figs. 2-8; pl. 13, figs. 1-4 (with synonymy).
1974 *Lepidocyclina (Eulepidina) ephippioides* Jones & Chapman; Adams & Belford, pp. 500-502, pl. 74, figs. 4-6, 9, 12, 14; text-fig. 12 (with synonymy).

Remarks. Adams & Belford (1974) have discussed the status of *L.* (*Eulepidina*) *ephippioides*, which was originally described from Tertiary lower *e* limestones from Christmas Island. The original description is based on specimens from random thin sections, and because no statistical data are available the exact concept of this species is not known. Saddle-shaped forms, which are so common in other parts of the Indo-Pacific region, are not present in the local faunas. In the Christmas Island samples, both flattened and saddle-shaped forms are present (Adams & Belford, 1974, plate 74, figs. 4–6), suggesting that test-shape may be controlled by environmental factors and so is not a taxonomic criterion. For this reason the forms from similar levels to those from Christmas Island are here referred to *L.* (*E.*) *ephippioides.*

The forms referred to this species from the North West Cape area are associated with a similar Tertiary lower *e* fauna to those from Christmas Island, indicating that the two faunas are of similar age. On statistical grounds the specimens are more primitive than *L.* (*E.*) *badjirraensis* (Chaproniere, 1980a), and the differences in the means for all parameters

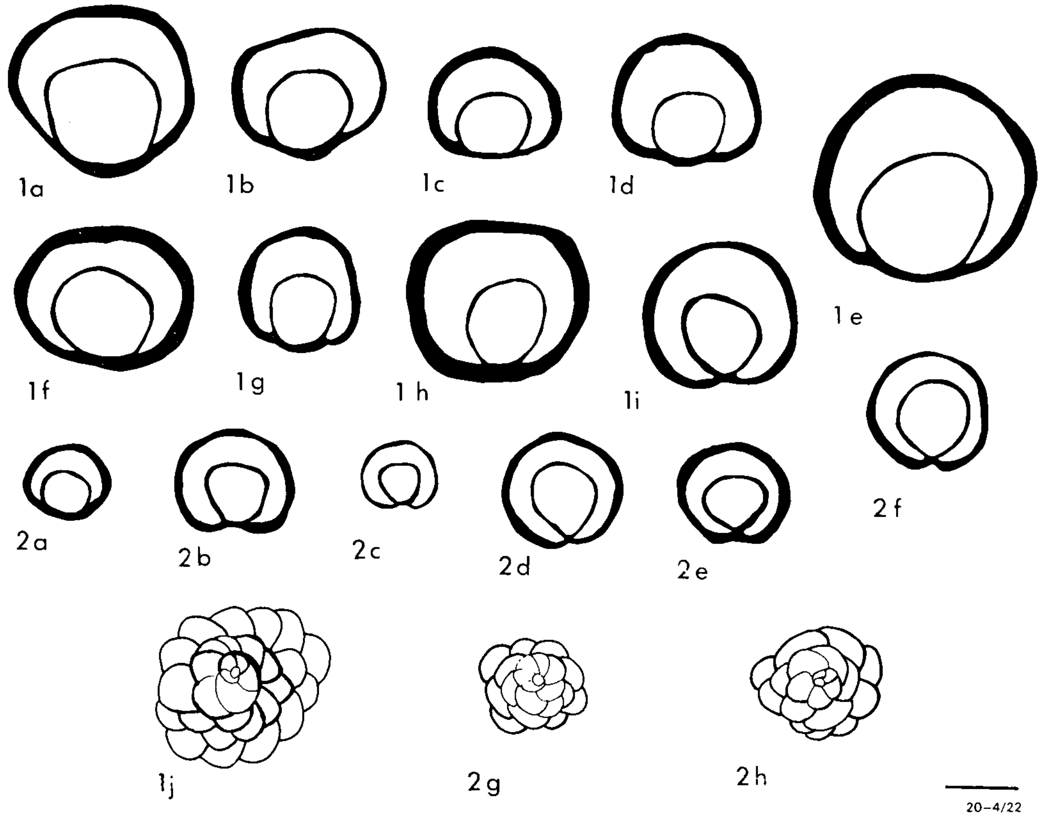

Fig. 19. Variations in embryoconchs of *Lepidocyclina (Eulepidina)* from the North West Cape: 1, *L. (E.) ephippioides* from UWA53674; 2, *L. (E.) badjirraensis* from UWA68318; 1j, 2g, and 2h are microspheric forms. The scale bar represents 200 μm for megalospheric and 100 μm for microspheric forms.

are significant on the basis of the t-test (Chaproniere, 1980a). The range of variation of the embryoconch is illustrated in Figure 19.

The forms referred to this species from New Zealand (samples UWA70613 and UWA 70614) are associated with a Tertiary upper *e* stage fauna. These few specimens preclude a proper statistical evaluation, but the values obtained compare closely with those from Rough Range. Matsumaru (1971b) recorded *L.* (*E.*) *dilatata dilatata* from the same locality as UWA70613. This is a European species, and the use of this name for an Indo-Pacific form seems unwarranted at this stage, since a local name is available. Matsumaru (1971b) did not discuss the relationship between the two species.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75113	4.30	1.23
UWA75125	6.80	1.50
UWA75126	8.82	1.12
UWA75127	9.10	1.56
UWA75128	4.78	—
UWA75129	4.95	—
UWA75130	4.35	—
UWA75131	4.24	—
UWA75132	5.02	2.05
UWA75133	7.28	1.97
F64	5.38	1.22
F79	7.51	1.34

Distribution. L. (*E.*) *ephippioides* is restricted to the upper part of the Bullara Limestone in the North West Cape area and to the LF.2 association; reworked specimens occur in the basal Trealla Limestone in Rough Range. It also occurs in samples UWA70613 (?Waitiiti Formation) and UWA70614 (Puketi Formation) in New Zealand, where it occurs with a typical LF.2 association. The figured specimens are from samples UWA53674, UWA70577, UWA70595, and UWA70600 from the Bullara Limestone, and UWA70613 probably from the Waitiiti Formation.

Subgenus **Nephrolepidina** Douvillé

Type species: *Nummulites marginata* Michelotti, 1841; original designation.

The definition of this subgenus given by Hanzawa (1962) is considered to be the most useful. The subgenus is most easily recognised by the following characteristics: (i) the embryoconch is surrounded by only a few auxiliary chambers, especially in the primitive types; the number of these chambers gradually increases as the embryoconch becomes more enveloped by the deuteroconch, but is never as high as the numbers in *L.* (*Eulepidina*); (ii) the embryoconch is fairly small, never attaining the size of that in *L.* (*Eulepidina*); (iii) the pectinations of the septa of the equatorial chambers, as seen in vertical section, are never as numerous nor as well developed as those found in *L.* (*Eulepidina*); (iv) the arrangement of the equatorial chambers forms an 'engine-turned' pattern of intersecting curves in phylogenetically primitive forms, becoming circular concentric then polygonally concentric and finally stellate in the phylogenetically advanced forms; (v) elongate hexagonal equatorial chambers become common in some lineages, but elongate spatulate or short hexagonal chambers are most commonly found; (vi) the test diameter of the megalospheric generation never reaches the sizes found in *L.* (*Eulepidina*).

Because the nephrolepidine type of embryoconch and some of the other features are found in some of the other subgenera, this subgenus should not be elevated to full generic rank. In phylogenetically advanced forms the embryoconch becomes trybliolepidine (eulepidine) and finally multilepidine (Fig. 18).

The absence of elongate hexagonal chambers and the rarity of short hexagonal chambers in the equatorial layer in the Australian and New Zealand species of this subgenus permit these to be recognised as a distinct lineage, different from the other Indo-Pacific species. The New Zealand forms are distinguished from the Australian group only on the rates of evolution of parameters A and F (Chaproniere, 1980a), which in the New Zealand forms are much slower.

The test microstructure for this subgenus has been studied by Eames & others (1962), and little more can be added here. SEM microphotographs (Plate 9, figs. 5b–f; Plate 10, figs. 4b,c, 5a–c) support the conclusions made by those authors, and show clearly the detailed microstructure.

Lepidocyclina (Nephrolepidina) howchini howchini Chapman & Crespin, 1932

Plate 8, figures 4–14; Plate 9, figures 5a–f; Plate 11, figures 1–5; Plate 19, figures 8–15; Plate 20, figures 1–12; Plate 21, figures 1–6; Plate 26, figures 3–6; Figures 20–22

1889 ?*Orbitoides stellata* Howchin (non-d'Archiac), p. 17, pl. 1, figs. 10a,b.

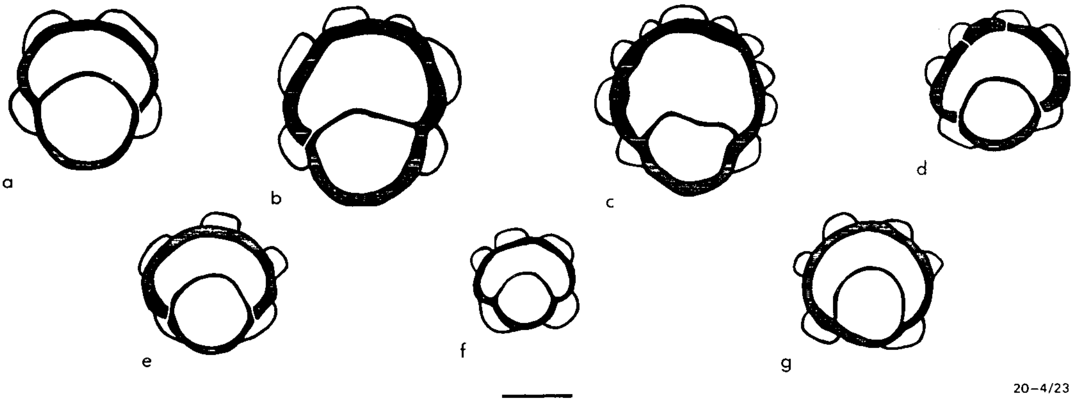

Fig. 20. Variations in embryoconchs of topotypes of *Lepidocyclina (Nephrolepidina) howchini howchini* from sample 77640413, Hamilton Bore, Victoria: a, specimen CPC21572; b, CPC21577; c, CPC21576; d, CPC21570; e, CPC21569; f, CPC21579; g, CPC21571. The scale bar represents 200 μm.

1932 *Lepidocyclina (Nephrolepidina) howchini* Chapman & Crespin, pp. 94-95, pl. 13, figs. 18-19.
1955a *Lepidocyclina (Trybliolepidina) martinii* (Schlumberger); Crespin, pp. 72 (list), 78 (list).
1964 *Lepidocyclina howchini* Chapman & Crespin; Carter, pp. 137-140, pl. 17, figs. 290-292; text-figs. 31-34 (with synonymy).
1969 *Lepidocyclina howchini* Chapman & Crespin; Lindsay, p. 23 (list), pl. 2, fig. 10.
1970 *Lepidocyclina howchini* Chapman & Crespin; Lindsay, p. 5 (list).
1971a *Nephrolepidina howchini* Chapman & Crespin; Matsumaru, p. 170, pl. 15, figs. 1-13; pl. 16, figs. 1-6; pl. 22, figs. 2, 6.
1973 *Lepidocyclina howchini* Chapman & Crespin; Lindsay & Giles, p. 3, figs. 2, 3.
1974b *Lepidocyclina* cf. *howchini* Chapman & Crespin; Quilty, figs. 30-32.

Remarks. The internal and external characters of this subspecies have been described by Crespin (1936), Carter (1964), and Matsumaru (1971a). The last two authors have presented some statistical details of the embryoconch. Carter (1964) considered only the nepionic spirals in the Victorian forms, stating that these ranged from eight to 20, but he failed to give any other information. Matsumaru (1971a) presented the results of a study of a population of 31 specimens of *L.* (*N.*) *howchini howchini* from the Batesford Limestone. Palmieri (1973) listed some statistical data for specimens identified as *L.* (*N.*) *angulosa*, *L.* (*N.*) *howchini*, *L.* (*N.*) *japonica*, and *L.* (*N.*) *martini* from the Capricorn Basin, Queensland. The single population from a sample from Wreck Island No. 1 well from the Capricorn Basin incorporated in this study has been identified as *L.* (*N.*) *howchini howchini*; it is suggested that the forms referred to several species by Palmieri (1973) belong to this taxon.

I have examined statistically thirty-five topotypes of *L.* (*N.*) *howchini howchini* from sample 77640413 (Hamilton Bore, Victoria). Values for parameters F, C, A, and B (see Table 3) are similar to those from sample UWA10653 from the Batesford Limestone (Chaproniere, 1980a, table 5). Results using the t-test indicate that the differences between the two populations (77640413 and UWA 10653) for these parameters are insignificant at the 95% level of confidence, so the two are statistically indistinguishable.

The rarity of hexagonal chambers in the equatorial layer of *L.* (*N.*) *howchini* distinguishes it from other Indo-Pacific species (Crespin, 1943a; Carter, 1964). *L.* (*N.*) *howchini howchini* is characterised by the dominance of specimens with a polygonal or stellate arrangement of spatulate equatorial chambers, as indicated by the mean values for parameter F, which exceed 3 (Chaproniere, 1980a). This serves to distinguish this subspecies from *L.* (*N.*) *howchini praehowchini*, in which the mean values for parameter F are less than 3. Biometric data indicate that this species is similar to *L.* (*N.*) *orakeiensis hornibrooki* from similar levels (Zone N.8) in New Zealand (see also Matsumaru, 1971b).

Populations from the North West Cape area referred to this taxon have the same characteristics as those from Victoria, although some populations are more phylogenetically advanced, having mean values of more than 4 for parameter F (Chaproniere, 1980a). These advanced populations are dominated by specimens with trybliolepidine embryoconchs, and rarely by forms with even more advanced multilepidine types (see Fig. 22), similar to that figured by van der Vlerk (1961) or *L.* (*N.*) *radiata*. In an individual population there is a wide range of variation of the embryoconch type, from isolepidine to trybliolepidine (Plate 8, figs. 5–14; Fig. 21).

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75134	0.65	—
UWA75135	0.33	—
UWA75136	0.30	—
UWA75137	0.25	—
UWA75138	0.28	—
UWA75139	0.30	—
UWA75140	0.32	—
UWA75141	0.34	—
UWA75142	0.33	—
UWA75143	0.34	—
UWA75144	0.32	—
UWA75145	3.68	0.95
UWA75146	3.64	1.19
UWA75147	4.40	1.35
UWA75148	2.19	1.62
UWA75149	3.25	—
UWA75150	3.55	—
UWA75151	2.45	—
UWA75152	3.35	—
UWA75153	3.30	—
UWA75154	3.40	0.95
UWA75155	3.02	1.18
UWA75156	3.15	0.90
UWA75157	3.40	—
UWA75158	2.00	—
UWA75159	2.70	—

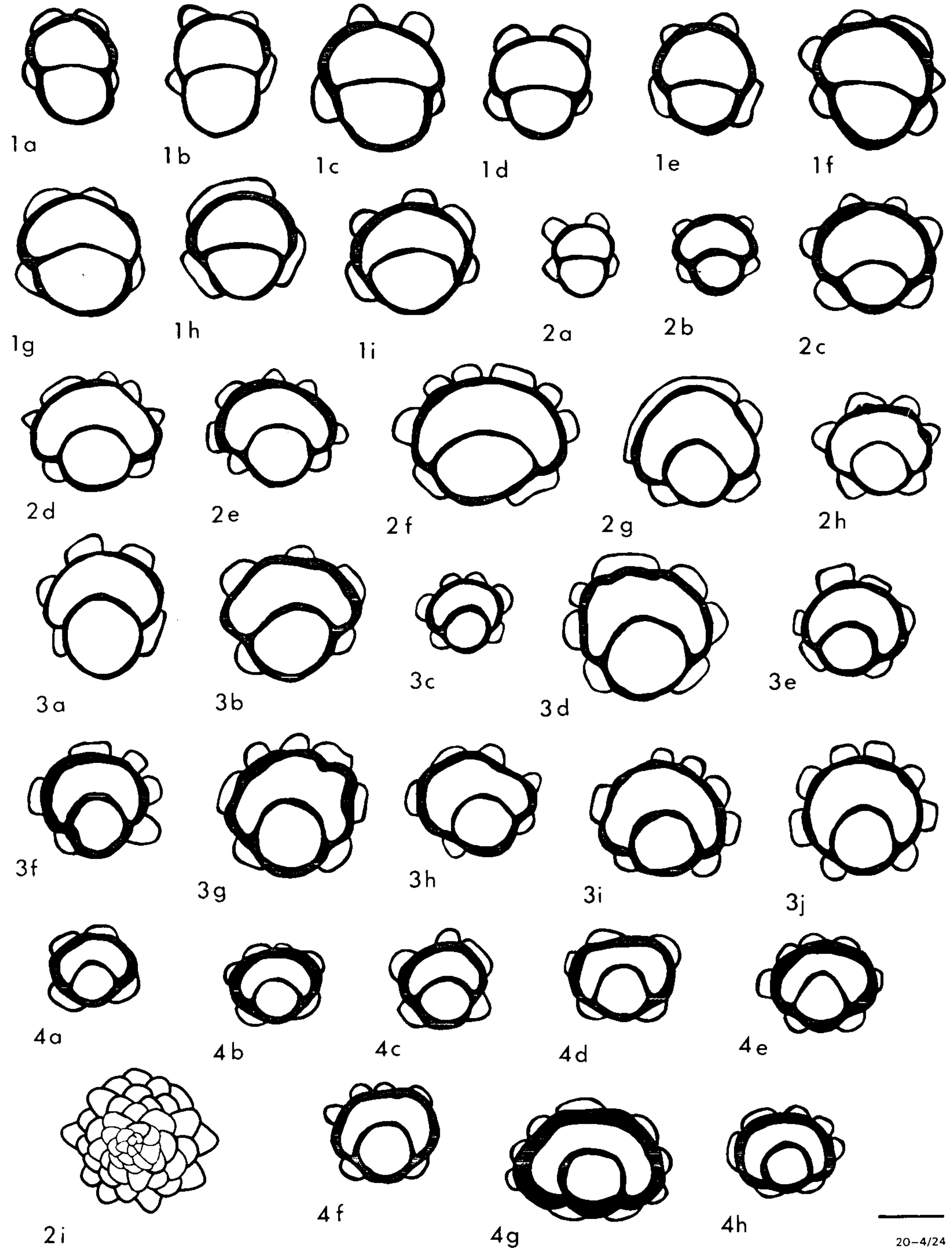

Fig. 21. Variations in embryoconchs of *Lepidocyclina (Nephrolepidina)* **from Australia: 1,** *L. (N.) sumatrensis* **from UWA53674; 2,** *L. (N.) howchini praehowchini* **from UWA68324; 3–4,** *L. (N.) howchini howchini*, **3 from UWA10653, 4 from UWA70509. The scale bar represents 200 μm for megalospheric and 100 μm for microspheric forms.**

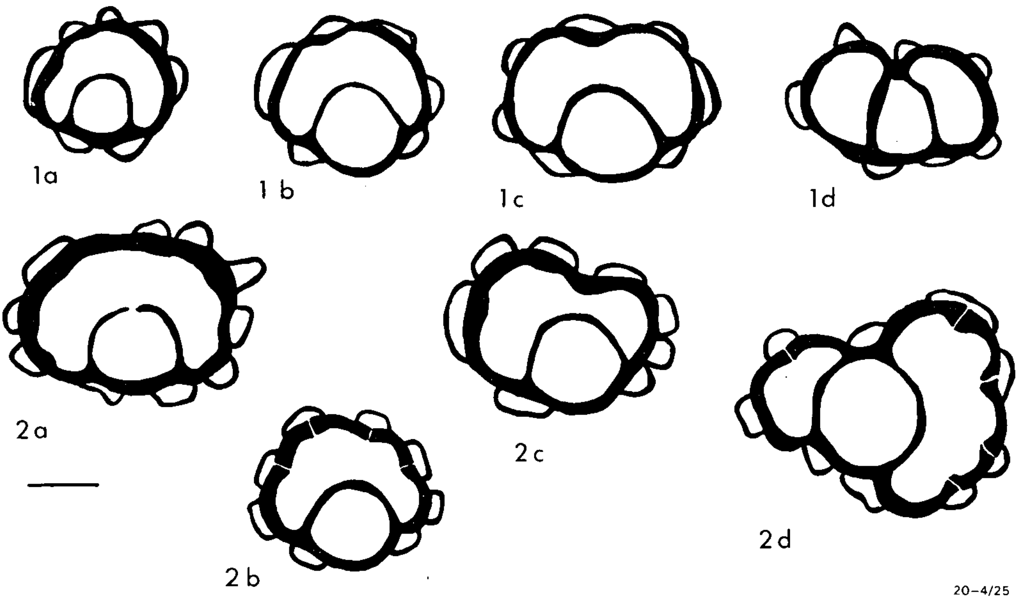

Fig. 22. Gradations between trybliolepidine and primitive multilepidine types of embryoconch in populations of *Lepidocyclina (Nephrolepidina)*: 1, *L. (N.) howchini howchini* from 77640413, a — CPC21587, b — CPC21589, c — CPC21586, d — CPC21588; 2, *L. (N.) orakeiensis waikukuensis* from UWA70612 (=N2/619), a — F46, b — F49, c — F47, d — F48. The scale bar represents 200 µm.

UWA75160	2.65	1.80
UWA75161	2.00	2.20
UWA75162	2.43	1.82
CPC15701	1.38	0.78
CPC15702	1.80	—
CPC15703	1.82	—
CPC15704	2.14	—
CPC15705	1.82	—
CPC15706	2.15	—
CPC15707	2.95	—
CPC21568	3.06	—
CPC21573	2.75	—
CPC21574	2.60	—
CPC21575	2.46	—
CPC21578	2.65	—
CPC21580	1.75	—
CPC21581	3.45	1.25
CPC21582	2.65	1.30
CPC21583	3.10	1.45
CPC21584	3.55	1.15
CPC21585	2.25	0.90

Distribution. This subspecies is found in the lowermost Tulki Limestone and the uppermost Mandu Calcarenite from the western side of Cape Range, and in the upper levels of the unnamed calcarenite in Ashmore Reef No. 1 well. It also occurs in the Stark Bay Formation in Gage Roads No. 2 well in the Perth Basin; in the Bochara and Batesford Limestones from Victoria; and in unit M3 in Wreck Island No. 1 well. In all areas it is restricted to the LF.6 association. The figured specimens are from samples UWA70486 and UWA70488 from the lower part of the Tulki Limestone, and 80642008 and 71640345 from the Mandu Calcarenite; UWA70603 from the unnamed calcarenite in Ashmore Reef No. 1 well; UWA 10653 from the Batesford Limestone; and 77640413 from the Bochara Limestone.

Lepidocyclina (Nephrolepidina) howchini praehowchini subsp. nov.

Plate 10, figures 3a–4c; Plate 22, figures 1–13, 15–17; Plate 26, figures 7–14; Figure 21

1955a *Lepidocyclina (Nephrolepidina) borneensis*, Provale; Crespin, pp. 72 (list), 78 (list).

Diagnosis. A subspecies of the subgenus *Nephrolepidina*, with a nephrolepidine or trybliolepidine type of embryoconch, with ogival to spatulate equatorial chambers arranged in a circular or polygonal concentric pattern, and with mean values for parameter F between 2 and 3.

Holotype. UWA75163.

Paratypes. UWA75164 to UWA75230; CPC 15708 to CPC15718.

Number of specimens. 78

Type locality and level. Sample UWA68324 from the upper Mandu Calcarenite 3.4 m below the contact with the Tulki Limestone at the base of the type section of the Tulki Limestone, Badjirrajirra Creek, Cape Range. Some of the figured paratypes are from core 3, Ashmore Reef No. 1 well, from the unnamed calcarenite.

Description. External characters. Test of megalospheric generation discoidal, lenticular; of moderate size, ranging from 1.85 to 4.65 mm in diameter and from 0.86 to 1.41 mm in thickness; centrum fairly narrow, surrounded by wide, delicate peripheral flange, which is sharply delineated and commonly broken; centrum weakly pustulose; test outline circular to polygonal, rarely stellate. Microspheric generation larger than megalospheric, ranging from 5.44 to 6.01 mm in diameter and 0.92 to 1.33 mm in thickness; larger centrum and narrower peripheral flange, which is not sharply delineated.

Internal characters of megalospheric generation. Embryoconch nephrolepidine to trybliolepidine, rarely isolepidine; parameter A ranges from 33.80 to 62.60% ($\bar{A} = 48.52 \pm 6.09\%$); parameter dc ranges from 9.70 to 59.00% ($\overline{dc} = 36.14 \pm 12.21\%$); parameter E ranges from 11.80 to 61.70% ($\bar{E} = 44.01 \pm 12.95\%$); embryoconch surrounded by two to eight ($\bar{C} = 3.33 \pm 1.06$) accessory auxiliary chambers; the percentage of the embryoconch covered by auxiliary chambers ranges from 37.20 to 70.90% ($\bar{B} = 53.31 \pm 7.75\%$); the evolutionary factor A+B ranges from 74.20 to 128.00 ($\overline{A+B} = 101.83 \pm 11.26$); protoconch small, ranging from 115 to 307 μm ($\bar{D}_{I} = 180.31 \pm 39.82$ μm); deuteroconch moderately large, ranging from 187 to 475 μm ($\bar{D}_{II} = 313.73 \pm 73.84$ μm); partition between protoconch and deuteroconch thin and imperforate.

Equatorial chambers initially arcuate becoming ogival then spatulate; rarely hexagonal; hexagonal chambers when present restricted to outer parts of equatorial layer; equatorial chambers arranged in circular concentric or polygonal patterns, rarely 'engine-turned' or stellate; parameter F ranges from 1 to 4 ($\bar{F} = 2.54 \pm 0.68$).

Lateral chambers moderately large; seven to 10 layers over each side of embryoconch; mostly elongate subquadrangular, rarely lenticular; lateral chamber walls thin; pillars and pseudopillars may or may not be present; when present they may form a single, large central pillar or several small pillars scattered throughout the centrum; pillars may or may not project above surface as pustules.

Internal characters of microspheric generation. Equatorial layer similar to megalospheric in all characters, but larger; embryoconch is a small spire of one whorl surrounded by secondary spirals; the layers of lateral chambers are more numerous.

Remarks. The range of variation of the statistical parameters for the different populations referred to this subspecies is listed by Chaproniere (1980a, table 5); most parameters overlap with those for *L.* (*N.*) *howchini howchini*. The individual taxa of the bioseries incorporating this subspecies are differentiated on the basis of the mean values for parameter F; those with values of less than 2 are *L.* (*N.*) *sumatrensis*, between 2 and 3 are *L.* (*N.*) *howchini praehowchini*, and greater than 3 are *L.* (*N.*) *howchini howchini*.

L. (*N.*) *howchini praehowchini* is quite similar to *L.* (*N.*) *orakeiensis orakeiensis* from slightly older biostratigraphic levels in New Zealand. The differences reflect the differing rates of evolution between the New Zealand and Australian forms. Those from New Zealand are more retarded than the Australian forms, and the mean values for parameters A, B, and A+B differ for the same biostratigraphic intervals (see Chaproniere, 1980a, table 5).

The rarity of hexagonal chambers in *L.* (*N.*) *howchini praehowchini* distinguishes it from *L.* (*N.*) *japonica*. Many other species of this subgenus that have been described are similar to *L.* (*N.*) *howchini praehowchini*, but no comparisons can be made until they have been adequately described and statistical information is available.

Crespin (1955a) listed eight species of *L.* (*Nephrolepidina*) from the Mandu Calcarenite: *L. borneensis*, *L. parva*, *L. sumatrensis*, *L. verbeeki*, *L. gippslandica*, *L. martini*, *L. pilifera*, and *L. sondica*. Among the thin sections studied by Crespin (1955a) is one labelled *L.* (*N.*) *borneensis*, from sample CR106 from the type section of the Mandu Calcarenite. This specimen falls within the range of variation of *L.* (*N.*) *howchini praehowchini*, and since it comes from the type locality for that taxon it must be referred to that subspecies. It is obvious, on statistical evidence, that only one species is present. Crespin's identifications were made at a time before the large amount of morphologic variation within individual species was realised, and also before biometric studies on this group had been initiated. All of the species identified by Crespin (1955a; see p. 381) from the Mandu Calcarenite are believed to belong to *L.* (*N.*) *howchini praehowchini.*

Dimensions of figured types.	Maximum diameter (mm)	Maximum thickness (mm)
Holotype:		
UWA75163	4.12	1.09
Paratypes:		
UWA75164	1.86	0.90
UWA75165	4.22	1.17
UWA75166	0.55	0.21
UWA75167	4.00	0.98
UWA75168	3.00	1.12
UWA75169	3.50	0.86
UWA75170 (microspheric)	6.01	1.33
UWA75171	4.25	0.97
UWA75172 (microspheric)	5.44	0.92
UWA75173	2.30	—
UWA75174	2.86	—
UWA75175	3.41	—
UWA75176 (microspheric)	5.72	—
UWA75177	2.38	—
UWA75178	2.68	—
UWA75179	2.80	0.91
UWA75180	4.65	1.00
UWA75181	3.71	1.05
UWA75224	2.03	—
UWA75225	2.23	—
UWA75226	3.40	—
UWA75227	2.18	—
UWA75228	2.04	—
UWA75229	3.16	1.02
UWA75230	1.85	1.41

Distribution. *L.* (*N.*) *howchini praehowchini* has been recorded only from the upper parts of the Mandu Calcarenite. It is the only form of *L.* (*Nephrolepidina*) present on the eastern side of Cape Range. It underlies and grades into *L.* (*N.*) *howchini howchini* in Ningaloo No. 1 well. A similar relationship is seen in the unnamed calcarenite in Ashmore Reef No. 1 well. Rare specimens of this subspecies occur in the top part of the LF.5 association; it is otherwise restricted to the LF.6 association.

Lepidocyclina (Nephrolepidina) howchini
Chapman & Crespin, 1932, sensu lato

Remarks. Many specimens of *L.* (*Nephrolepidina*) are present in random thin sections of rocks from the Tulki and lower Trealla Limestones. Because these could not be studied statistically, they could not be identified to subspecific level. They are similar to *L.* (*N.*) *howchini* in all visible characteristics and so they have been referred to this taxon.

Crespin (1955a) identified 16 species of *L.* (*Nephrolepidina*) from the Tulki and Trealla Limestones; for similar reasons to those advanced above, these identifications are considered to be *L.* (*N.*) *howchini.*

Distribution. These forms are found throughout the Tulki and lower Trealla Limestones, where they are associated with typical LF.6 and LF.7 assemblages.

Lepidocyclina (Nephrolepidina) japonica
(Yabe, 1906)

Plate 20, figures 13–16; Plate 24, figures 16–18; Figure 23

1906 *Orbitoides (Lepidocyclina) japonicus* Yabe, p. 317, figs. 1-2.
1963 *Lepidocyclina* (*Nephrolepidina*) *japonica* (Yabe); Coleman, pp. 17-18, pl. 6, figs. 1-6 (with synonymy).
1971a *Nephrolepidina japonica* (Yabe); Matsumaru, pp. 166-168, pl. 9, figs. 1-12; pl. 10, figs. 1-14; pl. 11, figs. 1-8; pl. 14, figs. 1-6; pl. 17, figs. 7-19; pl. 20, fig. 5; pl. 23, figs. 1-3, 5-7; pl. 24, figs. 1-6 (with synonymy).
1971a *Nephrolepidina angulosa* (Provale); Matsumaru, pp. 168-169, pl. 12, figs. 1-10; pl. 13, figs. 1-11; pl. 14, figs. 7-21; pl. 20, fig. 3; pl. 21, fig. 5; pl. 23, fig. 4.

Remarks. Specimens of *L.* (*Nephrolepidina*) are found with *L.* (*Eulepidina*) *badjirraensis* and a planktic fauna typical of Zone N.6-7 in the lower parts of the unnamed calcarenite in Ashmore Reef No. 1 well. These forms differ form *L.* (*N.*) *howchini praehowchini*, which occurs at higher stratigraphic levels in this well, by having a larger proportion of hexagonal chambers in the equatorial layer, and higher values for parameters $\overline{A}$, $\overline{dc}$, and $\overline{E}$ (see Chaproniere, 1980a, table 5). The values for parameters $\overline{A}$, $\overline{A+B}$, $\overline{dc}$, and $\overline{E}$ are similar to those in *L.* (*N.*) *howchini howchini* associated with a planktic fauna typical of Zones N.8 or N.9, while the values for parameter $\overline{F}$ are similar to those for *L.* (*N.*) *howchini praehowchini* from horizons with a Zone N.6 assemblage. These data suggest that this form is distinct from *L.* (*N.*) *howchini*; because of

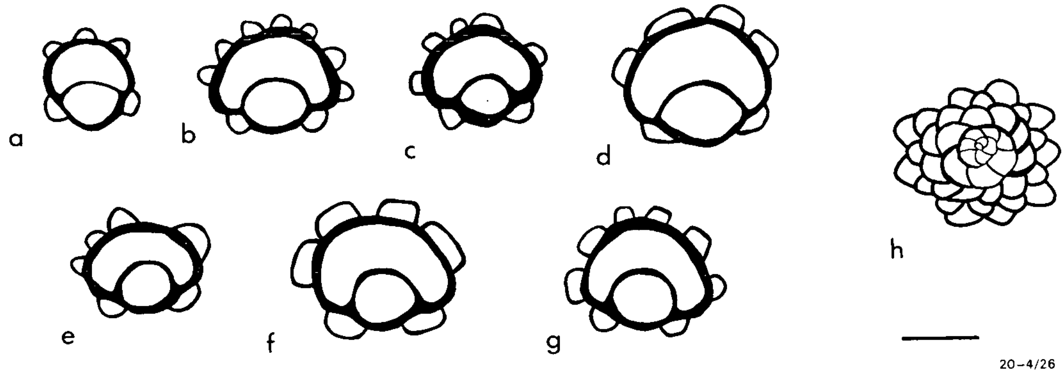

Fig. 23. Variations in embryoconchs of *Lepidocyclina (Nephrolepidina) japonica* from UWA70606, Ashmore Reef No. 1 well. The scale bar represents 200 μm for megalospheric and 100 μm for microspheric forms.

the presence of hexagonal equatorial chambers, it has been referred to *L.* (*N.*) *japonica.*

Matsumaru (1971a) has published biometric data for Japanese *L.* (*Nephrolepidina*). He recognised two species, *L.* (*N.*) *angulosa* and *L.* (*N.*) *japonica,* which differ only in their external forms and in the construction of lateral chambers. He recorded both forms from most of the Japanese populations. As noted earlier, such morphological features are probably environmentally controlled, and subdivision of populations solely on these grounds cannot be upheld; for these reasons the forms identified by Matsumaru (1971a) as *L.* (*N.*) *angulosa* are considered to be referable to *L.* (*N.*) *japonica.* The mean values for parameters A ($\bar{A}$ ranges from 47.02 to 56.55%) and A+B ($\overline{A+B}$ ranges from 93.53 to 117.76) are variable in the Japanese populations, especially as they all are recorded from Zone N.8 (Matsumaru, 1971a).

The data listed by Matsumaru (1971a) are the only biometric data published for this species. The populations from Ashmore Reef No. 1 well fall into the more advanced levels of the range for the Japanese populations though they are from a lower biostratigraphic level, equivalent to planktic Zone N.6. It is concluded, therefore, that either there are other lineages of this subgenus in the Indo-Pacific area containing similar forms, or parameters A and A+B are highly variable for this species. This problem cannot be resolved until detailed studies have been made on Indonesian populations. For the present those forms with hexagonal equatorial chambers arranged in polygonal concentric patterns are referred to *L.* (*N.*) *japonica.*

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75231	2.24	—
UWA75232	2.85	0.91
UWA75233	3.54	0.97
UWA75234	3.28	—
UWA75235	2.48	—
UWA75236	2.38	—
UWA75237	1.88	—

Distribution. This species has been recorded only from the lower parts of the unnamed calcarenite in Ashmore Reef No. 1 well, between 884 and 908 m. It is restricted to the LF.5 association. The figured specimens are from sample UWA70606.

Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis (Karrer, 1864)

Plate 9, figures 1,4a,b; Plate 10, figures 5a–c; Plate 21, figure 14; Plate 23, figures 8–15; Plate 24, figures 14, 15; Figures 24, 25

1864 *Orbitoides orakeiensis* Karrer, p. 86, pl. 16, fig. 21.

1971 *Lepidocyclina (Nephrolepidina) orakeiensis* (Karrer); Hornibrook, pp. 24, 25, pl. 12, figs. 1-5; pl. 13, fig. 1; text-fig. 6.

1971b *Nephrolepidina orakeiensis* (Karrer); Matsumaru, pp. 185-186, pl. 22, figs. 1-27.

Remarks. This species was first described from the Orakei Greensand Member of the East Coast Bays Formation at Orakei Bay, Auckland, New Zealand. The specimens incorporated in this study were collected from the same stratigraphic level as the types, but 1.25 km away; another population is from a similar biostratigraphic level at Hokianga Harbour (see Hornibrook, 1971): the planktic fauna of both populations correlate to Zone N.3/4, which is older than that for L. (*N.*) *howchini praehowchini* in the North West Cape area. Topotypes have been described by Hornibrook (1971), and similar forms from both Hokianga Harbour and from a locality near Gisborne have been described by Matsumaru (1971b). With the exception of biometric information, little more can be added to these descriptions; Matsumaru (1971b) gave values for parameter A for only three specimens.

Eight specimens, including three described by Hornibrook (1971), from sample 79640025 (the Orakei Greensand Member), and twenty-five specimens from sample UWA70613 (from the ?Waitiiti Formation), were studied biometrically and the results are given by Chapronière (1980a, table 5—UWA70613) and in Table 3 (79640025). Most of the parameters for the population from 79640025 compare closely with those of phylogenetically primitive forms of *L.* (*N.*) *howchini praehowchini*, but the mean values for parameters B and A+B vary widely, and some of these values are similar to those for *L.* (*N.*) *howchini howchini*; mean values for parameter C are always much higher than, and values for parameter F are similar to those from, equivalent levels in Australia. Most specimens have the equatorial chambers arranged in a circular concentric pattern as indicated by the mean value for parameter F; 'engine-turned' and polygonal concentric arrangements are subordinate. Parameter F seems to be the best criterion for taxonomic usage (Chapronière, 1980a). Because there is a continuous variation in values for this parameter in Australian assemblages, any subdivision within the *orakeiensis* bioseries is arbitrary. Thus, in this study those populations where the mean value for F is 2.50 or less are referred to the subspecies *orakeiensis*. In common with the Australian species, hexagonal equatorial chambers are rare.

Because of the wide variation in values for parameter B, these forms are regarded as specifically distinct from *L.* (*N.*) *howchini*, even though they probably had a common ancestry. For the same reasons as those advanced for the Australian lineage, the New Zealand forms are regarded as a single species in which different members of the bioseries are distinguished at the subspecific level.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
F50	3.53	1.29
F51	2.32	0.91
F52	2.22	1.03
F53	2.20	—
F54	2.75	—
F55	2.48	—
F57 (microspheric)	3.60	—
F58	2.40	0.98
F59	2.85	1.04
F60	2.36	0.87
F61 (microspheric)	5.15	1.70
F80	2.67	1.05
F81 (microspheric)	5.24	1.26
CPC21563	1.55	—

Distribution. *L.* (*N.*) *orakeiensis orakeiensis* is confined to New Zealand at biostratigraphic levels similar to those at Hokianga Harbour. The subspecies is associated with a typical LF.2 fauna (except for the presence of *Miogypsina*). The figured specimens are from samples UWA70613 and 79640025.

Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki Matsumaru, 1971b

Plate 11, figure 6; Plate 21, figures 7–13; Figure 24

1971b *Nephrolepidina hornibrooki* Matsumaru, pp. 186-187, pl. 23, figs. 12-37.

Remarks. Twenty-nine topotypes (kindly supplied by Dr N. de B. Hornibrook) of this taxon were thin-sectioned. The biometric data obtained are presented in Table 3; the results of t-tests comparing this taxon with others are illustrated in Figure 15. The range of variation of embryoconchs is shown for six specimens in Figure 24.

Matsumaru (1971b) based his taxon on changes in test allometry through ontogeny. Because this measure relies on the number of lateral chambers, a feature closely controlled by environmental factors, Chapronière (1980a) rejected it as being inappropriate as a taxonomic criterion. Instead Chapronière (1980a) introduced another criterion, believed to be little influenced by environmental factors; this was parameter F. As noted above, parameter F is used to arbitrarily subdivide the *orakeiensis* bioseries; those populations where the mean values for F are greater than 2.50 and less than 3 are here referred to the subspecies *hornibrooki*.

The *orakeiensis* bioseries can be distinguished from the *howchini* bioseries on the slower rate of evolution for most characters. At lower levels, mean values of F are similar in Australia and New Zealand, whereas both A and C are higher in the New Zealand

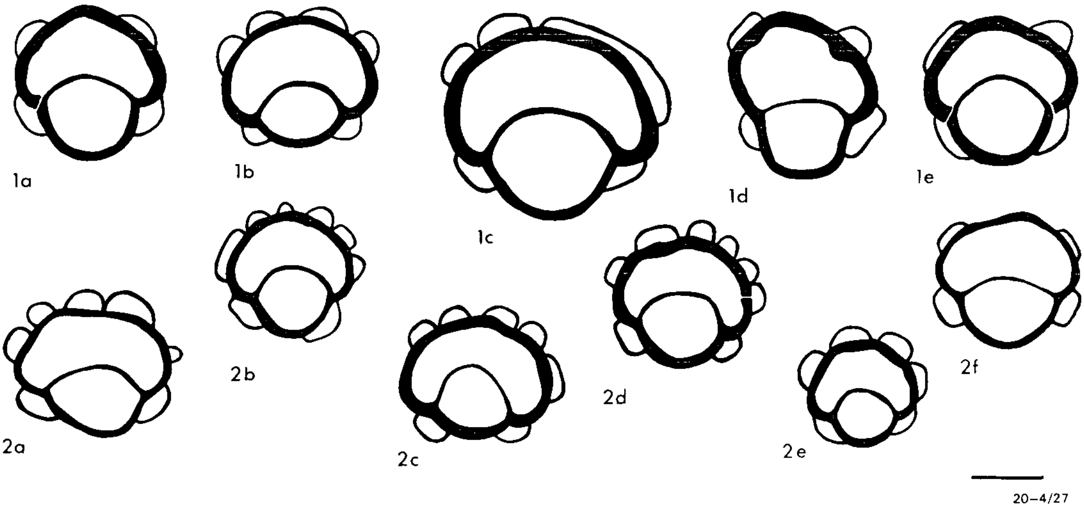

Fig. 24. Variations in embryoconchs of *Lepidocyclina (Nephrolepidina) orakeiensis*: **1,** *L. (N.) orakeiensis orakeiensis* **from 79640025, a — CPC21563, b — CPC21564, c— CPC21565, d — CPC21566, e — CPC21567; 2,** *L. (N.) orakeiensis hornibrooki* **(topotypes) from 79640027 (=S44/559). The scale bar represents 200 μm.**

sample. At higher levels, values of F, A, and C are higher in the Australian populations.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
NZGS FP3206	2.03	0.75
NZGS FP3207	2.85	—
NZGS FP3208	2.10	—
NZGS FP3209	1.89	—
NZGS FP3210	2.30	—
NZGS FP3211	1.83	—
NZGS FP3212	1.90	—
NZGS FP3213	2.51	0.47

Distribution. This subspecies has been recorded only from its type locality (Matsumaru, 1971b), within the Stillwater Mudstone. It occurs in a typical LF.6 association. The figured specimens come from sample 79640027 (= S44/559).

Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis subsp. nov.

Plate 9, figures 2,3; Plate 24, figures 1–13; Figures 22, 25

1953 *Trybliolepidina* aff. *rutteni* (van der Vlerk); Finlay (*in* Lillie, 1953), p. 142.

1971b *Nephrolepidina howchini* Chapman & Crespin; Matsumaru, pp. 187-188, pl. 23, figs. 1-11 (non-*howchini* Chapman & Crespin).

Diagnosis. A subspecies of the subgenus *Nephrolepidina* with a trybliolepidine type of embryoconch, with ogival to spatulate equatorial chambers arranged in polygonal concentric or stellate patterns, and with mean values for F of greater than 3.

Holotype. F15.

Paratypes. F16 to F49.

Number of specimens. 35.

Type locality and level. Sample N2/584 (UWA70612ii) from an outcrop of the Waikuku Limestone (see Leitch & others, 1969, fig. 1) immediately above high-tide level at the southern end of Waikuku Beach, northernmost New Zealand. One figured paratype (F25) comes from locality N2/528 (Leitch & others, 1969, fig. 1).

Description. External characters. Test of megalospheric generation discoidal, lenticular, stellate; of small size, ranging from 1.45 to 2.42 mm in diameter and from 0.56 to 0.81 mm in thickness; centrum broad in relation to test size, surrounded by delicate peripheral flange, which is poorly delineated; centrum may extend into peripheral flange as radiating 'arms', forming rays; centrum covered by numerous small, weak pustules; test outline polygonal or stellate. Microspheric generation small, but larger than the megalospheric; the single specimen measures 3.25 mm in diameter.

Internal characters of megalospheric generation. Embryoconch commonly trybliolepidine, rarely nephrolepidine; parameter A ranges from 43.80 to 70.50% ($\bar{A} = 54.91 \pm$

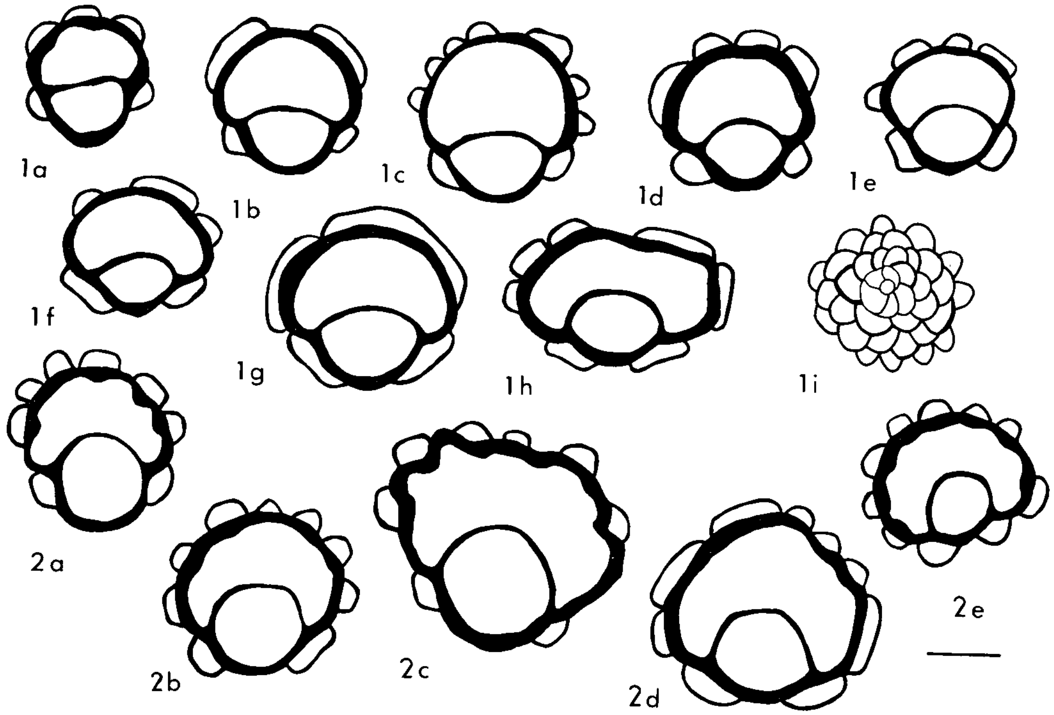

Fig. 25. Variations in embryoconchs of *Lepidocyclina (Nephrolepidina) orakeiensis*: **1,** *L. (N.) orakeiensis orakeiensis* **from UWA70613 (=N18/569); 2,** *L. (N.) orakeiensis waikukuensis* **(paratype) from UWA70612 (=N2/584). The scale bar represents 200 μm for megalospheric and 100 μm for microspheric forms.**

7.60%); parameter dc ranges from 28.40 to 72.50% ($\overline{dc}$ = 51.23 ± 13.09%); parameter E ranges from 36.00 to 87.30% ($\overline{E}$ = 58.96 ± 14.12%); embryoconch surrounded by four to eight ($\overline{C}$ = 6.33 ± 1.35) accessory auxiliary chambers; the percentage of the embryoconch covered by auxiliary chambers ranges from 46.50 to 84.40% ($\overline{B}$ = 63.91 ± 9.00%); the evolutionary factor A+B ranges from 101.50 to 144.50 ($\overline{A+B}$ = 118.83 ± 13.42); protoconch moderately large, ranging from 174 to 440 μm ($\overline{D}_I$ = 258.00 ± 64.45 μm); deuteroconch large, ranging from 245 to 647 μm ($\overline{D}_{II}$ = 439.53 ± 93.06 μm); partition between protoconch and deuteroconch thin and imperforate.

Equatorial chambers initially arcuate or ogival, rapidly becoming spatulate then elongate-spatulate, rarely hexagonal; chambers in rays are more elongate than those in the inter-ray areas; equatorial chambers arranged in polygonal concentric or stellate patterns, rarely circular concentric (only in juvenile parts), never 'engine-turned'; parameter F ranges from 3 to 5 ($\overline{F}$ = 3.67 ± 0.62).

Lateral chambers moderately large; only three or four layers over each side of the embryoconch; mostly elongate subquadrangular, some lenticular; lateral chamber walls thin; pillars and pseudopillars present; pillars may or may not project above surface as pustules.

Internal characters of microspheric generation. Equatorial layer similar to megalospheric generation; chambers arranged in polygonal concentric pattern in the single specimen observed; vertical section not known.

Remarks. The range of variation of the biometric parameters (except parameter B) for the type population is similar to another population (UWA70612i) from a nearby locality of the Waikuku Limestone. Based on the t-test, the difference between the means of parameter B for the two populations is significant. Furthermore, the mean value of parameter B for the type fauna is close to one obtained for a population of *L. (N.) orakeiensis orakeiensis*. This parameter, therefore, is of little use for the differentiation of the two subspecies of this bioseries (cf. *L.* (*N.*) *howchini*, p. 60.

Because this subspecies is from a high biostratigraphic level (based on planktic foraminiferids), it should be phylogenetically more advanced in all characters than the Australian *L.* (*N.*) *howchini howchini*. However, except for parameter C this is not the case; parameter F is also less than that for *L.* (*N.*) *howchini*. This evidence suggests that the rate of evolution of the embryoconch for the New Zealand forms was retarded with respect to *L.* (*N.*) *howchini*, indicating that the two groups were genetically isolated and can be regarded as two species groups. This is supported by the values of parameter C, which are consistently larger for *L.* (*N.*) *orakeiensis* than for *L.* (*N.*) *howchini*.

Leitch & others (1969) noted that the larger foraminiferal fauna from Waikuku Beach is matched by one from a slightly younger stratigraphic level at Pourerere in the East Coast Basin of the North Island of New Zealand. The fauna from Pourerere has been examined by Matsumaru (1971b) as well as being included in this study. Matsumaru (1971b) listed a similar planktic fauna to that collected from the Waikuku Limestone for this study. He referred the specimens of *Lepidocyclina* to *L.* (*N.*) *howchini* because of the similarity of the values for parameter A, but noted (p. 188) that they have a 'more steroidal outline in shell shape than the Australia (sic) specimens'. In another part of the text, Matsumaru (1971b, p. 181) referred to the forms from Pourerere as *Trybliolepidina* n. sp. aff. *rutteni*. There are no statistical differences between the populations from Pourerere and Waikuku Beach. However, the mean value of F is lower in the Pourerere population. This is anomalous because, as noted earlier (p. 22), the populations from Waikuku Beach are older than that from Pourerere.

Finlay (*in* Lillie, 1953) recorded *Trybliolepidina* aff. *rutteni* from Pourerere. *L.* (*N.*) *rutteni* is certainly similar to the specimens of *L.* (*N.*) *orakeiensis waikukuensis* from Pourerere in the arrangement of the equatorial chambers, but differs in containing a high proportion of hexagonal equatorial chambers. *L.* (*N.*) *rutteni* seems to be an advanced form of the *L.* (*N.*) *martini* bioseries, and so also is descended from a stellate form (i.e., values of F greater than 4). Thus, advanced populations of *waikukuensis* and *rutteni* may represent examples of atavism.

Some specimens of this subspecies from sample UWA70612i (from the Waikuku Limestone) and 79640006 (from the Tutamoe Formation) have embryoconchs intermediate between trybliolepidine and multilepidine types (see Fig. 22), similar to those from the phylogenetically most advanced *L.* (*N.*) *howchini howchini* from the North West Cape area.

L. (*N.*) *orakeiensis waikukuensis* is distinguished from *L.* (*N.*) *japonica* by the rarity of hexagonal chambers in its equatorial layer. It is best differentiated from other subspecies of *L.* (*N.*) *orakeiensis* on the mean values for parameter F: those populations with mean values greater than 3 are referred to *L.* (*N.*) *orakeiensis waikukuensis*; those with mean values between 2.5 and 3 to *L.* (*N.*) *orakeiensis hornibrooki*; and those with mean values less than 2.5 to *L.* (*N.*) *orakeiensis orakeiensis*.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
Holotype:		
F15	2.05	0.71
Paratypes:		
F16	2.04	0.81
F17	2.42	0.78
F18	2.15	—
F19	2.10	—
F20	1.67	—
F21	2.08	—
F22	1.85	—
F23	1.62	—
F24	1.70	0.56
F25 (microspheric)	3.25	—
F46	1.45	—
F47	1.66	—
F48	1.87	—
F49	1.45	—

Distribution. This subspecies is found in the Tutamoe Formation and the Waikuku Limestone, New Zealand, where it is associated with an LF.6 association.

Lepidocyclina (Nephrolepidina) sumatrensis (Brady, 1875)

Plate 10, figures 1a–c, 2; Plate 22, figure 14; Plate 23, figures 1–7; Plate 26, figures 15,16; Figure 21

1875 *Orbitoides sumatrensis* Brady, p. 536, pl. 14, figs. 3a,b.

1957b *Lepidocyclina (Nephrolepidina) sumatrensis* (Brady); Cole, pp. 773-775, pl. 239, figs. 1-4; pl. 241, figs. 1-30; pl. 242, figs. 3-20 (with synonymy).

1963 *Lepidocyclina (Nephrolepidina) sumatrensis* (Brady); Coleman, pp. 20-22, pl. 7, figs. 3-10.

Remarks. The range of values for the biometric parameters for this species are listed by Chaproniere (1980a, table 5). Very little statistical information on the phylogenetically primitive forms of *L.* (*Nephrolepidina*)—such as *L.* (*N.*) *isolepidinoides*, *L.* (*N.*) *parva*, and *L.* (*N.*) *sumatrensis*—has been published, which makes it difficult to compare similar forms from the North West Cape area with those from elsewhere in the Indo-Pacific region. Van der Vlerk (1966) has presented values of parameter A for certain species from eastern Borneo: for *L.* (*N.*) *isolepidinoides*, $\bar{A} = 37.4\%$; *L.* (*N.*) *parva*, $\bar{A} = 40.5$ to 44.4%; *L.* (*N.*) *borneensis*, $\bar{A} = 50.2\%$; *L.* (*N.*) *martini*, $\bar{A} = 53.3\%$; and for *L.* (*N.*) *talahabensis*, $\bar{A} = 59.8\%$. He recorded *L.* (*N.*) *isolepidinoides* associated with *L.* (*Eulepidina*) sp. and *Heterostegina borneensis*, a fauna he considered to be typical of the Tertiary lower *e* stage, but noted that a correlation to the Tertiary *d* stage could not be ruled out, because a large number of *Nummulites fichteli-intermedia* were found 'immediately nearby'. He recorded *L.* (*N.*) *parva* from the Tertiary upper *e* stage, where it occurs with *Spiroclypeus*, *Miogypsina* (*Miogypsina*), and *M.* (*Miogypsinoides*) in one sample and with *L.* (*Eulepidina*) in another. More recently, Hashimoto & Matsumaru (1973) have recorded *L.* (*N.*) *parva* (with $\bar{A} = 42.02\%$) associated with *Spiroclypeus* and *Miogypsina*. The forms from the North West Cape area have values for $\bar{A}$ intermediate between those listed by van der Vlerk (1966) for *L.* (*N.*) *isolepidinoides* and *L.* (*N.*) *parva*, but are associated with a similar fauna to that recorded with *L.* (*N.*) *isolepidinoides*; this suggests that the North West Cape forms may be of the same age as those from Borneo, and also that *isolepidinoides* and *sumatrensis* may be related. However, more biometric evidence is required before definite conclusions can be made.

Cole (1957b) considered *L.* (*N.*) *parva* to be a junior synonym for *L.* (*N.*) *sumatrensis*, basing this conclusion on basic morphologic criteria not supported by biometric data. The status of these species can be decided only by biometric studies on type material, as the initial descriptions are based on morphologic criteria. For the present, I have referred the specimens from the North West Cape area to *L.* (*N.*) *sumatrensis* because this is the senior name. Future work may show that *L.* (*N.*) *isolepidinoides*, *L.* (*N.*) *parva*, and *L.* (*N.*) *sumatrensis* may be separable on biometric grounds and that the intergradations noted by Cole (1957b)—which might be expected in an evolving bioseries—may prove to be of less taxonomic importance than he suggested.

L. (*N.*) *sumatrensis* is here distinguished from *L.* (*N.*) *howchini* on the basis of the mean values of parameter F; these are less than 2 for *sumatrensis*. This indicates that the populations are dominated by individuals with equatorial chambers arranged in 'engine-turned' and circular concentric patterns. Thus, on biometric and stratigraphic evidence this species is phylogenetically more primitive than *L.* (*N.*) *howchini* and is considered to be the ancestor for the Australian forms.

The mean values for parameters A and dc are similar to those obtained by van der Vlerk & Postuma (1967) and van der Vlerk (1968) for populations from the *Globorotalia kugleri* Zone, which is the same biostratigraphic level as the Bullara Limestone from the Rough Range area.

Dimensions of figured specimens.	Maximum diameter (mm)	Maximum thickness (mm)
UWA75238	2.00	0.86
UWA75239	2.18	0.94
UWA75240	3.42	1.23
UWA75241	2.71	1.17
UWA75242	2.30	—
UWA75243	3.44	—
UWA75244	2.18	—
UWA75245	2.44	—
UWA75246	2.66	—
UWA75247	2.67	1.32
UWA75248	2.01	0.85
UWA75249	2.23	1.04

Distribution. This species is found in the upper part of the Bullara Limestone and in the LF.2 association in the North West Cape area; rare reworked specimens occur in the basal Trealla Limestone in Rough Range. The figured specimens are from sample UWA53674.

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APPENDIX 1. METHODOLOGY

Sample preparation

About 300 g of rock sample was crushed, air-dried in an oven, and heated to about 100°C. The sample was then immersed in 20-volume hydrogen peroxide and left for a minimum of 3 hours. This procedure was repeated until sufficient material had been disaggregated. Subsequently, each sample was sieved through a 5-mesh sieve; any foraminiferids retained on the sieve were picked out. The −5-mesh fraction was cleaned ultrasonically, and then sieved through a 200-mesh sieve; the resulting −5 to +200-mesh fraction was air-dried and stored.

One half of the washed residue was stored; the other half was split into smaller fractions. A sample of convenient size was then sieved and the −10 to +120-mesh (−2 to +0.125-mm) fractions were picked; a representative fauna was picked out for samples which were to be studied qualitatively; for those studied statistically, the first 250 specimens were removed. The entire picked fauna was mounted on normal faunal slides and stored. If specimens required further cleaning, they were treated ultrasonically; at this stage, care was necessary if the specimens were not to be damaged.

Methods and techniques

Several faunas of larger foraminiferids were studied biometrically. The samples were prepared as outlined above, and splits of washings lying on the 120 mesh (0.125-mm) sieve were picked for larger foraminiferids. Wherever possible the first 50 specimens were removed; these were then thin-sectioned using the procedure outlined below.

Thin-sectioning

Thin sections of well-cemented limestones were prepared by standard procedures. Some of the poorly cemented rocks were impregnated with epoxy plastic using both vacuum and pressure techniques. The impregnated specimens were glued to glass slides with 'Araldite D' and then thin-sectioned in the normal way.

Orientated thin sections of larger Foraminiferida

Orientated thin sections of larger foraminiferids were prepared using the method outlined by van Morkhoven (1958).

SEM techniques

Specimens chosen for study by scanning electron microscopy (SEM) were mounted either singly or in groups on aluminium stubs. Each stub was first coated with a thick film of 'Silver Dag No. 915' (manufactured by Acheson Colloides Company, Prince Rock, England); this adheres strongly to the metal stub and provides a spongy base onto which gum-tragacanth can cement. The microfossil was glued directly onto the 'silver dag' by means of water soluble gum-tragacanth. This method permits easy manipulation of the fossil, so making orientation easier; this is an advantage over other methods, such as double-sided adhesive tape. Once mounted the specimens were coated with a gold or gold-palladium film.

Biometric methodology

All raw data were transferred to punched cards for computer use. The Cyber 76 of the CSIRO Division of Computing Research was used for calculating all statistics. The following programs are all stored in the BMR computer program library (see Mayo & Long, 1976):

BMD04M —	discriminant analysis for two groups
CABFAC —	Q-mode factor analysis
VARPLOT —	calculates basic statistics: mean, standard deviation, Pearson's coefficient of variability, regression equations, t-test values, X-Y plots of selected pairs of variables.

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APPENDIX 2. SAMPLE LOCALITIES

Details of sample localities are annotated below. More accurate locations of the samples from the North West Cape are illustrated graphically in Appendix 4. Even though samples stored in the collections of the Geology Department, University of Western Australia (prefix UWA) or the Bureau of Mineral Resources, Geology and Geophysics, Canberra (prefix CR, CRC, 7164, 7764, 7964, 8064, or CPC) may be from the same section, for convenience they are listed separately.

University of Western Australia samples

UWA10653 Upper quarry (Australian Portland Cement Co.), Batesford, Victoria; from quarry face; coll. F. A. Singleton. Friable hard yellow bioclastic limestone: Batesford Limestone.

UWA51524 Surface outcrop in vicinity of Rough Range No. 1 well. Hard cream bioclastic limestone: Trealla Limestone.

UWA51883 to 51891 Shothole Canyon, Cape Range; from canyon wall at about 4.5 m intervals (Appendix 4, Fig. A3); coll. C. Williams.

UWA51883-51889: friable white or light grey to hard yellow, bioclastic calcarenite: Mandu Calcarenite.

UWA51890-51891: hard yellow bioclastic limestone: Tulki Limestone.

UWA51892 to 51900 Canyon near base of Mount Lefroy, Cape Range; from canyon wall (Appendix 4, Fig. A4B); coll. C. Williams.

UWA51892-51894: hard pink to pink-red bioclastic limestone: Tulki Limestone.

UWA51895-51899: hard creamy fine-grained limestone: recrystallised Tulki Limestone.

UWA51900: hard creamy fine-grained bioclastic limestone: Trealla Limestone.

UWA51901 to 51909 Type section of Trealla Limestone, Mount Lefroy, Cape Range (see Condon & others, 1955; Appendix 4, Fig. A4A); coll. C. Williams.

UWA51901-51903: hard creamy fine-grained limestone: recrystallised Tulki Limestone.

UWA51904-51909: hard white or cream fine-grained limestone: Trealla Limestone.

UWA53673 to 53679 Rough Range South No. 1 well (lat. 22°37′20″S, long. 113°57′40″E), Rough Range; cores 3, 4, 8-12 (Appendix 4, Fig. A6); coll. WAPET.

UWA53673: hard white or cream bioclastic limestone: Trealla Limestone.

UWA53674-53678: Friable to hard, brown to dark grey, coarse to fine-grained bioclastic limestone: Bullara Limestone.

UWA53679: friable brown coarse-grained dolomitic bioclastic limestone: lateral equivalent of Giralia Calcarenite.

UWA68306 to 68322 Type section of Mandu Calcarenite, Badjirrajirra Creek, Cape Range, (see Condon & others, 1955; Appendix 4, Fig. A5B); coll. G. C. Chaproniere & P. G. Quilty.

UWA68306-68312: friable light grey bioclastic calcarenite with rare larger foraminiferids: Mandu Calcarenite.

UWA68313-68320: friable light grey bioclastic calcarenite, commonly with abundant larger foraminiferids: Mandu Calcarenite.

UWA68321: hard grey-yellow bioclastic limestone: Tulki Limestone.

UWA68322: hard yellow bioclastic limestone: Tulki Limestone.

UWA68323 to 68340 Type section of Tulki Limestone, Badjirrajirra Creek, Cape Range (see Condon & others, 1955; Appendix 4, Fig. A5A); coll. G. C. Chaproniere & P. G. Quilty.

UWA68323-68324: friable to hard yellow-grey bioclastic calcarenite: Mandu Calcarenite.

UWA68325-68333: hard red-pink to pink-yellow bioclastic limestone: Tulki Limestone.

UWA68334-68337: hard yellow-cream fine-grained limestone: recrystallised Tulki Limestone.

UWA68338-68340: hard yellow to cream bioclastic limestone: Trealla Limestone.

UWA68341 to 68347 Type section of Trealla Limestone, Mount Lefroy, Cape Range (see Condon & others, 1955; Appendix 4, Fig. A4A); coll. G. C. Chaproniere & P. G. Quilty.

UWA68341: pisolitic calcrete: Recent.

UWA68342-68347: hard white to cream bioclastic limestone: Trealla Limestone.

UWA68348 to 68355 Type section of Pilgramunna Formation, Yardie Creek, Cape Range (see Condon & others, 1955); UWA68348 at base; coll. G. C. Chaproniere & P. G. Quilty.

UWA68348-68349: hard pink-white limestone: recrystallised Tulki Limestone.

UWA68350-68355: cream to yellow-grey coarse or fine-grained calcareous sandstone: Pilgramunna Formation.

UWA70433 Gage Roads No. 2 well (lat. 31°57′05″S, long. 115°21′45″E) offshore from Perth; coll. WAPET; ditch-cuttings 427 m; see also UWA72223. Lithology not known: Stark Bay Formation.

UWA70469 In creek bed 5.6 km above mouth of Badjirrajirra Creek, midway between type sections of Tulki Limestone and Mandu Calcarenite, Cape Range; coll. G. C. Chaproniere & P. G. Quilty. Friable grey-brown bioclastic calcarenite: Mandu Calcarenite.

UWA70470 Badjirrajirra Creek bed 180 m upstream from base of type section of Tulki Limestone; coll. G. C. Chaproniere & P. G. Quilty. Friable light grey bioclastic calcarenite: Mandu Calcarenite.

UWA70471 to 70476 Cliff section above small tributary on west side of Badjirrajirra Creek opposite type section of Tulki Limestone; coll. G. C. Chaproniere & P. G. Quilty.

UWA70471-70472: 3 m above base Tulki Limestone; hard pink-red bioclastic limestone: Tulki Limestone.

UWA70473-70474: at contact of Tulki Limestone and Mandu Calcarenite; hard yellow-grey bioclastic calcarenite: Mandu Calcarenite.
UWA70475-70476: 5 m below base Tulki Limestone; friable grey-brown bioclastic calcarenite: Mandu Calcarenite.

UWA70477 to 70482 Cliff section immediately behind Cape Range No. 1 well site (22°03′57″S, 114°00′38″E), Shothole Canyon, Cape Range (Appendix 4, Fig. A9A); coll. G. C. Chaproniere & P. G. Quilty. Friable to hard, grey-brown to yellow-brown bioclastic calcarenite: Mandu Calcarenite.

UWA70483 to 70500 Ningaloo No. 1 well (lat. 22°34′25″S, long. 113°46′40″E), Cape Range; 6 sidewall cores and 12 ditch-cutting samples (Appendix 4, Fig. A7); coll. WAPET.
UWA70483-70484: friable grey-brown medium sandstone; Vlaming Sandstone.
UWA70485-70490: hard cream to red-brown bioclastic limestone: Tulki Limestone.
UWA70491-70495: friable grey-white to grey-brown bioclastic calcarenite: Mandu Calcarenite.
UWA70496-70500: friable dark grey to green-grey calcarenite: Giralia Calcarenite lateral equivalent.

UWA70501 to 70531 Sandy Point No. 2 well (lat. 22°22′18″S, long. 113°50′42″E), Cape Range; 20 sidewall cores and 11 ditch-cutting samples (Appendix 4, Fig. A8); coll. WAPET.
UWA70501-70502: hard pink-red to cream bioclastic limestone: Tulki Limestone.
UWA70503-70530: friable grey-white to grey-brown bioclastic calcarenite: Mandu Calcarenite.
UWA70531: friable green-brown calcarenite: Giralia Calcarenite lateral equivalent.

UWA70532 to 70554 Cape Range No. 1 well (lat. 22°03′57″S, long. 114°00′38″E), Cape Range; 2 cores and 21 ditch-cutting samples (Appendix 4, Fig. A9B); coll. WAPET. Friable light grey to brown-grey, in places bioclastic, calcarenite: Mandu Calcarenite.

UWA70555 to 70563 Muiron No. 1 well (lat. 21°39′04″S, long. 114°21′18″E), Muiron Islands; 9 ditch-cutting samples (Appendix 4, Fig. A10); friable grey-brown to grey calcarenite: Mandu Calcarenite.

UWA70564 to 70569 Learmonth No. 1 well (lat. 22°10′58″S; long. 114°03′30″E), Cape Range, 6 ditch-cutting samples (Appendix 4, Fig. A11); coll. WAPET.
UWA70564-70567: friable grey-brown bioclastic calcarenite: Mandu Calcarenite.
UWA70568-70569: friable brown bioclastic calcarenite: Giralia Calcarenite lateral equivalent.

UWA70570 to 70576 Learmonth No. 2 well (lat. 22°17′35″S, long. 114°03′48″E), Rough Range; 7 ditch-cutting samples (Appendix 4, Fig. A12); coll. WAPET.
UWA70570-70574: friable to hard brown-grey coarse to fine-grained bioclastic calcarenite: Bullara Limestone.
UWA70575-70576: friable brown-grey calcarenite: Giralia Calcarenite lateral equivalent.

UWA70577 to 70580 Exmouth No. 1 well (lat. 22°37′20″S, long. 114°06′40″E), Rough Range; 4 ditch-cutting samples (Appendix 4, Fig. A13); coll. WAPET.
UWA70577-70579: friable to hard brown-grey coarse to fine-grained bioclastic calcarenite: Bullara Limestone.
UWA70580: friable medium-grained brown calcarenite: Giralia Calcarenite lateral equivalent.

UWA70581 to 70598 Exmouth No. 2 well (lat. 22°21′22″S, long. 114°08′18″E), Rough Range; 18 ditch-cutting samples (Appendix 4, Fig. A14); coll. WAPET.
UWA70581-70585: friable red-brown medium-grained sandstone: Exmouth Sandstone.
UWA70586-70590: hard cream to cream-brown bioclastic limestone: Trealla Limestone.
UWA70591-70596: friable to hard brown-grey bioclastic limestone: Bullara Limestone.
UWA70597-70598: friable brown calcarenite: Giralia Calcarenite lateral equivalent.

UWA70599 to 70600 Rough Range South No. 1 well (lat. 22°37′20″S, long. 113°57′40″E), Rough Range; 2 core samples (Appendix 4, Fig. A6); coll. WAPET.
UWA70599: friable red medium-grained sandstone: Exmouth Sandstone (core 2).
UWA70600: hard brown-grey bioclastic limestone: Bullara Limestone (core 7).

UWA70601 to 70610 Ashmore Reef No. 1 well (lat. 12°10′50″S, long. 123°05′11″E), Ashmore Reef, northwest Western Australia: 4 core, 3 sidewall core, and 3 ditch-cutting samples (Appendix 4, Fig. A15); coll. BOCAL.
UWA70601: friable yellow bioclastic limestone: unnamed limestone (107 m).
UWA70602-70607: friable light grey to cream bioclastic calcarenite: unnamed calcarenite.
UWA70608-70610: friable grey to grey-brown, in places bioclastic, calcareous mudstone: Cartier beds.

UWA70611 = sample N2/528. North end of Waikuku Beach (grid ref. N2/495519), Northland, New Zealand (see Leitch & others, 1969, fig. 1); type locality for Waikuku Limestone; coll. E. C. Leitch & J. A. Grant-Mackie. Friable yellow-white bioclastic limestone: Waikuku Limestone.

UWA70612 = sample N2/619. South end of Waikuku Beach (grid ref. N2/490504), Northland, New Zealand (see Leitch & others, 1969, fig. 1); coll. E. C. Leitch. Friable yellow bioclastic limestone: Waikuku Limestone.

UWA70613 = sample N18/569. South Head (grid ref. N18/895183), Hokianga Harbour, Northland, New Zealand; coll. G. W. Gibson. Friable brown-grey bioclastic mudstone: Orbitolite bed, ?Waitiiti Formation, Otaua Group.

UWA70614 = sample N28/631. North end of bay (grid ref. U28/695361), south of Pupuia Island, Kaipara Harbour, Northland, New Zealand; coll. G. W. Gibson. Friable grey bioclastic mudstone: Orbitoid bed, Puketi Formation, Waitakere Group.

UWA72223 Gage Roads No. 2 well (lat. 31°57′05″S, long. 115°21′45″E), offshore from Perth; coll. WAPET; ditch-cutting sample 454 m; see also UWA 70433. Lithology not known: Stark Bay Formation.

UWA72224 Wreck Island No. 1 well (lat. 23°20′00″S, long. 151°57′30″E), Wreck Island, Great Barrier Reef, Queensland; coll. Humber Barrier Reef Oils Pty Ltd (see Derrington, 1960). Lithology not known: unit M3 (core 8).

UWA72225 = sample MX 51 (see Condon & others, 1955, map). Badjirrajirra Creek, Cape Range; coll. Caltex Oil Ltd. Friable grey-brown bioclastic calcarenite: Mandu Calcarenite.

UWA72226 Ashmore Reef No. 1 well (lat. 12°10′50″S, long. 123°05′11″E), Ashmore Reef, northwest Western Australia; core 1 (Appendix 4, Fig. A15); coll. BOCAL. Hard light grey bioclastic limestone: unnamed calcarenite.

Bureau of Mineral Resources samples

Localities for numbers prefixed by CR and CRC are annotated on maps and plate 18 accompanying Condon & others (1955).

CR6, 7, 9, CRC3 to 8 Type section of Tulki Limestone, Badjirrajirra Creek, Cape Range (Appendix 4, Fig. A5A); coll. M. A. Condon & others.
CR6, 7, CRC3-8: hard to moderately hard, pink to cream crystalline limestone: Tulki Limestone.
CR9: Hard cream fine-grained limestone: Trealla Limestone.

CR12 6 km N48°W of trig 158 m, Cape Range. Hard cream crystalline limestone: Trealla Limestone.

CR13 5.2 km N43°W of trig 159 m, Cape Range; coll. M. A. Condon & others. Hard cream crystalline limestone: Trealla Limestone.

CR24, 28 4.4 km N49°W of No. 1 well, Exmouth Gulf station, Cape Range; coll. M. A. Condon & others.
CR24: hard cream bioclastic limestone: Tulki Limestone.
CR28: hard cream, fine-grained limestone: Trealla Limestone.

CR46 5.2 km S19°E from Yardie Creek homestead, Cape Range; coll. M. A. Condon & others. Hard cream-yellow bioclastic crystalline limestone: Tulki Limestone.

CR51, CR52 7.2 km N83°E upstream from mouth of Mandu Mandu Creek, Cape Range (Appendix 4, Fig. A2); coll. M. A. Condon & others. Hard, cream-yellow bioclastic limestone: Tulki Limestone.

CR53 7.2 km N83°E upstream from mouth of Mandu Mandu Creek, Cape Range (Appendix 4, Fig. A2); coll. M. A. Condon & others. Hard cream crystalline limestone: recrystallised Tulki Limestone.

CR54 6.8 km N83°E upstream from mouth of Mandu Mandu Creek, Cape Range (Appendix 4, Fig. A2); coll. M. A. Condon & others. Hard cream fine-grained crystalline limestone: recrystallised Tulki Limestone.

CR55 3 km N69°E from Milyering Well, Yardie Creek Station, Cape Range; coll. M. A. Condon & others. Hard cream bioclastic crystalline limestone: Trealla Limestone.

CR83 Type section of Trealla Limestone, Mount Lefroy, Cape Range (Appendix 4, Fig. A4A); coll. M. A. Condon & others. Hard cream bioclastic limestone: Trealla Limestone.

CR103 3 km S10°E from trig. 122 m, Cape Range; coll. M. A. Condon & others. Hard cream bioclastic crystalline limestone: Trealla Limestone.

CR113, 114, 117, 118 Type section of Mandu Calcarenite, Badjirrajirra Creek, Cape Range (Appendix 4, Fig. A5B); coll. M. A. Condon & others. Hard pink-red to cream bioclastic crystalline limestone: Tulki Limestone.

CR106-112, CR123, CRC9, 11 Type section of Mandu Calcarenite, Badjirrajirra Creek, Cape Range (Appendix 4, Fig. A5B); coll. M. A. Condon & others. Friable light grey bioclastic calcarenite: Mandu Calcarenite.

71640342 to 71640359 Surface samples from head of Mandu Mandu Creek, Cape Range (Appendix 4, Fig. A2); coll. D. J. Belford.
71640342-71640344: friable to hard yellow-grey bioclastic calcarenite: Mandu Calcarenite.
71640345: friable grey-brown bioclastic calcarenite: Mandu Calcarenite.
71640346-71640356: hard yellow to cream bioclastic crystalline limestone: Tulki Limestone.
71640357-71640359: hard cream fine-grained crystalline limestone: recrystallised Tulki Limestone.

77640413 Hamilton Bore, Yulecart, near Hamilton, Victoria: ditch-cuttings 80-85 feet (24.4-25.9 m). Bochara Limestone.

79640006 Poanui Beach, near Pourerere, New Zealand, Friable green-grey bioclastic fine sandstone: Tutamoe Formation.

79640025 Takaparawha Point, Waitemata Harbour, Auckland, New Zealand. Friable dark green-grey bioclastic muddy sandstone: Orakei Greensand Member, East Coast Bays Formation.

79640027 = NZ Geological Survey locality S44/559. Alexander Street cutting, Greymouth, New Zealand. Stillwater Mudstone.

80640565 to 80640588 Cape Range No. 1 well, Cape Range (lat. 22°03′57″S, long. 114°00′38″E), 23 ditch-cutting samples (Appendix 4, Fig. A9B); coll. WAPET. Friable light grey to brown-grey, in places bioclastic, calcarenite: Mandu Calcarenite.

80640520 to 80640530 Rough Range South No. 1 well (lat. 22°37′20″S, long. 113°57′40″E), Rough Range; cores 3 to 15 and 2 sidewall cores (Appendix 4, Fig. A6); coll. WAPET.

80650520 to 80640521: friable to hard cream to yellow limestone: Trealla Limestone.

80640522 to 80640528: friable to hard, brown to dark grey, coarse to fine-grained bioclastic limestone: Bullara Limestone.

80640529 to 80640530: friable brown coarse-grained, dolomitic limestone: lateral equivalent of Giralia Calcarenite.

80640986, 80640987 Rough Range No. 1 well (lat 22°25′07″S, long. 114°04′54″E), Rough Range; ditch-cuttings, 5 m and 21 m; coll. WAPET. Hard cream bioclastic crystalline limestone: Trealla Limestone.

80641354 to 80641360 Surface outcrop in vicinity of Rough Range No. 1 well; coll. WAPET. See Crespin (1955).

80642000 to 80642017 Muiron No. 1 well (lat. 21°39′04″S, long. 114°21′18″E), Muiron Islands; 18 sidewall core samples (Appendix 4, Fig. A10); coll. WAPET.

80642000: friable yellow sandstone: unnamed Quaternary sands.

80642001-80642002: hard yellow to cream bioclastic limestone: Trealla Limestone.

80642003-80642005: hard cream fine-grained limestone: recrystallised Tulki Limestone.

80642006-80642017: friable grey-brown to white bioclastic calcarenite: Mandu Calcarenite.

80646999 Ashmore Reef No. 1 well (lat. 12°10′50″S, long. 123°05′11″E), Ashmore Reef, northwest Western Australia; core 1 (Appendix 4, Fig. A15); coll. BOCAL. Hard light grey bioclastic limestone: unnamed calcarenite.

80647032 Ashmore Reef No. 1 well (lat. 12°10′50″S, long. 123°05′11″E), Ashmore Reef, northwest Western Australia; core 3 (798.5-806.1 m; Appendix 4, Fig. A15); coll. BOCAL. Unnamed calcarenite.

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APPENDIX 3. CATALOGUED SPECIMENS RECOVERED FROM SAMPLES

The numbers assigned to catalogued specimens recovered from samples are listed below. Specimens stored in the collections of the Geology Department of the University of Western Australia are prefixed UWA: those stored in the Commonwealth Palaeontological Collection of the Bureau of Mineral Resources are prefixed CPC; those stored in the collections of the Geology Department, University of Auckland, are prefixed F; and those stored in the collections of the New Zealand Geological Survey, Lower Hutt, are prefixed FP. A double asterisk (**) indicates that the specimen is a holotype; a single asterisk (*), a figured paratype; a single cross ($^{+}$), an unfigured paratype; a double cross ($^{++}$), an unfigured specimen; ^{x}, a figured topotype; and ^{xx}, an unfigured topotype.

University of Western Australia specimens

Specimen number	*Sample number*	*Taxon*
UWA75006	UWA51524	*Austrotrillina howchini*
UWA75007	UWA51524	*Austrotrillina howchini*
UWA75008	UWA53674	*Austrotrillina striata*
UWA75009	UWA53676	*Lacazinella* cf. *wichmanni*
UWA75010	UWA53676	*Lacazinella* cf. *wichmanni*
UWA75011	UWA53676	*Lacazinella* cf. *wichmanni*
UWA75012	UWA68347	*Peneroplis* sp.
UWA75013	UWA51524	*Sorites* sp.
UWA75014	UWA51524	*Peneroplis* sp.
UWA75015	UWA51900	*Sorites* sp.
UWA75016	UWA53674	*Sorites* sp.
UWA75017	UWA51908	*Marginopora vertebralis*
UWA75018	UWA51909	*Marginopora vertebralis*
UWA75019	UWA51909	*Marginopora vertebralis*
UWA75020	UWA51909	*Marginopora vertebralis*
UWA75021	UWA51909	*Marginopora vertebralis*
UWA75022	UWA70600	*Borelis pygmaeus*
UWA75023	UWA51908	*Flosculinella bontangensis bontangensis*
UWA75024	UWA68346	*Flosculinella bontangensis bontangensis*
UWA75025	UWA70586	*Flosculinella bontangensis bontangensis*
UWA75026	UWA70587	*Flosculinella bontangensis globulosa*
UWA75027	UWA70587	*Flosculinella bontangensis globulosa*
UWA75028	UWA68316	*Operculina complanata*
UWA75029	UWA10653	*Operculina complanata*
UWA75030	UWA68324	*Operculina complanata*
UWA75031	UWA70470	*Operculina complanata*
UWA75032	UWA70470	*Operculina complanata*
UWA75033	UWA70470	*Operculina complanata*
UWA75034	UWA70470	*Operculina complanata*
UWA75035	UWA53674	*Operculina complanata*
UWA75036	UWA53674	*Operculina complanata*
UWA75037	UWA70504	*Operculina complanata*
UWA75038	UWA70493	*Operculinella venosa*
UWA75039	UWA70490	*Operculinella venosa*
UWA75040	UWA70490	*Operculinella venosa*
UWA75041	UWA70509	*Cycloclypeus (Cycloclypeus) carpenteri*
UWA75042	UWA70509	*Cycloclypeus (Cycloclypeus) carpenteri*
UWA75043	UWA70509	*Cycloclypeus (Cycloclypeus) carpenteri*
UWA75044	UWA68312	*Cycloclypeus (Cycloclypeus) eidae*
UWA75045	UWA68316	*Cycloclypeus (Cycloclypeus) eidae*$^{++}$
UWA75046	UWA68324	*Cycloclypeus (Cycloclypeus) eidae*
UWA75047	UWA68324	*Cycloclypeus (Cycloclypeus) eidae*
UWA75048	UWA70606	*Cycloclypeus (Cycloclypeus) eidae*
UWA75049	UWA68318	*Cycloclypeus (Cycloclypeus) eidae*
UWA75050	UWA70564	*Cycloclypeus (Cycloclypeus) eidae*
UWA75051	UWA70564	*Cycloclypeus (Cycloclypeus) eidae*

Specimen number	*Sample number*	*Taxon*
UWA75052	UWA70604	*Cycloclypeus (Cycloclypeus) eidae*
UWA75053	UWA70606	*Cycloclypeus (Cycloclypeus) eidae*
UWA75054	UWA51889	*Cycloclypeus (Cycloclypeus)* cf. *eidae*
UWA75055	UWA51889	*Cycloclypeus (Cycloclypeus)* cf. *eidae*
UWA75056	UWA51886	*Cycloclypeus (Katacycloclypeus)* cf. *annulatus*
UWA75057	UWA53674	*Heterostegina borneensis*
UWA75058	UWA70577	*Heterostegina borneensis*
UWA75059	UWA70577	*Heterostegina borneensis*
UWA75060	UWA53674	*Heterostegina borneensis*
UWA75061	UWA70594	*Heterostegina borneensis*
UWA75062	UWA70600	*Heterostegina borneensis*
UWA75063	UWA70600	*Heterostegina borneensis*
UWA75064	UWA68324	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75065	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75066	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75067	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75068	UWA70603	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75069	UWA68324	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75070	UWA70603	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75071	UWA70603	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75072	UWA70603	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75073	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75074	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75075	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75076	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75077	UWA70604	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75078	UWA72225	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75079	UWA72225	*Miogypsina (Lepidosemicyclina) thecideaeformis*
UWA75080	UWA70495	*Miogypsina (Miogypsinoides) dehaarti*
UWA75081	UWA70495	*Miogypsina (Miogypsinoides) dehaarti*
UWA75082	UWA70495	*Miogypsina (Miogypsinoides) dehaarti*
UWA75083	UWA70564	*Miogypsina (Miogypsinoides) dehaarti*
UWA75084	UWA70564	*Miogypsina (Miogypsinoides) dehaarti*
UWA75085	UWA70564	*Miogypsina (Miogypsinoides) dehaarti*
UWA75086	UWA70600	*Amphistegina bikiniensis*++
UWA75087	UWA70600	*Amphistegina bikiniensis*
UWA75088	UWA68315	*Amphistegina hauerina*
UWA75089	UWA68315	*Amphistegina hauerina*
UWA75090	UWA70504	*Amphistegina hauerina*
UWA75091	UWA70507	*Amphistegina hauerina*
UWA75092	UWA70509	*Amphistegina hauerina*
UWA75093	UWA70509	*Amphistegina hauerina*
UWA75094	UWA68339	*Borodinia septentrionalis*
UWA75095	UWA68314	*Gypsina globulus*
UWA75096	UWA68324	*Gypsina globulus*
UWA75097	UWA70509	*Gypsina globulus*
UWA75098	UWA68324	*Gypsina howchini*
UWA75099	UWA10653	*Gypsina howchini*
UWA75100	UWA10653	*Gypsina howchini*
UWA75101	UWA10653	*Gypsina howchini*
UWA75102	UWA68345	*Gypsina howchini*
UWA75103	UWA70600	*Gypsina howchini*
UWA75104	UWA51909	*Gypsina mastaelensis*
UWA75105	UWA51909	*Gypsina mastaelensis*
UWA75106	UWA68314	*Gypsina* sp.
UWA75107	UWA70600	*Halkyardia* cf. *minima*++
UWA75108	UWA70503	*Biarritzina alternata*
UWA75109	UWA70469	*Biarritzina carpenteriaeformis*
UWA75110	UWA70469	*Biarritzina carpenteriaeformis*
UWA75111	UWA70509	*Biarritzina carpenteriaeformis*
UWA75112	UWA70503	*Biarritzina proteiformis*

Specimen number	*Sample number*	*Taxon*
UWA75113	UWA70595	*Lepidocyclina (Eulepidina) ephippioides*
UWA75114	UWA70469	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75115	UWA68316	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75116	UWA70609	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75117	UWA70604	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75118	UWA68318	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75119	UWA70470	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75120	UWA68318	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75121	UWA68318	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75122	UWA68318	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75123	UWA68318	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75124	UWA68318	*Lepidocyclina (Eulepidina) badjirraensis*
UWA75125	UWA70595	*Lepidocyclina (Eulepidina) ephippioides*
UWA75126	UWA70577	*Lepidocyclina (Eulepidina) ephippioides*
UWA75127	UWA70577	*Lepidocyclina (Eulepidina) ephippioides*
UWA75128	UWA53674	*Lepidocyclina (Eulepidina) ephippioides*
UWA75129	UWA53674	*Lepidocyclina (Eulepidina) ephippioides*
UWA75130	UWA53674	*Lepidocyclina (Eulepidina) ephippioides*
UWA75131	UWA53674	*Lepidocyclina (Eulepidina) ephippioides*
UWA75132	UWA53674	*Lepidocyclina (Eulepidina) ephippioides*
UWA75133	UWA70600	*Lepidocyclina (Eulepidina) ephippioides*
UWA75134	UWA70488	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75135	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75136	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75137	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75138	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75139	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75140	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75141	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75142	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75143	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75144	UWA70486	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75145	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75146	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75147	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75148	UWA70603	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75149	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75150	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75151	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75152	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75153	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75154	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75155	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75156	UWA10653	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75157	UWA70603	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75158	UWA70603	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75159	UWA70603	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75160	UWA70603	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75161	UWA70603	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75162	UWA70603	*Lepidocyclina (Nephrolepidina) howchini howchini*
UWA75163	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini***
UWA75164	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75165	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75166	UWA68318	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75167	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75168	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75169	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75170	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75171	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75172	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75173	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**

Specimen number	*Sample number*	*Taxon*
UWA75174	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75175	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75176	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75177	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75178	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75179	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75180	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75181	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75182 to UWA75223	UWA68324 UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini*$^{+}$ *Lepidocyclina (Nephrolepidina) howchini praehowchini*$^{+}$
UWA75224	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75225	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75226	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75227	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75228	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75229	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75230	UWA70604	*Lepidocyclina (Nephrolepidina) howchini praehowchini**
UWA75231	UWA70606	*Lepidocyclina (Nephrolepidina) japonica*
UWA75232	UWA70606	*Lepidocyclina (Nephrolepidina) japonica*
UWA75233	UWA70606	*Lepidocyclina (Nephrolepidina) japonica*
UWA75234	UWA70606	*Lepidocyclina (Nephrolepidina) japonica*
UWA75235	UWA70606	*Lepidocyclina (Nephrolepidina) japonica*
UWA75236	UWA70606	*Lepidocyclina (Nephrolepidina) japonica*
UWA75237	UWA70606	*Lepidocyclina (Nephrolepidina) japonica*
UWA75238	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75239	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75240	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75241	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75242	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75243	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75244	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75245	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75246	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75247	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75248	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75249	UWA53674	*Lepidocyclina (Nephrolepidina) sumatrensis*
UWA75250	UWA70509	*Cycloclypeus (Cycloclypeus) carpenteri*

Bureau of Mineral Resources specimens

CPC15686	80641354	*Spirolina* sp.
CPC15687	80641354	*Spiroclypeus* cf. *margaritatus*
CPC15688	80641354	*Borelis pygmaeus*
CPC15689	CR.28	*Flosculinella bontangensis bontangensis*
CPC15690	CRC.4	*Cycloclypeus (Cycloclypeus)* cf. *eidae*
CPC15691	CR.113	*Cycloclypeus (Cycloclypeus)* cf. *eidae*
CPC15692	71640345	*Cycloclypeus (Cycloclypeus) carpenteri*
CPC15693	71640345	*Cycloclypeus (Cycloclypeus) carpenteri*
CPC15694	71640345	*Cycloclypeus (Cycloclypeus) carpenteri*
CPC15695	80647032	*Heterostegina suborbicularis*
CPC15696	80641359	*Spiroclypeus* cf. *margaritatus*
CPC15697	CR.46	*Miogypsina (Lepidosemicyclina)* cf. *thecideaeformis*
CPC15698	CR.9	*Miogypsina (Lepidosemicyclina)* cf. *thecideaeformis*
CPC15699	CR.9	*Miogypsina (Lepidosemicyclina)* cf. *thecideaeformis*
CPC15700	CR.103	*Borodinia septentrionalis*
CPC15701	80642008	*Lepidocyclina (Nephrolepidina) howchini howchini*
CPC15702	71640345	*Lepidocyclina (Nephrolepidina) howchini howchini*
CPC15703	71640345	*Lepidocyclina (Nephrolepidina) howchini howchini*
CPC15704	71640345	*Lepidocyclina (Nephrolepidina) howchini howchini*
CPC15705	71640345	*Lepidocyclina (Nephrolepidina) howchini howchini*
CPC15706	71640345	*Lepidocyclina (Nephrolepidina) howchini howchini*

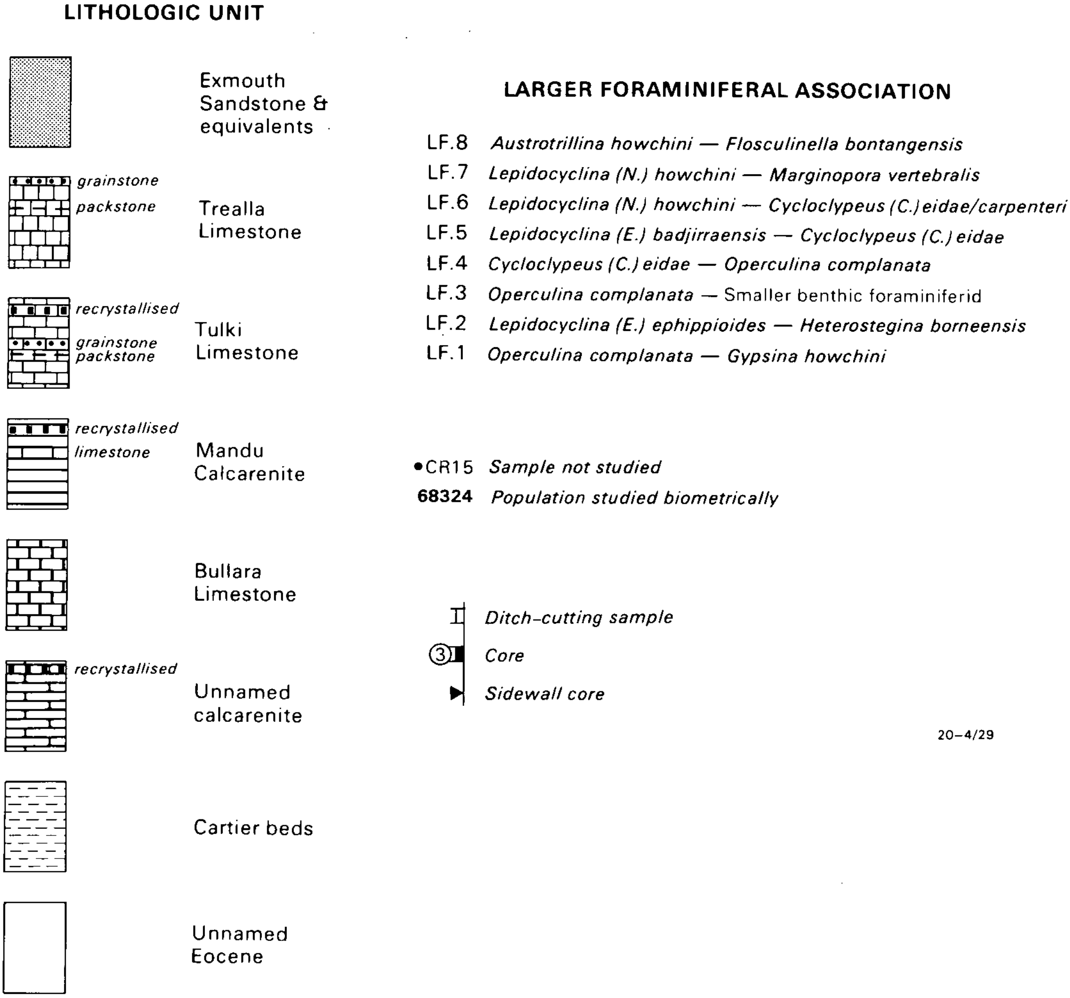
Specimen number	*Sample number*	*Taxon*
CPC15707	71640345	*Lepidocyclina (Nephrolepidina) howchini howchini*
CPC15708	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini*[+]
to		
CPC15718	UWA68324	*Lepidocyclina (Nephrolepidina) howchini praehowchini*[+]
CPC15719	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[+]
to		
CPC15722	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[+]
CPC21563	79640025	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
CPC21564	79640025	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
CPC21565	79640025	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
CPC21566	79640025	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
CPC21567	79640025	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
CPC21568	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21569	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21570	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21571	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21572	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21573	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21574	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21575	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21576	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21577	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21578	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21579	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21580	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21581	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21582	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21583	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21584	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21585	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[x]
CPC21586	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21587	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21588	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
CPC21589	77640413	*Lepidocyclina (Nephrolepidina) howchini howchini*[xx]
University of Auckland specimens		
F15	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[**]
F16	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F17	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F18	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F19	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F20	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F21	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F22	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F23	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F24	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F25	N2/528	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F26	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[+]
to		
F45	N2/584	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[+]
F46	N2/619	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F47	N2/619	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F48	N2/619	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F49	N2/619	*Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis*[*]
F50	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F51	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F52	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F53	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F54	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F55	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F56	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*[++]

Specimen number	*Sample number*	*Taxon*
F57	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F58	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F59	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F60	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F61	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F62	N18/569	*Lepidocyclina (Eulepidina) ephippioides*[++]
F63	N18/569	*Lepidocyclina (Eulepidina) ephippioides*[++]
F64	N18/569	*Lepidocyclina (Eulepidina) ephippioides*
F65	N18/569	*Miogypsina (Miogypsina) globulina*
F66	N18/569	*Miogypsina (Miogypsina) globulina*
F67	N18/569	*Miogypsina (Miogypsina) globulina*
F68	N18/569	*Miogypsina (Miogypsina) globulina*[++]
F69	N28/631a	*Miogypsina (Miogypsina) intermedia*
F70	N28/631a	*Miogypsina (Miogypsina) intermedia*
F71	N28/631a	*Miogypsina (Miogypsina) intermedia*
F72	N28/631a	*Miogypsina (Miogypsina) intermedia*
F73	N28/631a	*Miogypsina (Miogypsina) intermedia*
F74	N28/631a	*Miogypsina (Miogypsina) intermedia*
F75	N28/631a	*Miogypsina (Miogypsina) intermedia*
F76	N2/528	*Cycloclypeus (Cycloclypeus) carpenteri*
F77	N2/528	*Cycloclypeus (Cycloclypeus) carpenteri*
F78	N2/584	*Heterostegina borneensis*
F79	N18/569	*Lepidocyclina (Eulepidina) ephippioides*
F80	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F81	N18/569	*Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis*
F82	N28/631a	*Victoriella conoidea*
New Zealand Geological Survey specimens		
FP3206	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3207	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3208	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3209	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3210	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3211	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3212	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3213	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[x]
FP3214	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[xx]
FP3215	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[xx]
FP3216	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[xx]
FP3217	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[xx]
FP3218	S44/559	*Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki*[xx]

APPENDIX 4. STRATIGRAPHIC SECTIONS

Sample points, lithostratigraphy, and biostratigraphy of Western Australian surface and subsurface sections studied in this work are illustrated graphically in Figures A2 to A14; symbols used in these figures are explained in Figure A1. Wherever possible, the geophysical logs over the studied interval of the subsurface sections have been incorporated.

Those samples prefixed by CR were collected during the early 1950s by M. A. Condon and his field parties during the mapping of the Cape Range area; those samples prefixed by CRC were collected by I. Crespin during the same mapping program.



LF.8	*Austrotrillina howchini — Flosculinella bontangensis*
LF.7	*Lepidocyclina (N.) howchini — Marginopora vertebralis*
LF.6	*Lepidocyclina (N.) howchini — Cycloclypeus (C.) eidae/carpenteri*
LF.5	*Lepidocyclina (E.) badjirraensis — Cycloclypeus (C.) eidae*
LF.4	*Cycloclypeus (C.) eidae — Operculina complanata*
LF.3	*Operculina complanata* — Smaller benthic foraminiferid
LF.2	*Lepidocyclina (E.) ephippioides — Heterostegina borneensis*
LF.1	*Operculina complanata — Gypsina howchini*

Fig. A1. Key to symbols and abbreviations used in Figures A2 to A15.

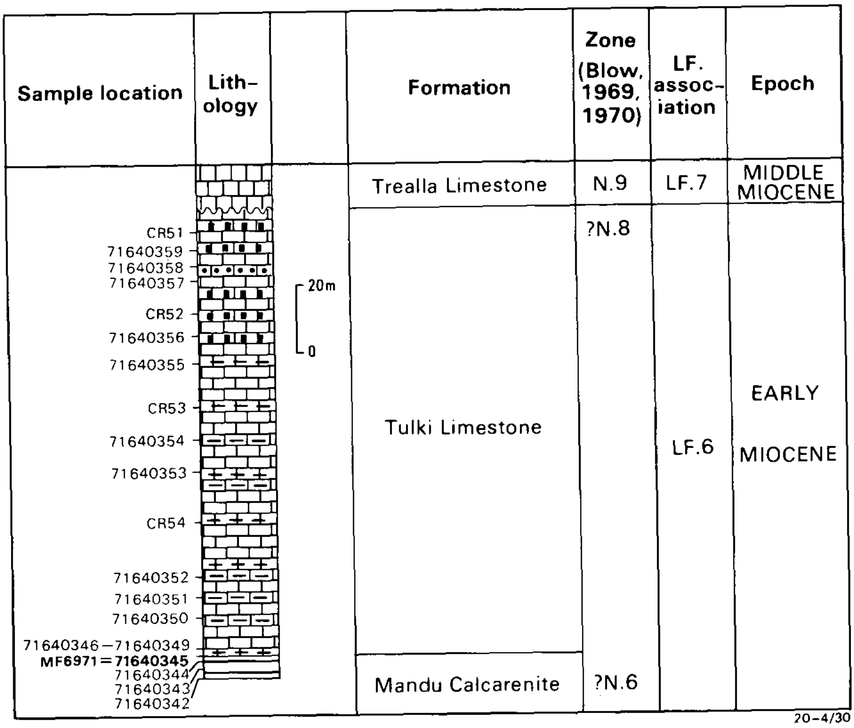


Fig. A2. Sample location, lithostratigraphy, and biostratigraphy of the section exposed along Mandu Mandu Creek.

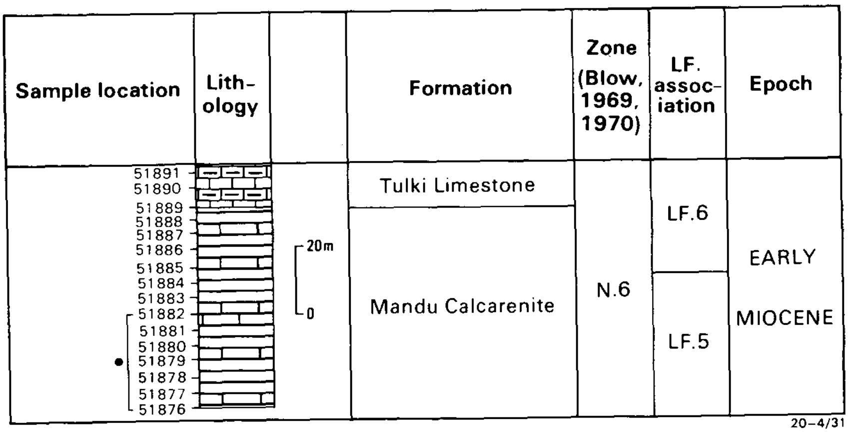


Fig. A3. Sample location, lithostratigraphy, and biostratigraphy of a section in the walls of Shothole Canyon.

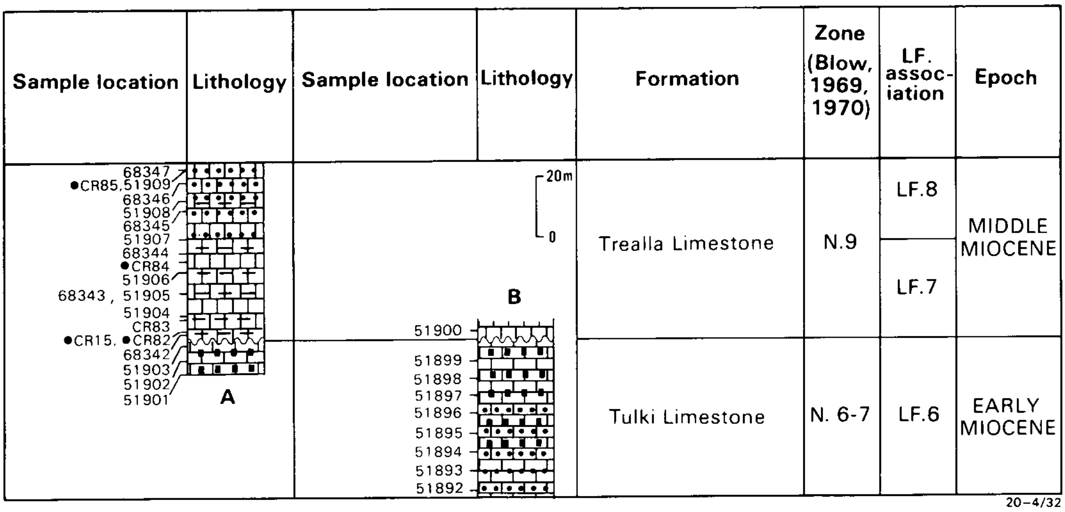


Fig. A4. Sample location, lithostratigraphy, and biostratigraphy of the type section of the Trealla Limestone (A), and of a section in an adjacent canyon (B).

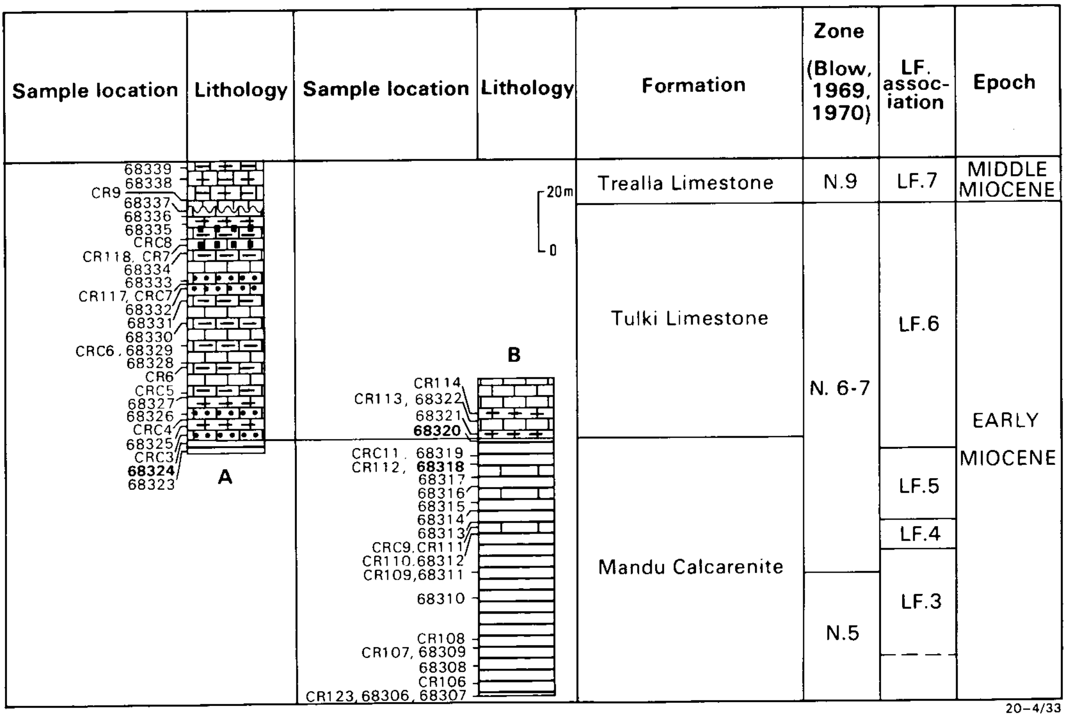


Fig. A5. Sample location, lithostratigraphy, and biostratigraphy of the type sections of the Tulki Limestone (A) and Mandu Calcarenite (B).

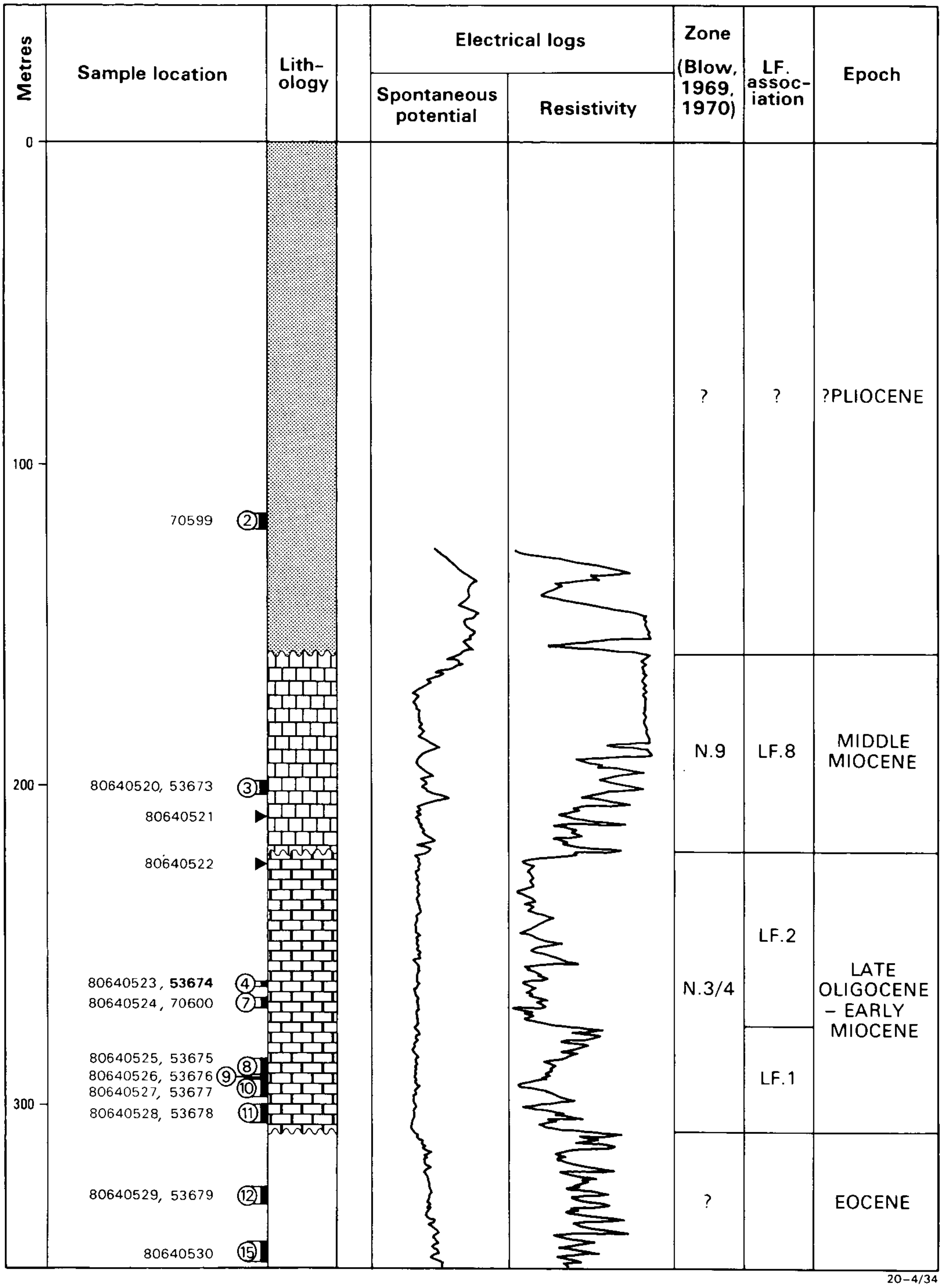


Fig. A6. Sample location, lithostratigraphy, and biostratigraphy of Rough Range South No. 1 well.

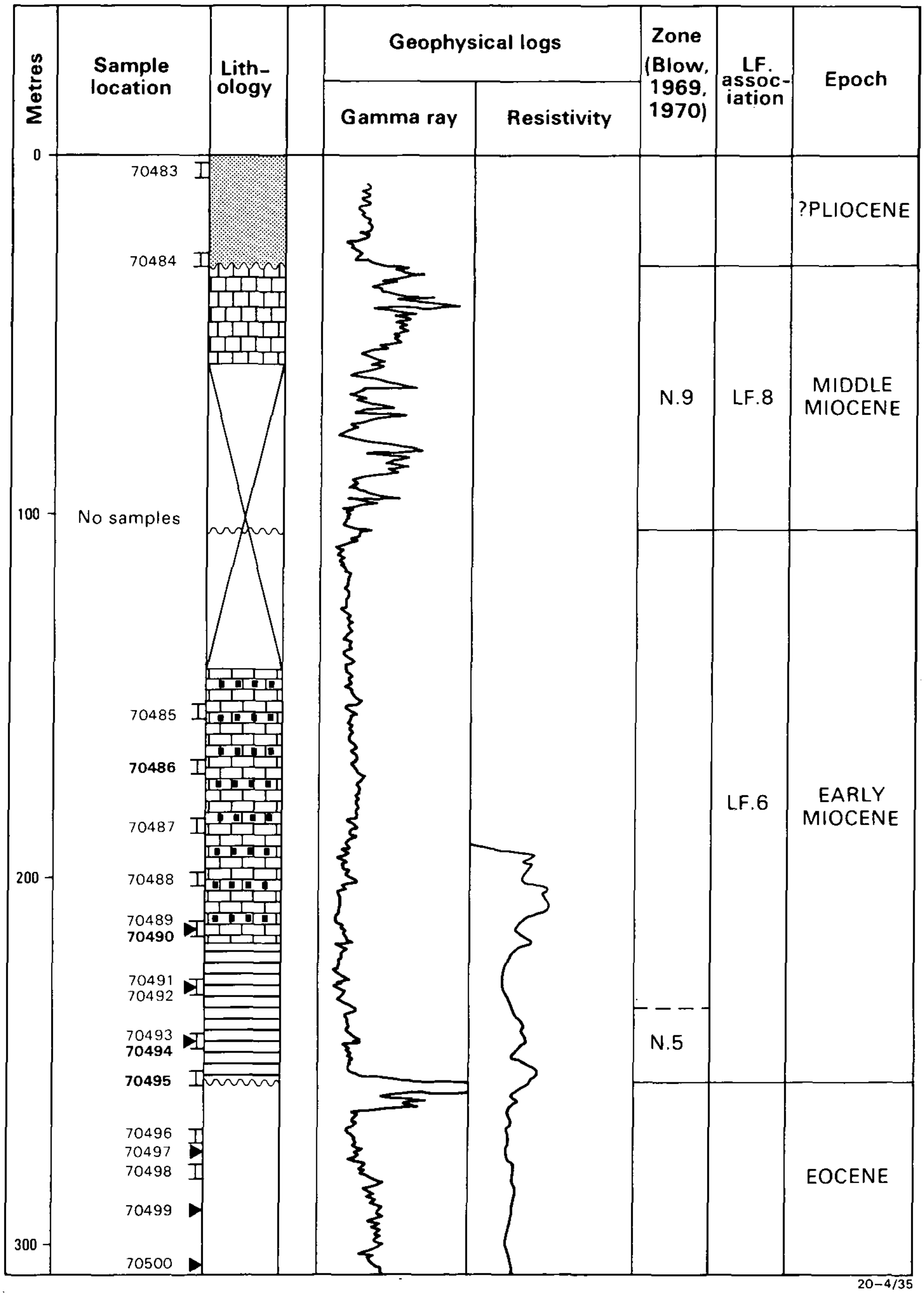


Fig. A7. Sample location, lithostratigraphy, and biostratigraphy of Ningaloo No. 1 well.

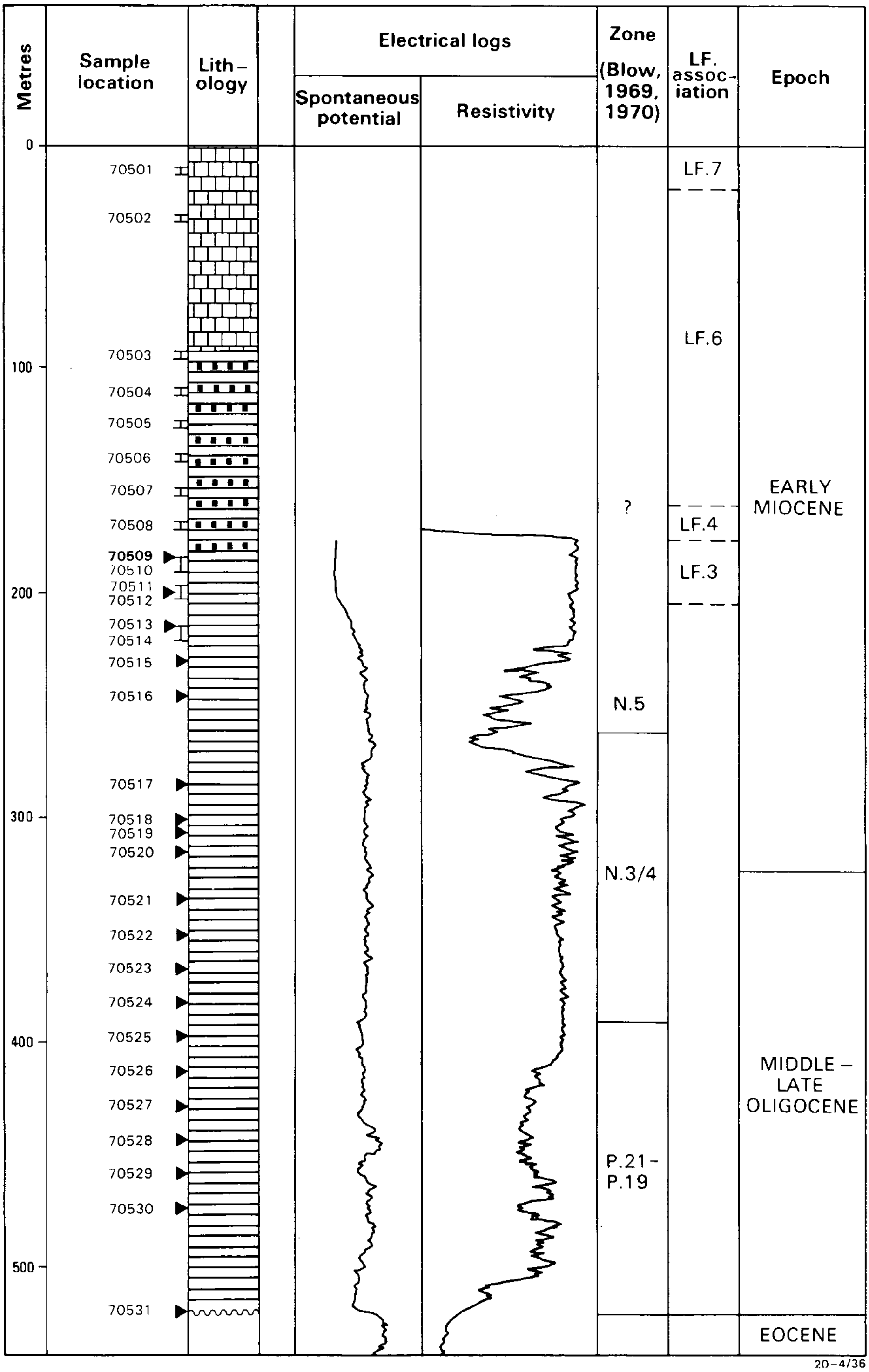


Fig. A8. Sample location, lithostratigraphy, and biostratigraphy of Sandy Point No. 2 well.

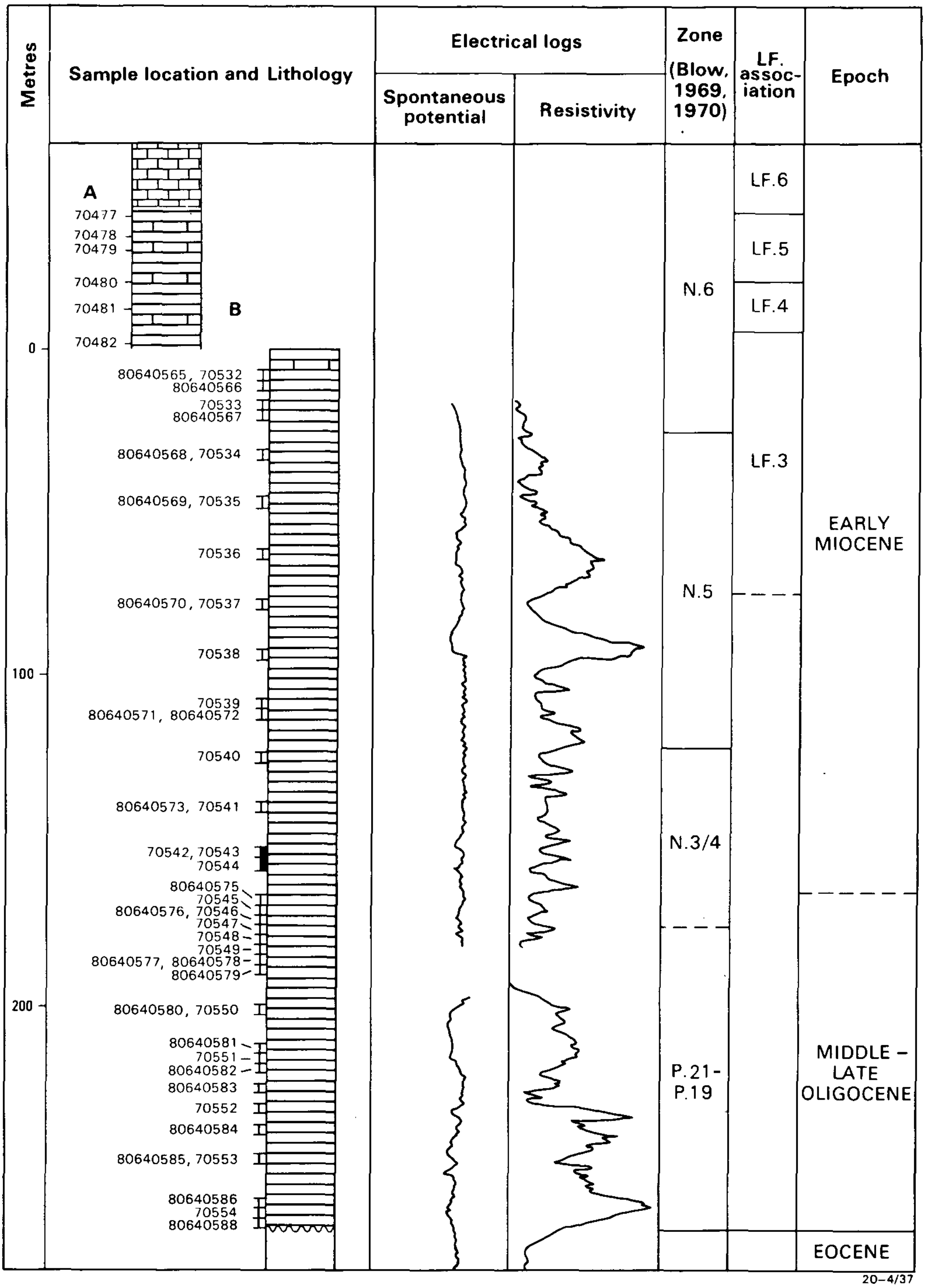


Fig. A9. Sample location, lithostratigraphy, and biostratigraphy of a section adjacent to the site of Cape Range No. 1 well (A), and of Cape Range No. 1 well (B).

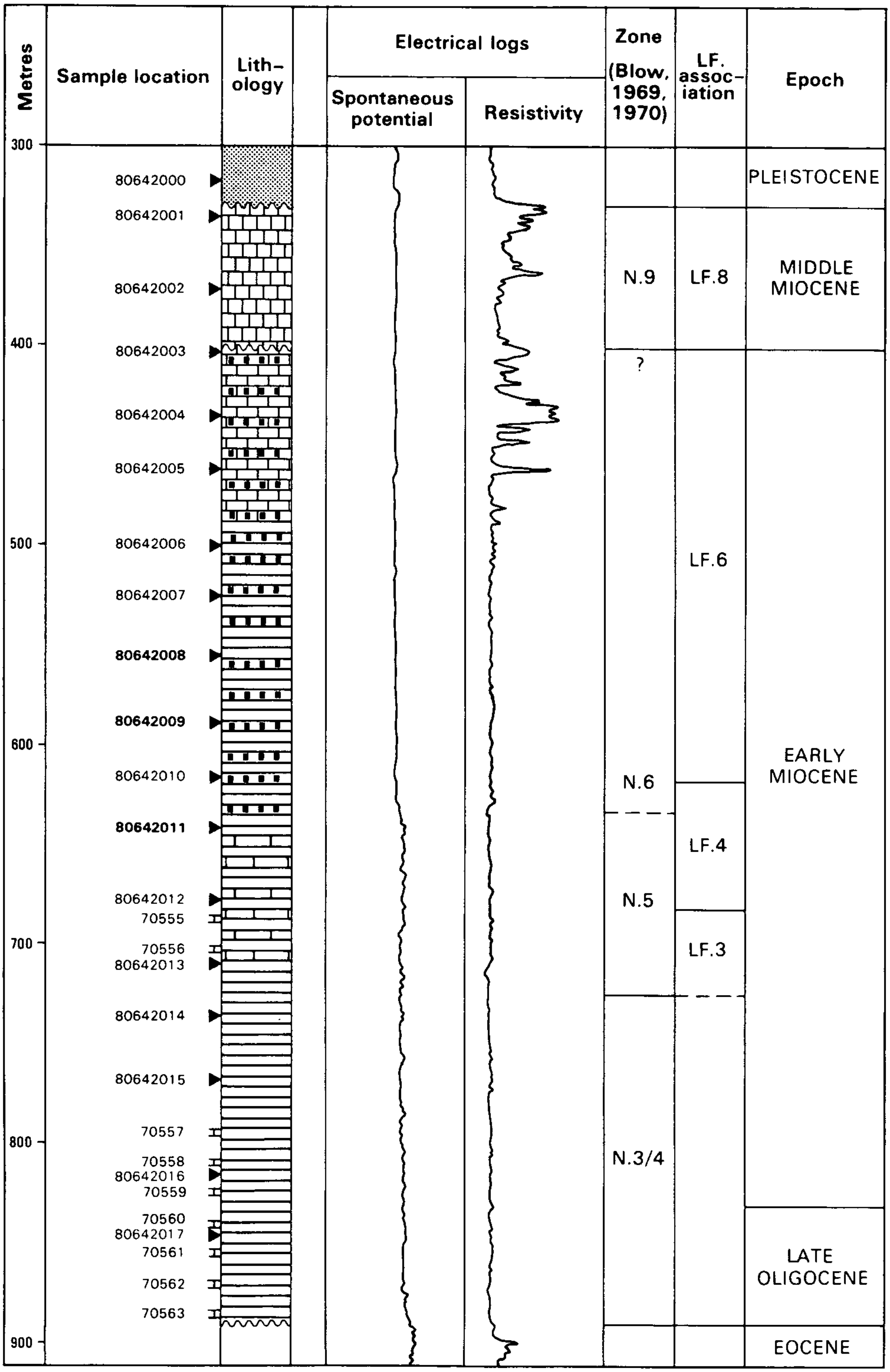


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Fig. A10. Sample location, lithostratigraphy, and biostratigraphy of Muiron No. 1 well.

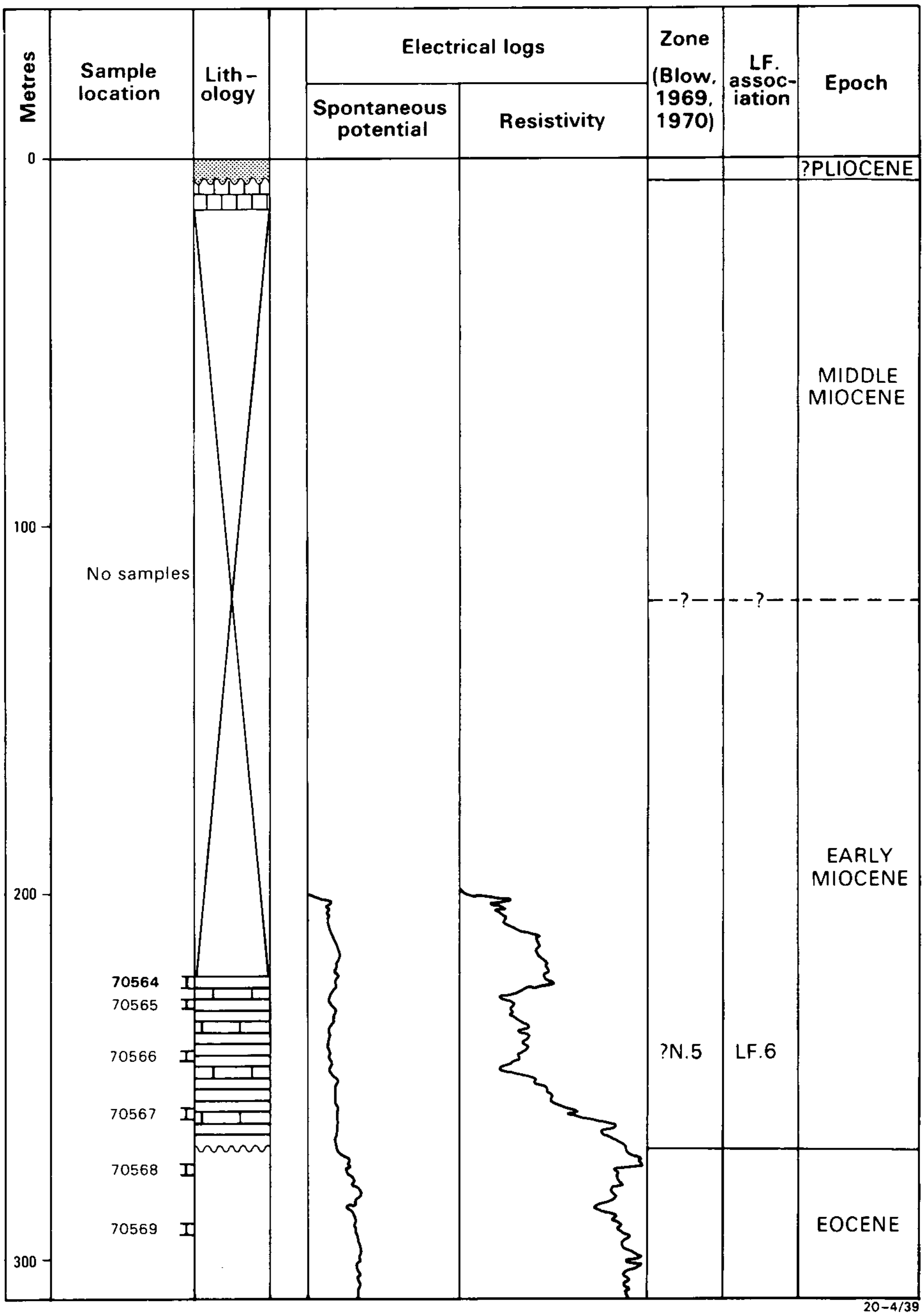


Fig. A11. Sample location, lithostratigraphy, and biostratigraphy of Learmonth No. 1 well.

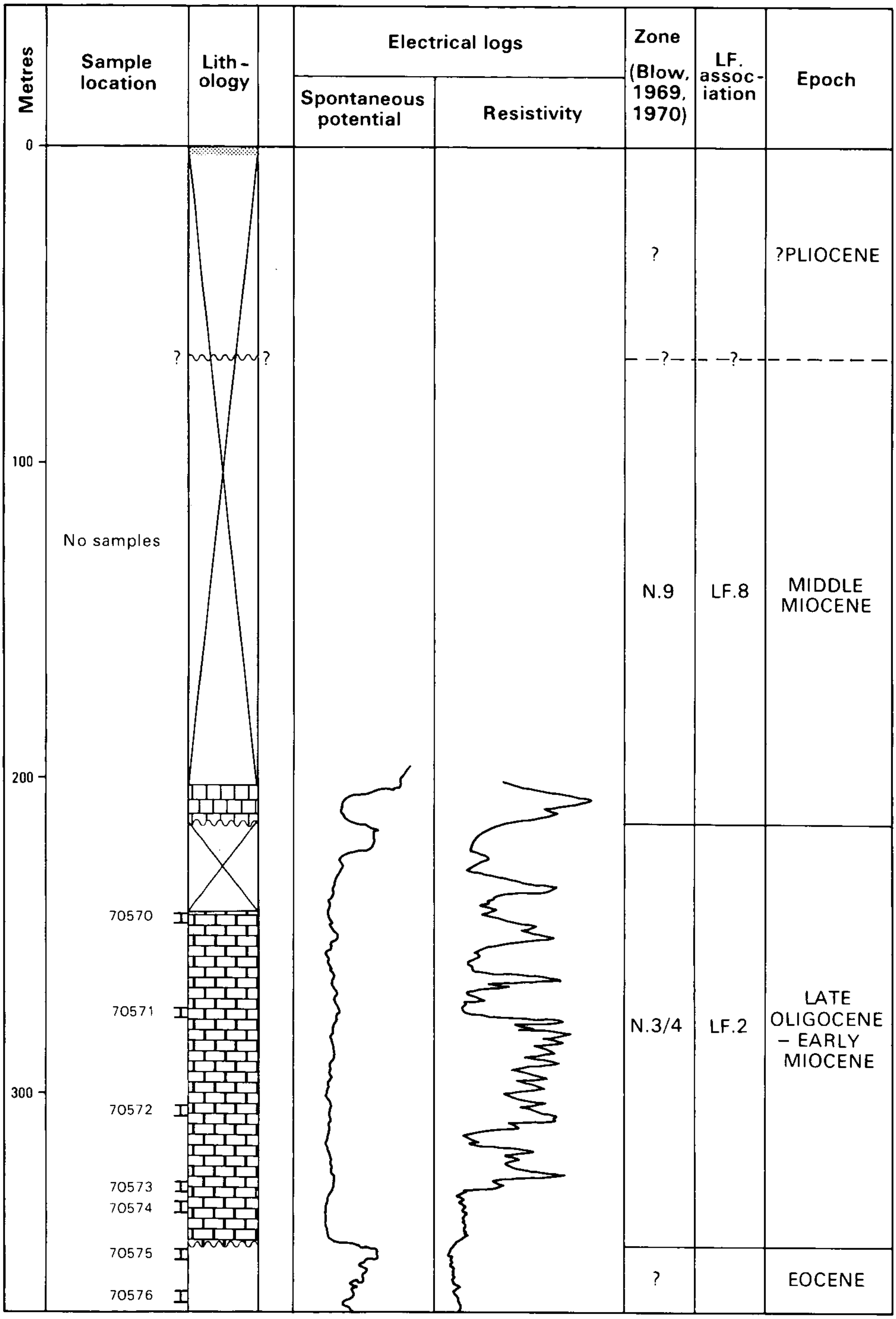


Fig. A12. Sample location, lithostratigraphy, and biostratigraphy of Learmonth No. 2 well.

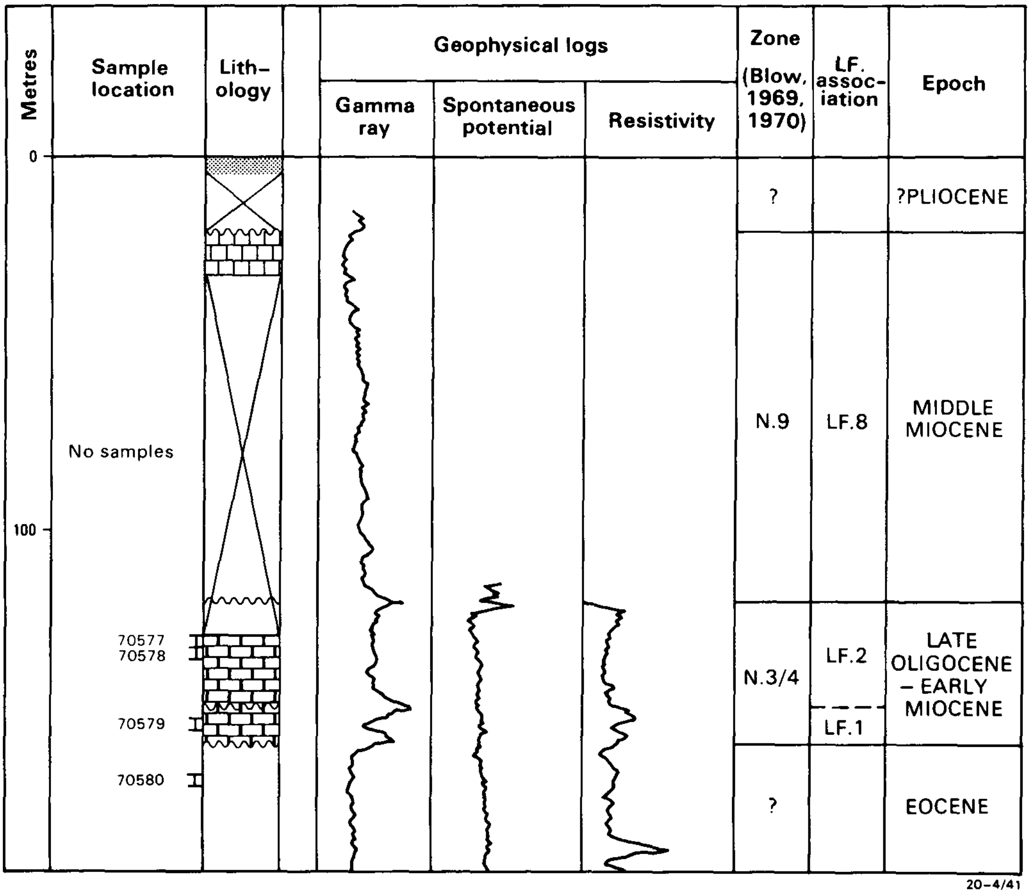


Fig. A13. Sample location, lithostratigraphy, and biostratigraphy of Exmouth No. 1 well.

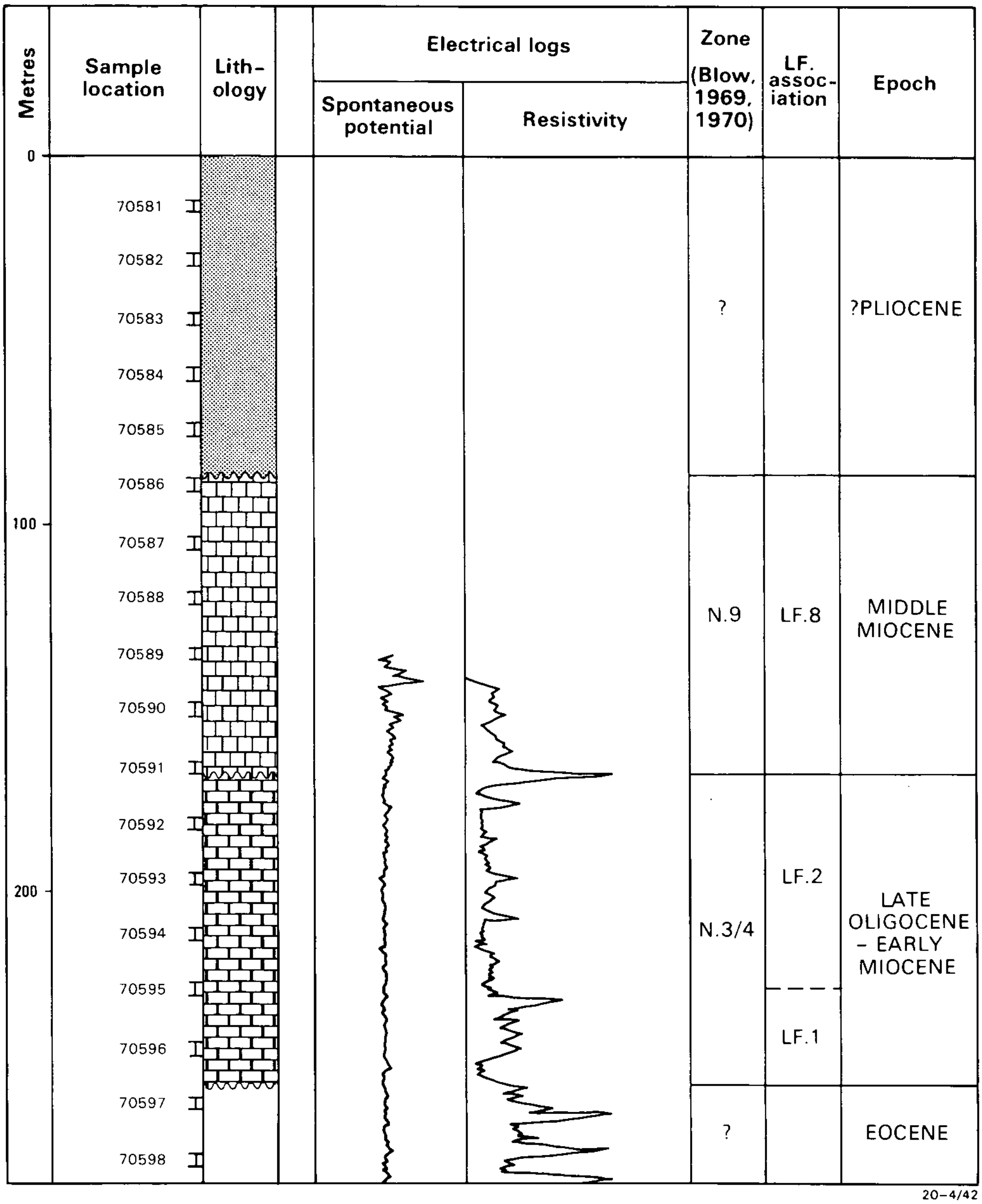


Fig. A14. Sample location, lithostratigraphy, and biostratigraphy of Exmouth No. 2 well.

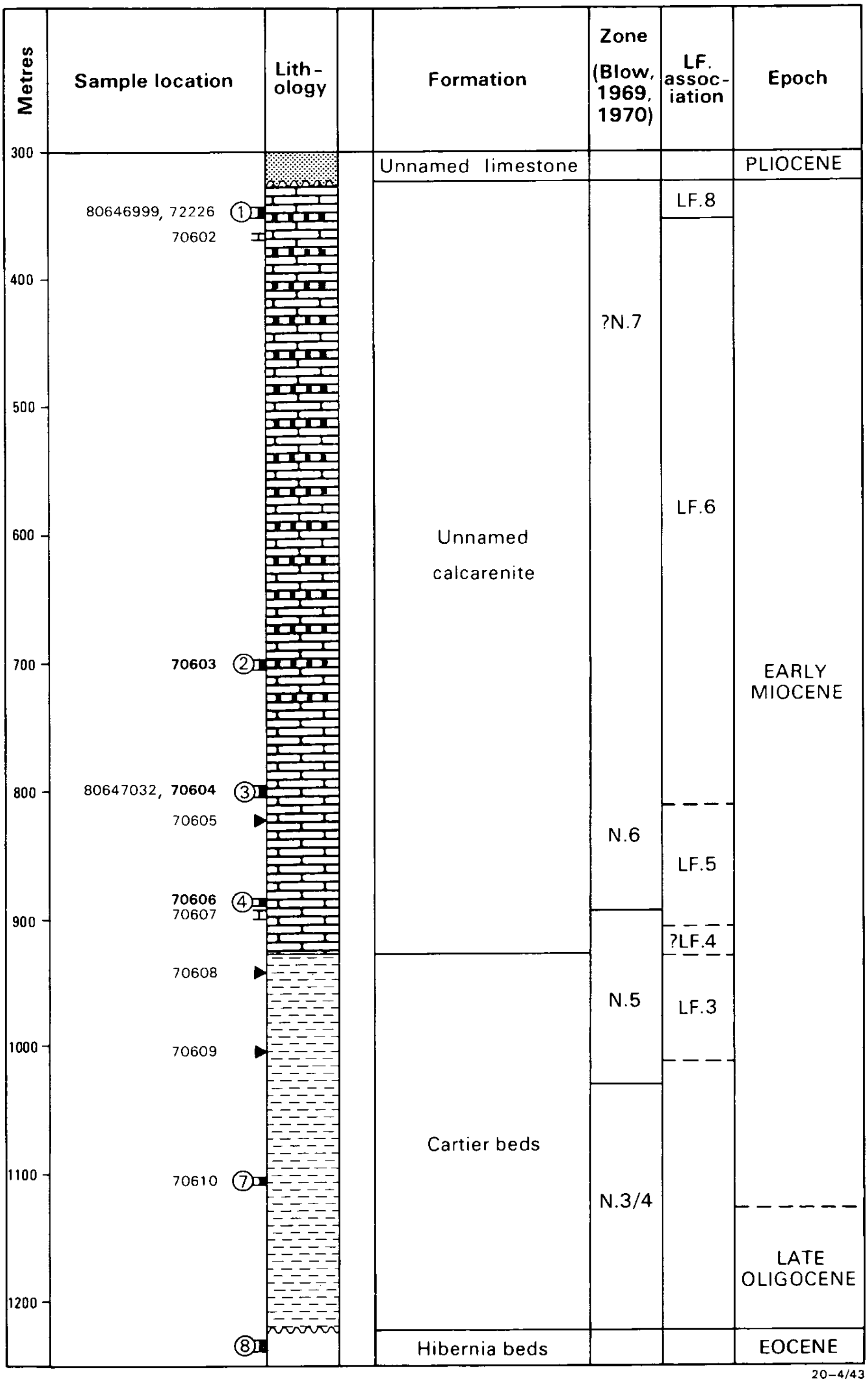
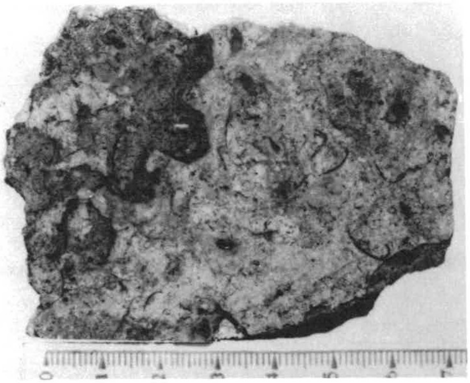


Fig. A15. Sample location, lithostratigraphy, and biostratigraphy of Ashmore Reef No. 1 well.

PLATE 1

Figs. 1–5, type section of the Bullara Limestone, Rough Range South No. 1 well; Fig. 6, type section of the Mandu Calcarenite, Badjirrajirra Creek, Cape Range.
(Scale bars in centimetres)

Fig.	
1	Trealla Limestone. Sample UWA53673.
2	Bullara Limestone: fine-grained bioclastic grainstone (see Chaproniere, 1975, fig. 8E). Sample UWA53674.
3	Bullara Limestone: coarse-grained algal-foraminiferal packstone (see Chaproniere, 1975, fig. 8G).
4	Bullara Limestone: coarse-grained algal grainstone. Sample UWA53677.
5	Bullara Limestone: coarse-grained algal-foraminiferal grainstone. Sample UWA53678.
6	Mandu Calcarenite: large tests of *Lepidocyclina (Eulepidina) badjirraensis* lying parallel to the bedding in a mud matrix (see Chaproniere, 1975, fig. 8B). Sample UWA68313.



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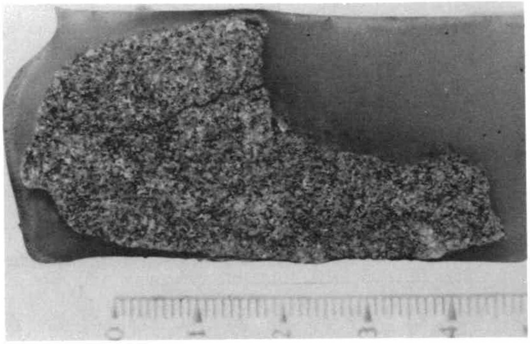

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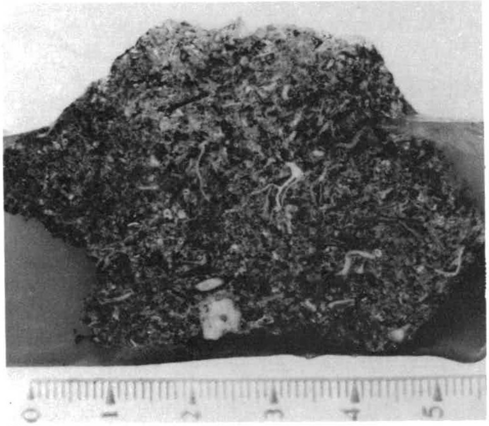

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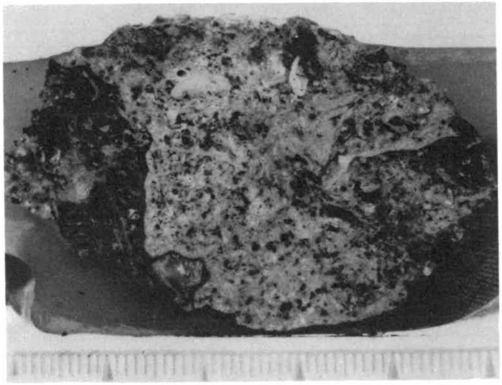

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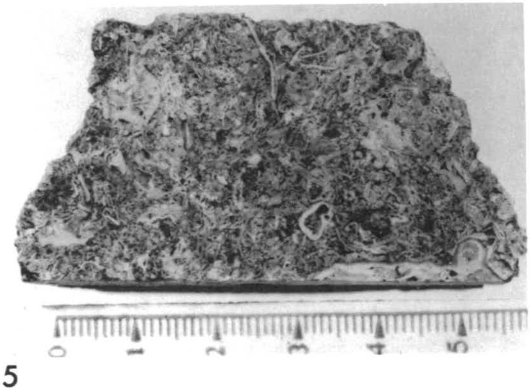

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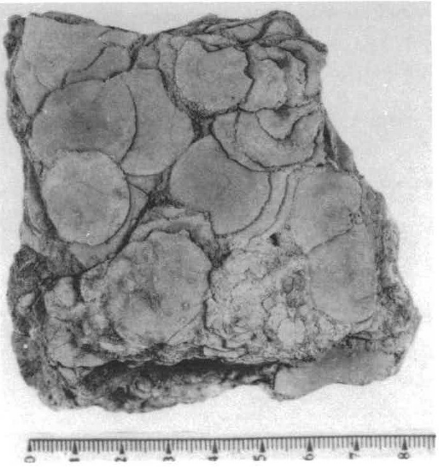


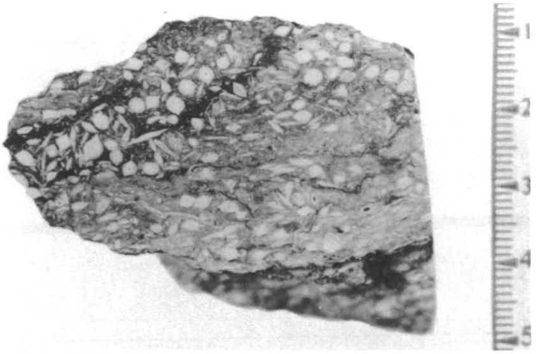
6

PLATE 2

Figs. 1, 3, 5, unnamed calcarenite, Ashmore Reef No. 1 well; Figs. 2, 4, 6, Badjirrajirra Creek, Cape Range.

(Scale bars in centimetres)

Fig.	
1	Packstone containing numerous spheroidal and flattened tests of *Lepidocyclina (Nephrolepidina) howchini howchini* with fragments of crustose coralline-algal plates (see Chaproniere, 1975, fig. 10F). Sample UWA70603.
2	Gradational contact between the Mandu Calcarenite and Tulki Limestone at the type section of the Mandu Calcarenite.
3	Packstone containing tests of *Lepidocyclina (Nephrolepidina) howchini praehowchini* and plates of crustose coralline algae (see Chaproniere, 1975, fig. 10E). Sample UWA70604.
4	View of the upper, recrystallised part of the Tulki Limestone. The abrupt change in slope at the top of the cliffs marks the contact with the overlying Trealla Limestone. The photograph is taken from the type section of the Tulki Limestone, facing north.
5	Bioclastic packstone containing numerous tests of *Lepidocyclina (Eulepidina) badjirraensis* (see Chaproniere, 1975, figs. 8B, 10D, and compare Pl. 1, fig. 6). Sample UWA70606.
6	Rock slab showing a minor disconformity in the zone of gradational contact between the Mandu Calcarenite and the Tulki Limestone. Note the large plates of *Halimeda* in the darker side of the contact (see Chaproniere, 1975, fig. 9A). Sample UWA70473.



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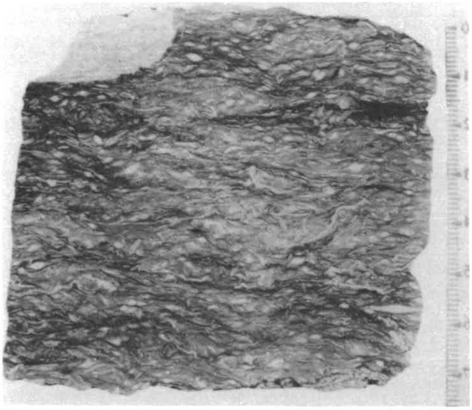

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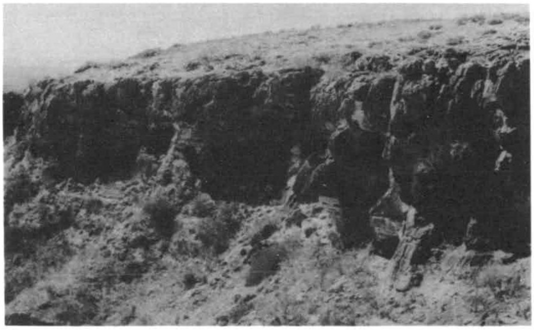

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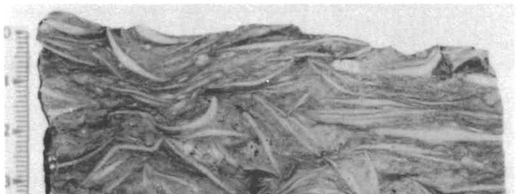

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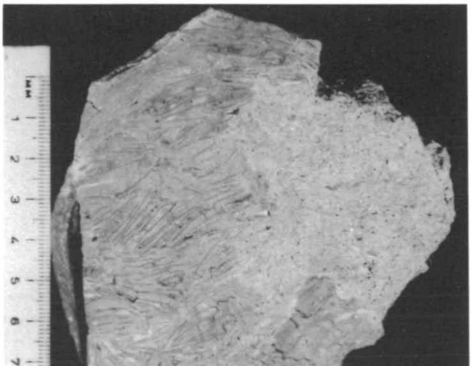


6

PLATE 3

Fig.

1a–e **Austrotrillina striata** Todd & Post.
UWA75008: a, b, side views—x80; c, apertural view—x110; d, e, detail of a and b respectively—x240.

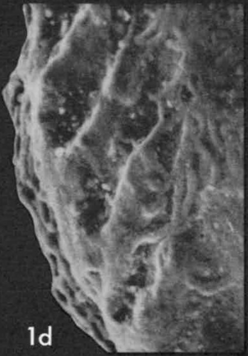
2a, b **Flosculinella bontangensis globulosa** (Rutten).
UWA75026: a, axial view—x35; b, detail of a—x175.

3a–c **Amphistegina hauerina** d'Orbigny.
UWA75088: a, spiral view—x30; b, side view—x40; c, detail of a—x400.

4a, b **Lacazinella** sp. cf. **L. wichmanni** (Schlumberger).
UWA75009: a, axial view—x55; b, equatorial view—x100.

5 **Amphistegina hauerina** d'Orbigny.
UWA75089: side view—x75.


1a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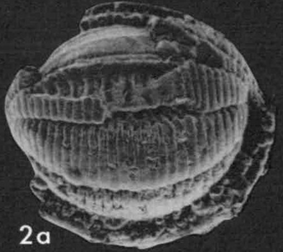
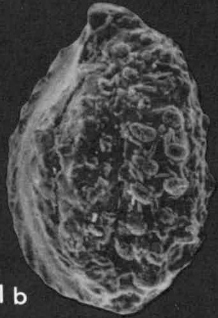

2a


2b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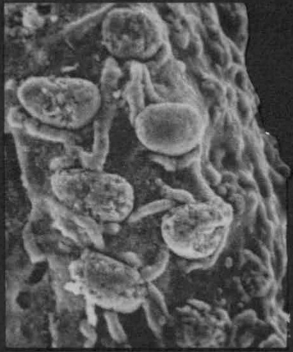
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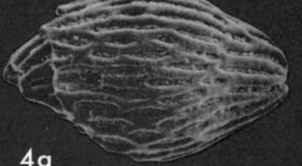
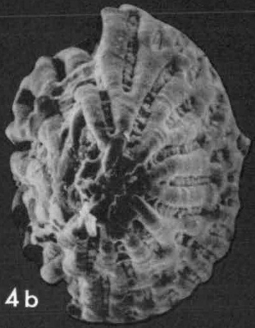

4a


1c


3a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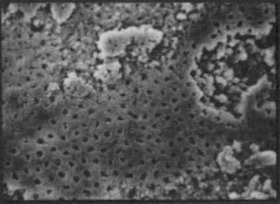
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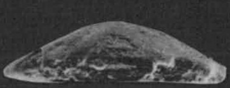
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PLATE 4

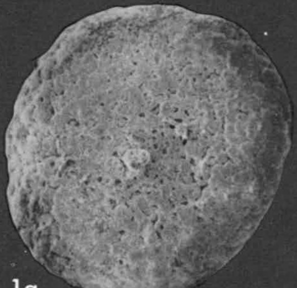
Fig.

1a–c **Gypsina howchini** Chapman.
UWA75098: a, external view—x25; b, detail of a—x50; c, side view—x25.

2a–d **Gypsina howchini** Chapman.
UWA75099: a, external view—x20; b, detail of a—x100; c, side view—x20; d, detail of c—x70.

3a, b **Gypsina globulus** (Reuss).
UWA75096: a, external view—x30; b, detail of a—x60.

4a–c **Gypsina globulus** (Reuss).
UWA75095: a–c, external views—x140.



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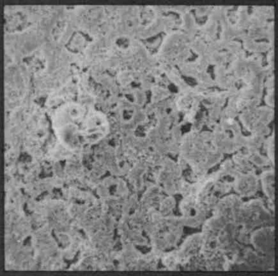

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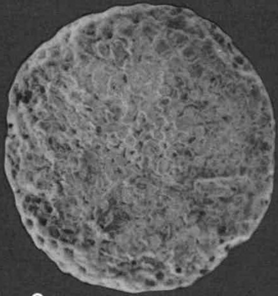
1c



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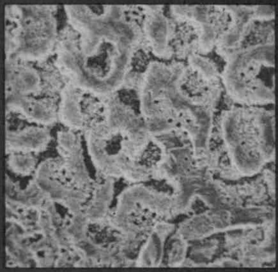

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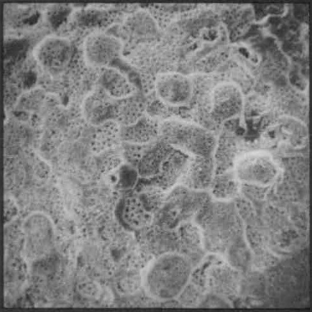
3a



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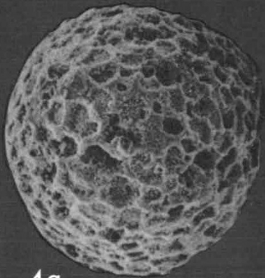

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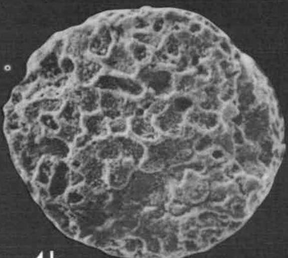

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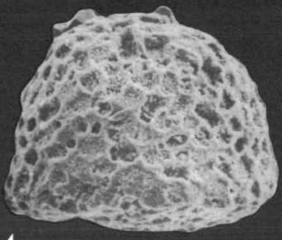
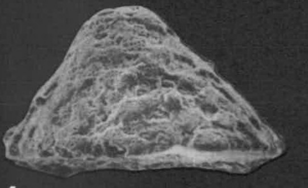


4c

PLATE 5

Fig.	
1a–d	**Gypsina** sp. UWA75106: a–c, external views, a—x75; b, c—x80; d, detail of a—x270.
2, 3	**Operculina complanata** (Defrance). UWA75028: 2, oblique external view—x20; 3, external view—x20.
4a, b	**Heterostegina borneensis** van der Vlerk. F78: a, internal view of broken specimen—x25; b, detail of a—x70.
5a–c	**Heterostegina borneensis** van der Vlerk. UWA75057: a, detail of b—x250; b, side view—x25; c, external view—x25.
6a, b	**Cycloclypeus (Cycloclypeus) eidae** Tan. UWA75044: juvenile, a, external view—x90; b, side view—x105.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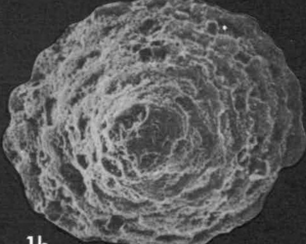
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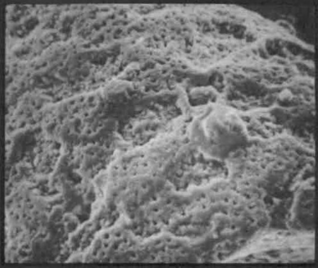
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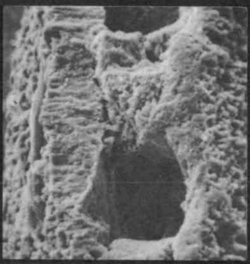
2


3

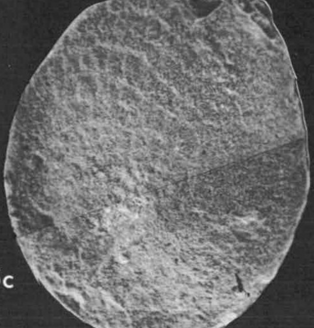

4a


5a


6a


4b


5b


5c


6b

PLATE 6

Fig.

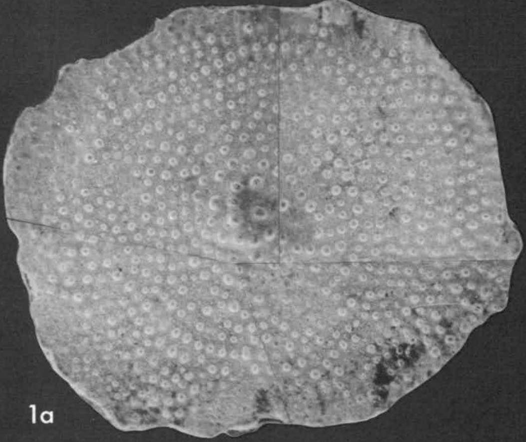
1a–c **Cycloclypeus (Cycloclypeus) carpenteri** Brady.
F76: a, external view—x20 (composite); b, detail of a, showing pustules—x200; c, detail of b, showing pores—x1000.

1d, 2 **Cycloclypeus (Cycloclypeus) carpenteri** Brady.
UWA75041: 1d, detail of 2, showing surface detail—x1000; 2, fragment of test, showing pustules forming concentric ridges—x20.

3 **Cycloclypeus (Cycloclypeus) carpenteri** Brady.
UWA75042: external view of fragment of test showing ridges produced by coalesced pustules—x25.

4a, b **Miogypsina (Miogypsina) intermedia** Drooger.
F70: a, detail of b, showing test microstructure—x150; b, side view—x20 (composite).

5a, b **Miogypsina (Miogypsina) globulina** Michelotti.
F65; a, external view—x20 (composite); b, detail of a, showing surface microstructure—x200.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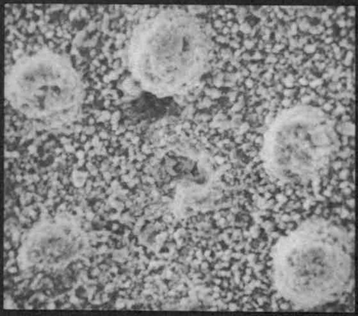
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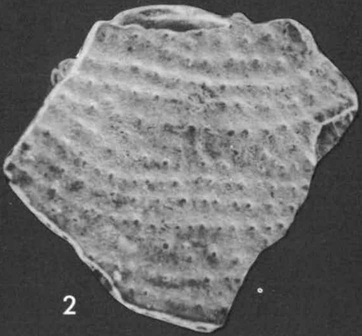
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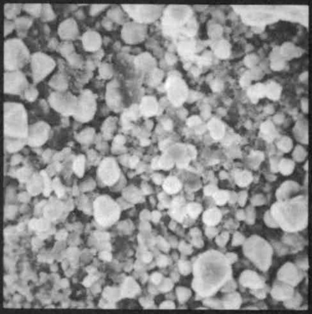
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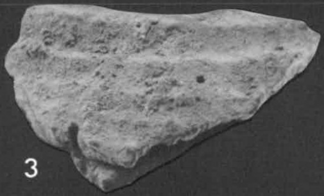
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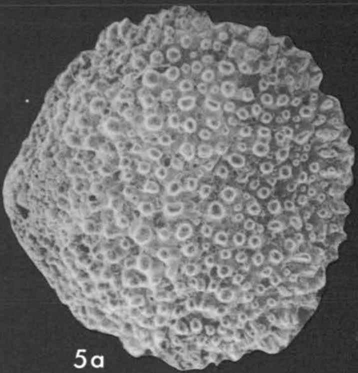
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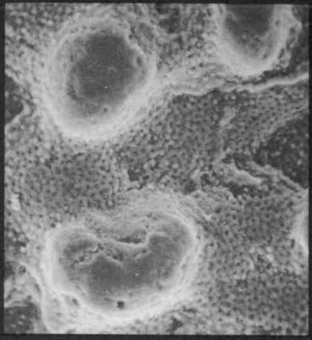
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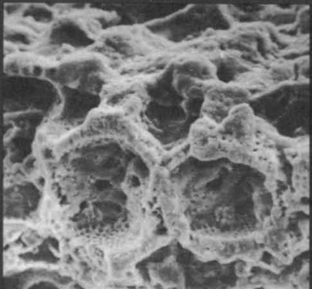
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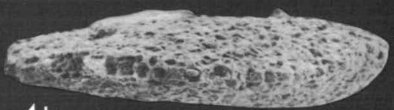

4b

PLATE 7

Fig.

1a–c **Miogypsina (Miogypsina) intermedia** Drooger.
F69: a, external view—x15; b, detail of a, showing surface microstructure on central part of test—x200; c, detail of a, showing surface microstructure of frontal margin of test—x150.

2a, b **Miogypsina (Miogypsina) intermedia** Drooger.
F71: a, vertical section—x20; b, detail of a, showing test microstructure; note stolon between equatorial chambers—x240.

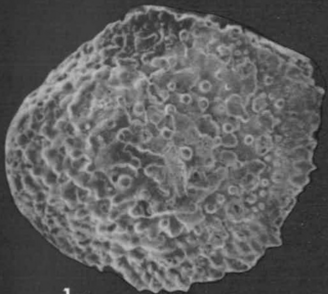
3 **Miogypsina (Lepidosemicyclina) thecideaeformis** (Rutten).
UWA75066: external view—x25.

4a, b **Miogypsina (Lepidosemicyclina) thecideaeformis** (Rutten).
UWA75067: a, external view—x20; b, detail of a—x250.

5 **Miogypsina (Lepidosemicyclina) thecideaeformis** (Rutten).
UWA75064: external view—x20 (composite).

6 **Miogypsina (Lepidosemicyclina) thecideaeformis** (Rutten).
UWA75065: side view showing the undulating frontal margin—x30.

7a, b **Miogypsina (Miogypsinoides) dehaarti** van der Vlerk.
UWA75080: a, side view—x45; b, detail of a, showing test microstructure—x220.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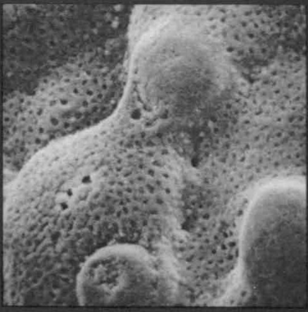
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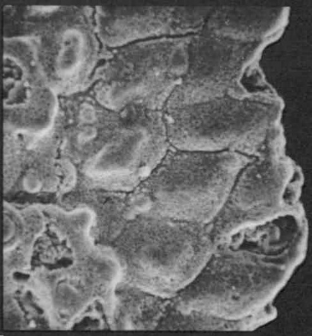
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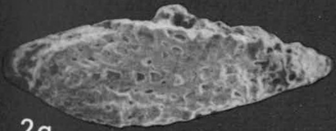
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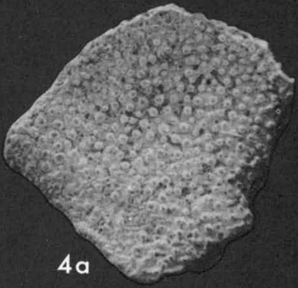
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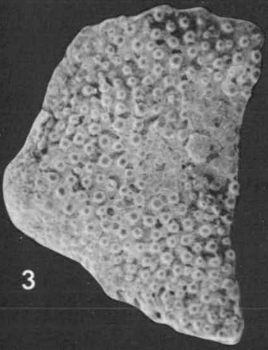
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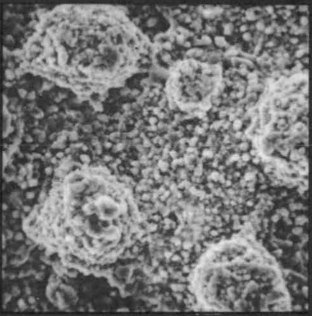
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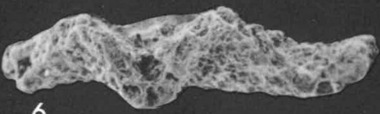
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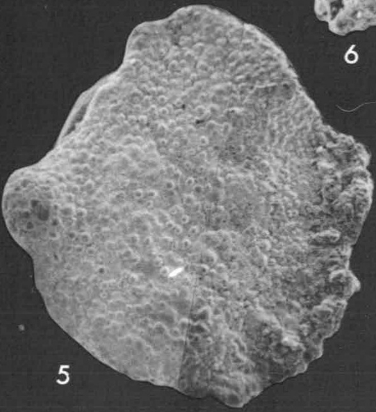
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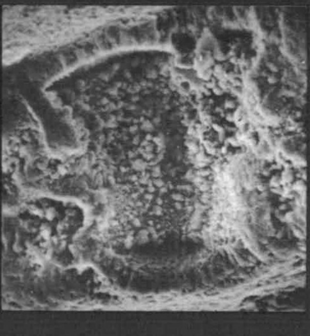
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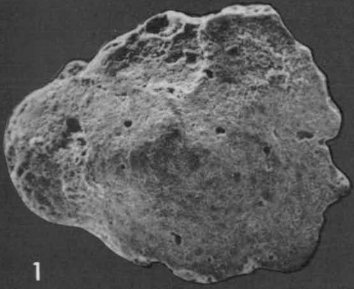
PLATE 8

Fig.

1–3 **Miogypsina (Miogypsinoides) dehaarti** van der Vlerk.
1, UWA75080: external view—x55. 2, UWA75081: microspheric form; 2a, equatorial view—x60; 2b, detail of a, showing nepionic stage—x150; 2c, detail of a, showing test microstructure—x600. 3, UWA75082: megalospheric form, equatorial view—x55.

4–14 **Lepidocyclina (Nephrolepidina) howchini howchini** Chapman & Crespin.
Nepionic stage of megalospheric form. All x100. 4, UWA75134: internal view showing auxiliary chambers. 5–14, external views. 5, UWA75135; 6, UWA75136; 7, UWA75137; 8, UWA75138; 9, UWA75139; 10, UWA75140; 11, UWA75141; 12, UWA75142; 13, UWA75143; 14, UWA75144.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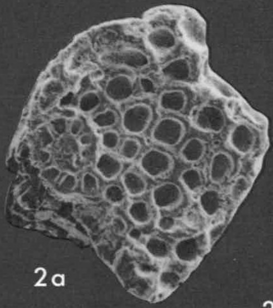
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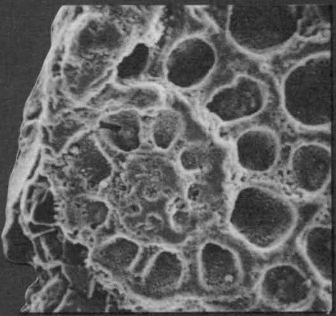
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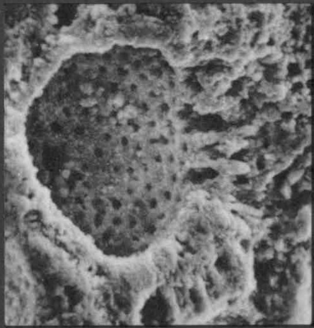
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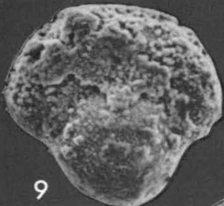
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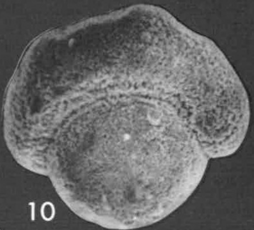
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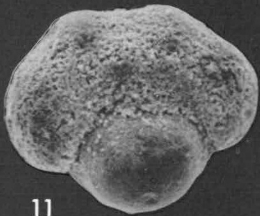
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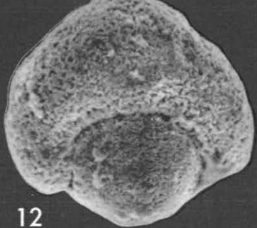
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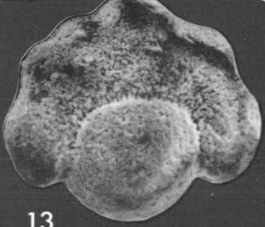
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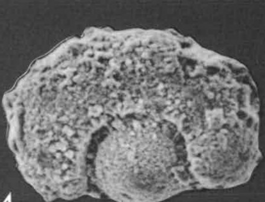
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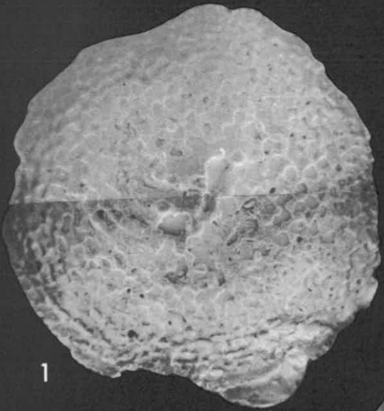
PLATE 9

Fig.	
1	**Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis** (Karrer). F50: external view—x15 (composite).
2	**Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis** subsp. nov. Paratype, F16: median view—x45.
3	**Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis** subsp. nov. Holotype, F15: external view—x20.
4a, b	**Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis** (Karrer). F52: a, external view—x20; b, detail of a, showing test microstructure—x120.
5a–f	**Lepidocyclina (Nephrolepidina) howchini howchini** Chapman & Crespin. CPC15701: a, median view—x35; b, detail of a, showing test microstructure—x350; c, detail of b, showing stolon—x900; d, detail of a, showing porous embryoconch wall—x175; e, detail of d—x650; f, detail of d, showing microstructure of embryoconch wall—x2000.



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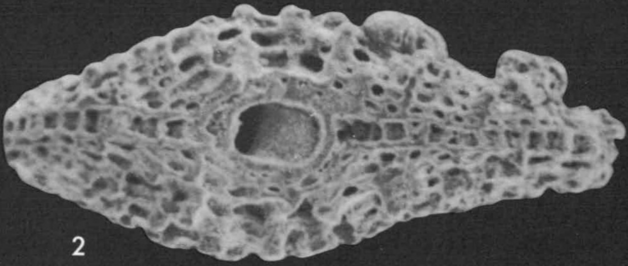

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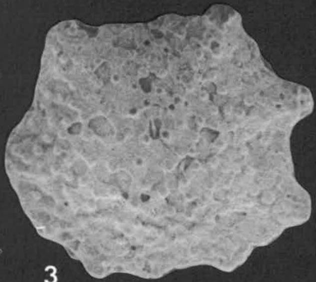

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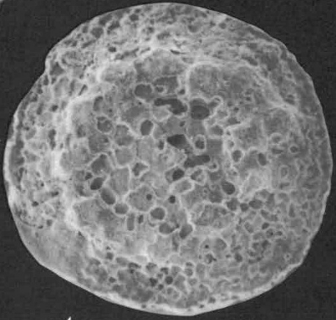

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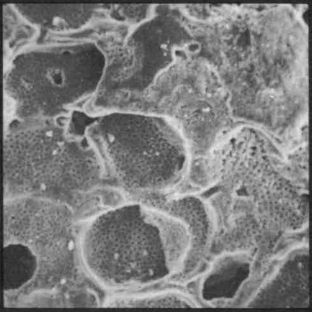

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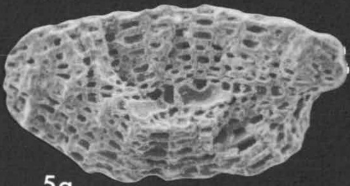

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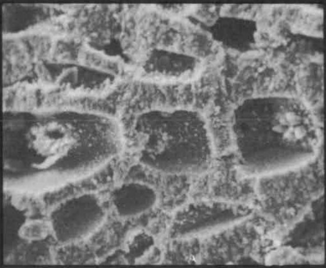

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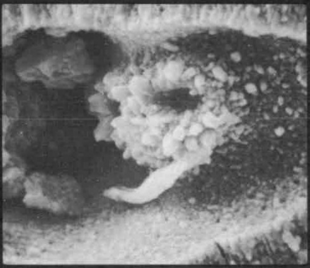

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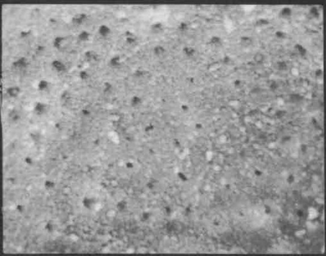

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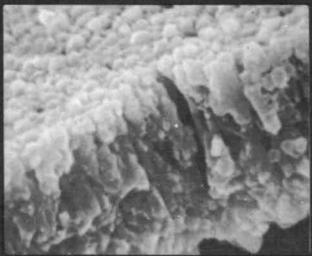


5f

PLATE 10

Fig.

1a–c **Lepidocyclina (Nephrolepidina) sumatrensis** (Brady).
UWA75238: a, external view—x25; b, detail of a, showing a possible spirilline foraminifer occupying a lateral chamber—x250; c, detail of b—x700.

2 **Lepidocyclina (Nephrolepidina) sumatrensis (Brady).**
UWA75239: external view—x20.

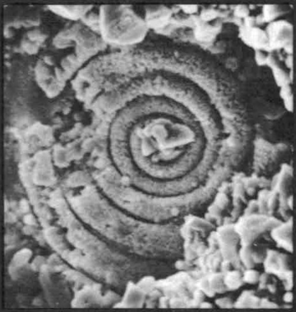
3a, b **Lepidocyclina (Nephrolepidina) howchini praehowchini** subsp. nov.
Paratype, UWA75166: young individual; a, external view—x90; b, detail of a, showing the porous wall of the lateral chambers—x750.

4a–c **Lepidocyclina (Nephrolepidina) howchini praehowchini** subsp. nov.
Paratype, UWA75164: a, external view—x25; b, detail of a, showing lateral chambers—x90; c, detail of a, showing microstructure of lateral chambers (oblique view)—x400.

5a–c **Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis** (Karrer).
F51: a, external side view—x40; b, detail of a, showing location of stolons between the equatorial chambers (cf. Pl. 9, fig. 5c; Pl. 12, figs. 2b, c, 6)—x150; c, detail of a, showing stolons opening into the lateral chambers—x150.


1a


1 b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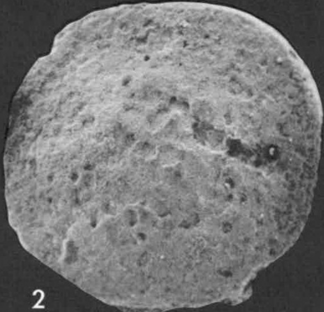
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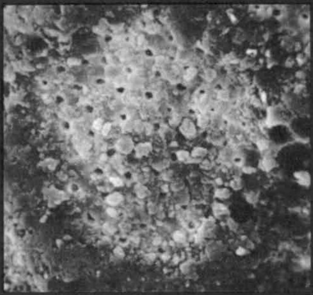
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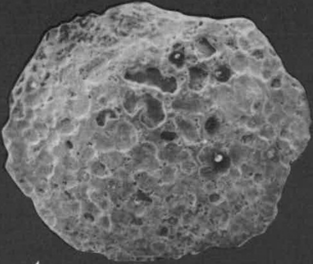
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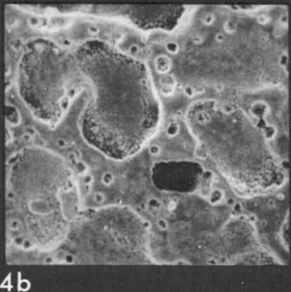
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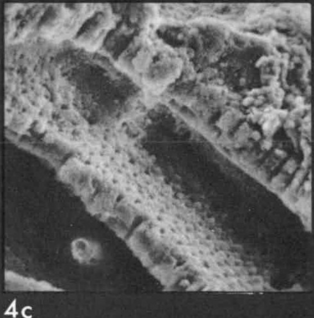
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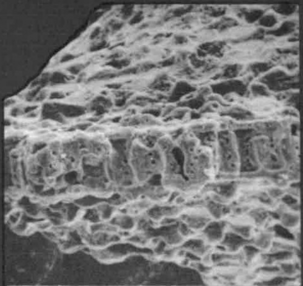
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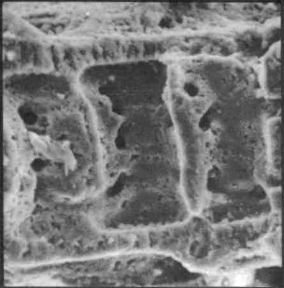
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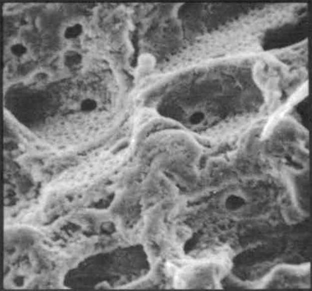
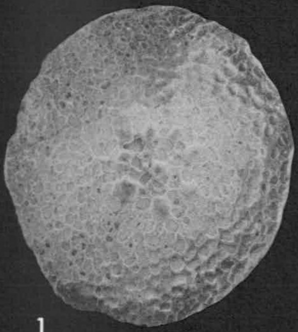

5 c

PLATE 11

(All SEM micrographs; scale bar = 1 mm for 1–6, 200 μm for 2b, 80 μm for 5b, c.)

Fig.	
1–5	**Lepidocyclina (Nephrolepidina) howchini howchini** Chapman & Crespin. Topotypes—1, CPC21582; 2, CPC21583; 3, CPC21584; 4, CPC21585; 5, CPC21581. External views: 2b, 5b, 5c, detail of test: 2b, showing unbroken peripheral flange; 5b, showing detail of equatorial chambers with stolons connecting chambers, and perforate and imperforate areas; 5c, similar to 5b, but detail of lateral chambers.
6	**Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki** Matsumaru. Topotype, FP3206: external view.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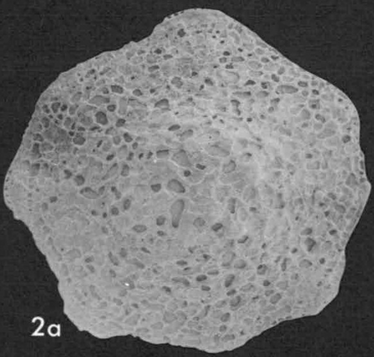
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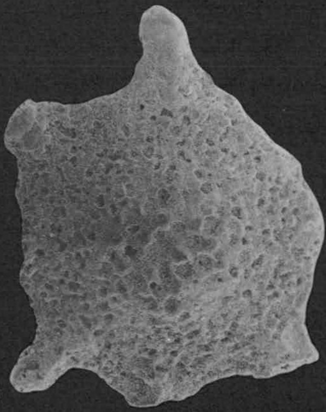
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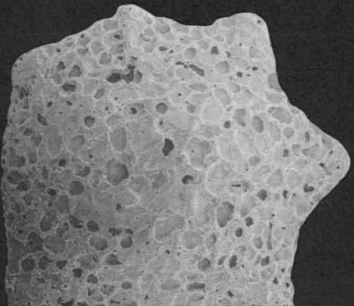
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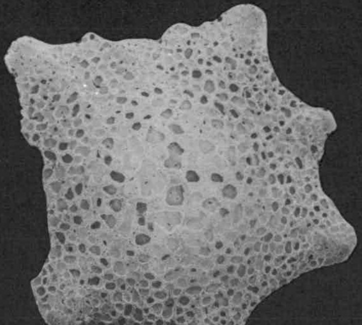
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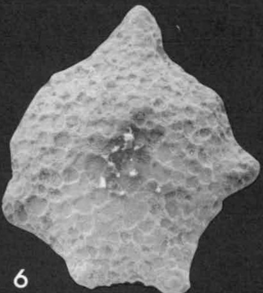
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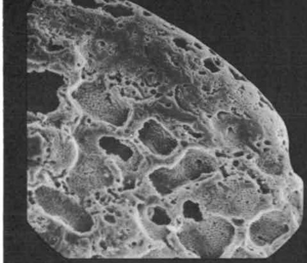
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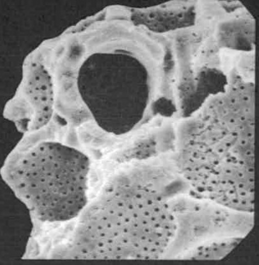
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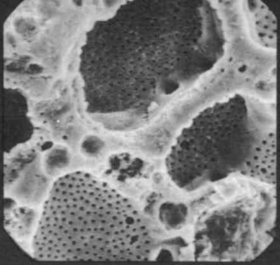

5c

PLATE 12

Fig.

1a–c **Lepidocyclina (Eulepidina) badjirraensis** Crespin.
UWA75117: a, external view of juvenile—x50; b, detail of a, showing porous lateral chamber walls—x310; c, equatorial view, showing embryoconch—x55.

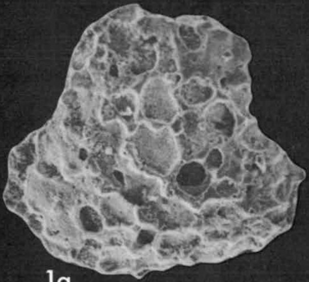
2a–c **Lepidocyclina (Eulepidina) badjirraensis** Crespin.
UWA75116: a, side view of part of test—x30; b, detail of a, showing the stolons opening into the equatorial chambers with their associated pectinations—x105; c, detail of b—x200. (cf. Pl. 9, fig. 5c; Pl. 10, figs. 5a–c.)

3 **Lepidocyclina (Eulepidina) badjirraensis** Crespin.
UWA75115: external view of small specimen—x20.

4a, b **Lepidocyclina (Eulepidina) ephippioides** Jones & Chapman.
UWA75113: a, external view showing lateral chambers—x20; b, detail of a, showing porous lateral chamber wall—x200.

5a, b **Lepidocyclina (Eulepidina) badjirraensis** Crespin.
UWA75114: a, side view of part of test—x15; b, detail of a, showing the layered structure of a lateral chamber wall—x200.

6 **Miogypsina (Miogypsina) intermedia** Drooger.
F70: side view of test, showing detail of the stolons of the equatorial chambers—x100 (cf. Pl. 9, fig. 5c; Pl. 10, figs. 5a–c).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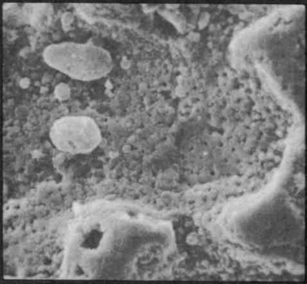
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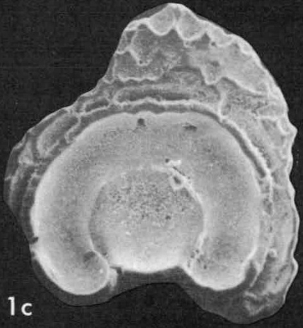
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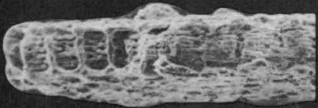
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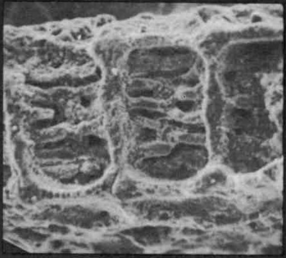
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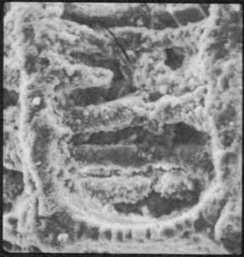
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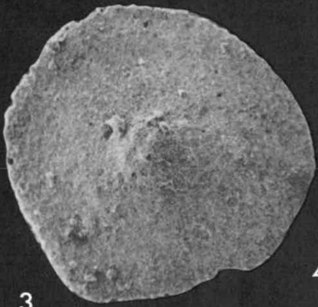
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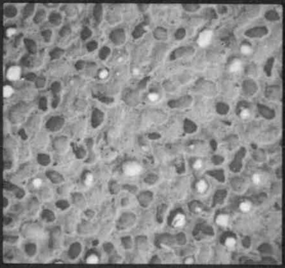
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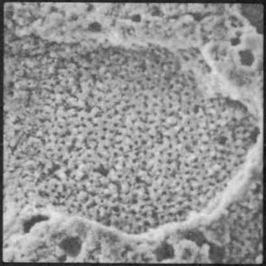
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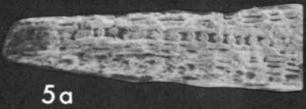
5a


5b


6

PLATE 13

Fig.

1a–d **Biarritzina proteiformis** (Goës).
UWA75112: a, side view showing basal attachment—x20; b, oblique view showing basal attachment—x20; c, apertural view—x40; d, detail of b, showing perforate wall—x80.

2a–d **Biarritzina carpenteriaeformis** (Halkyard).
UWA75109: a, side view—x20; b, view of opposite side to a, showing aperture of penultimate chamber—x20; c, basal view of attachment disc, showing juvenile part of test—x40; d, detail of test wall, showing pores—x200.

3a–c **Biarritzina carpenteriaeformis** (Halkyard).
UWA75110: a, side view of specimen attached to a fragment of a bryozoan; note apertures on earlier chambers—x30; b, apertural view—x40; c, detail of b, showing microstructure of test wall—x95.

4a, b **Biarritzina alternata** (Chapman & Crespin).
UWA75108: a, side view—x20, b, apertural view—x25.

5a, b **Victoriella conoidea** (Rutten).
F82: a, detail of b, showing morphology of test wall—x55; b, side view—x20.

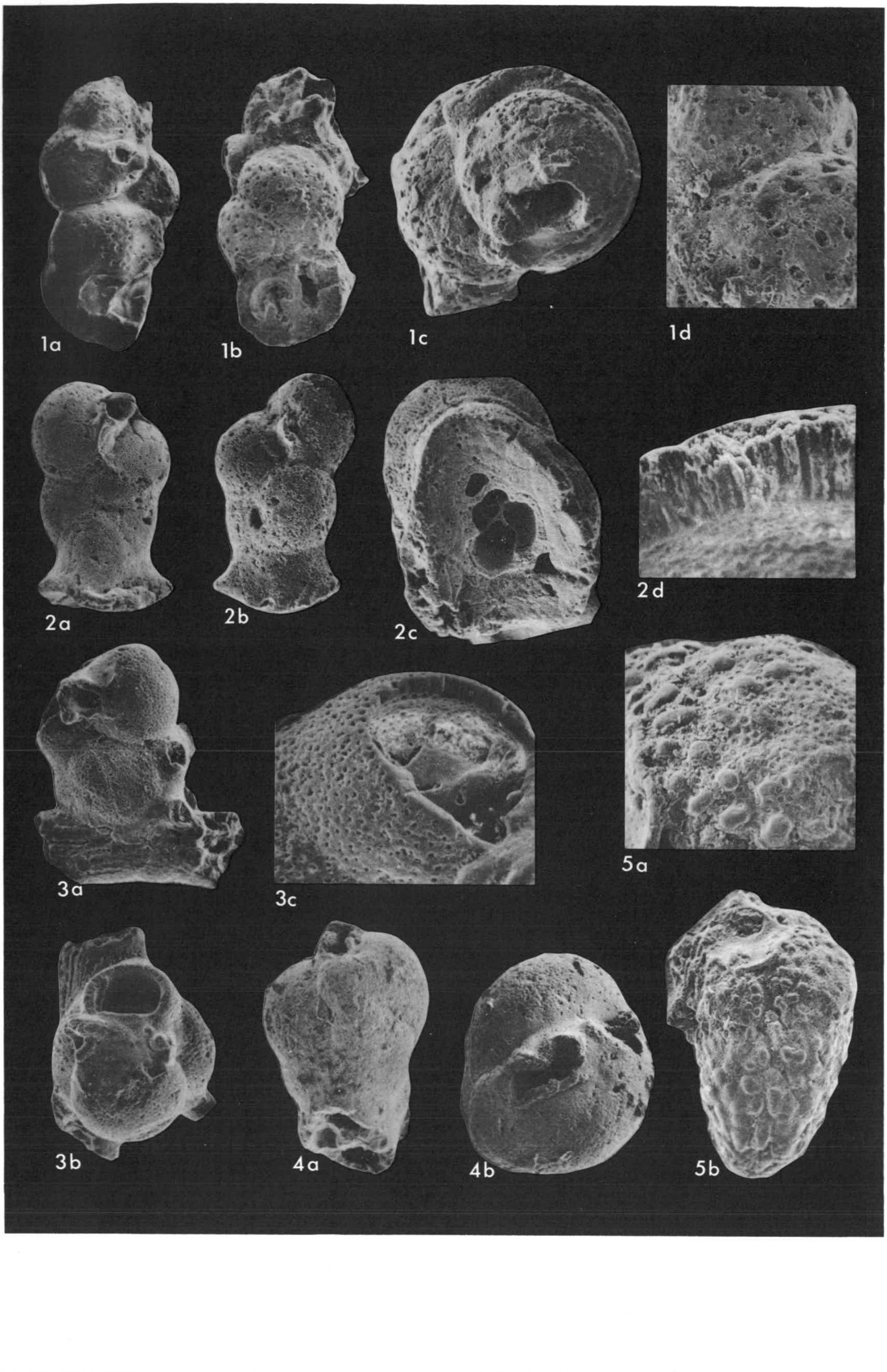
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PLATE 14

Fig.	
1, 2	**Austrotrillina howchini** (Schlumberger). Off-centre transverse sections: 1, UWA75006—x35; 2, UWA75007—x35.
3, 4	**Lacazinella** sp. cf. **L. wichmanni** (Schlumberger). Off-centre transverse sections: 3, UWA75011—x30; 4, UWA75010—x25.
5	**Spirolina** sp. CPC15686: equatorial section—x30.
6, 7	**Peneroplis** sp. 6, UWA75012: equatorial section—x30; 7, UWA75014: off-centre transverse section—x40.
8–10	**Sorites** sp. Off-centre transverse sections: 8, UWA75013—x35; 9, UWA75016—x35; 10, UWA75015—x15.
11–15	**Marginopora vertebralis** de Blainville. 11, UWA75017: transverse section—x20; UWA75019: transverse section—x25; 13, UWA75020: off-centre transverse section—x15; 14, UWA75018: off-centre transverse section—x25; 15, UWA75021: equatorial section—x20.
16, 17	**Borelis pygmaeus** Hanzawa. 16, CPC15688: off-centre transverse section—x30; 17, UWA75022: oblique axial section—x35.
18–21	**Flosculinella bontangensis bontangensis** (Rutten). 18, UWA75024: transverse section—x30; 19, CPC15689: transverse section—x20; 20, UWA75023: off-centre axial section—x15; 21, UWA75025: axial section—x16.
22	**Flosculinella bontangensis globulosa** (Rutten). UWA75027: axial section—x30.


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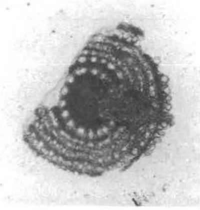
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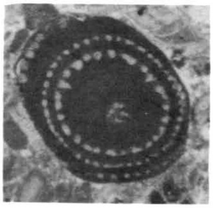
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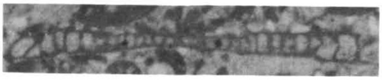
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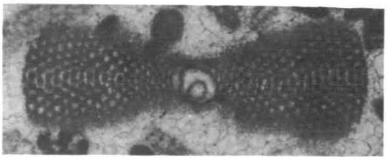
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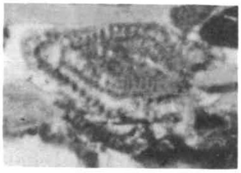
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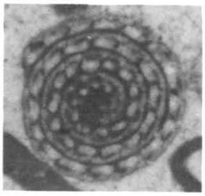
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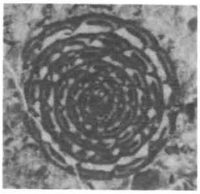
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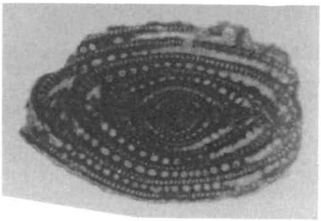
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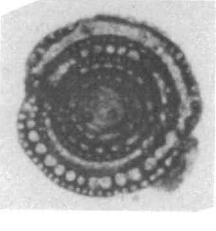
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PLATE 15

Fig.

1, 2 **Operculina complanata** (Defrance).
1, UWA75035: equatorial section—x15; 2, UWA75036: vertical section—x15.

3, 4 **Operculinella venosa** (Fichtel & Moll).
3, UWA75040: equatorial section—x20; 4, UWA75039: vertical section—x20.

5a–8 **Heterostegina borneensis** van der Vlerk.
5, UWA75062: 5a, equatorial section—x10; 5b, detail of 5a, showing embryoconch—x20; 6, UWA75061: equatorial section—x15; 7, UWA75060: equatorial section of microspheric form—x10; 8, UWA75063: vertical section—x25.

9, 10 **Spiroclypeus** sp. cf. **S. margaritatus** (Schlumberger).
9, CPC15696: slightly oblique equatorial section—x20; 10, CPC15687: slightly oblique, off-centre vertical section—x20.

11 **Operculina complanata** (Defrance).
UWA75037: vertical section—x20.

12, 13 **Cycloclypeus (Cycloclypeus)** sp. cf. **C. eidae** Tan.
12, CPC15690: equatorial section—x25; 13, CPC15691: equatorial section of microspheric form—x10.

14 **Cycloclypeus (Katacycloclypeus)** sp. cf. **C. annulatus** Martin.
UWA75056: vertical section—x10.

15, 16 **Cycloclypeus (Cycloclypeus)** sp. cf. **C. eidae** Tan.
15, UWA75055: vertical section—x10; 16, UWA75054: vertical section—x10.


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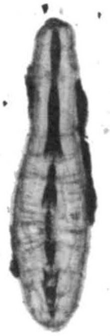
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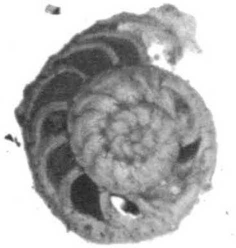
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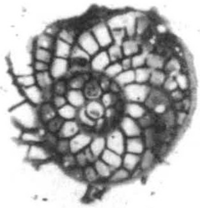
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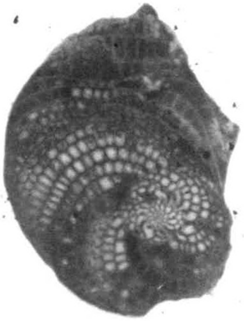
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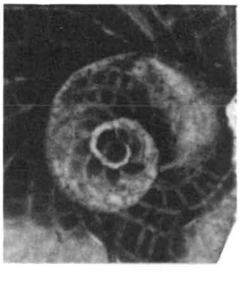
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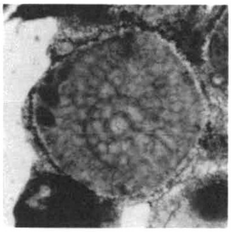
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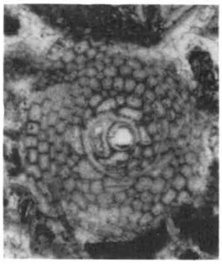
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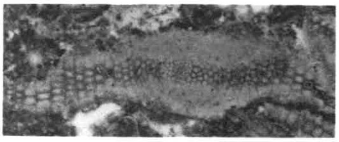
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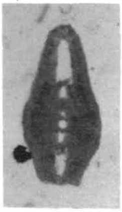
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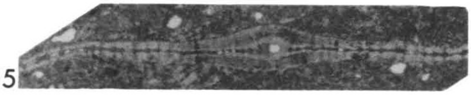
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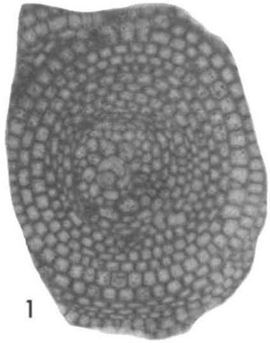
PLATE 16

Fig.	
1–5	**Cycloclypeus (Cycloclypeus) eidae** Tan. All equatorial sections: 1, UWA75050—x20; 2, UWA75053—x20; 3, UWA 75052—x20; 4, UWA75051—x20; 5, UWA75049—x20.
6–11	**Cycloclypeus (Cycloclypeus) carpenteri** Brady. All equatorial sections: 6, UWA75043—x20; 7, CPC15694—x20; 8, F77—x20; 9, CPC15692—x20; 10, CPC15693, microspheric form—x20; 11, UWA75250, microspheric form—x20.
12, 13	**Miogypsina (Miogypsina) intermedia** Drooger. Both equatorial sections: 12, F73—x12; 13, F72—x12.
14, 15	**Miogypsina (Miogypsina) globulina** (Michelotti). Both equatorial sections: 14, F67, microspheric form—x15; 15, F66—x20.
16, 17	**Miogypsina (Miogypsina) intermedia** Drooger. Both vertical sections: 16, F75—x15; 17, F74—x10.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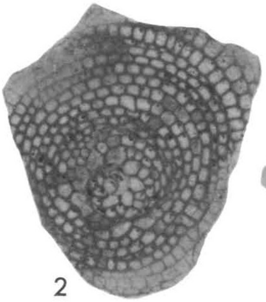
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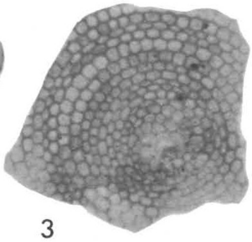
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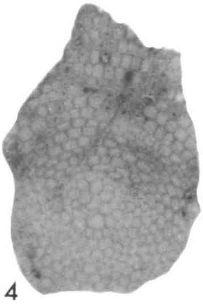
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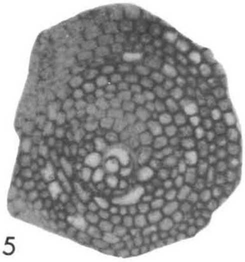
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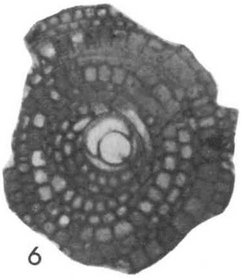
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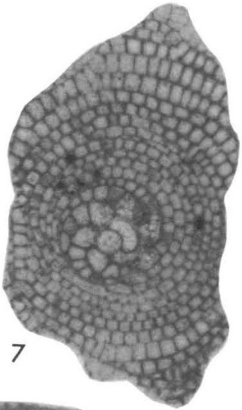
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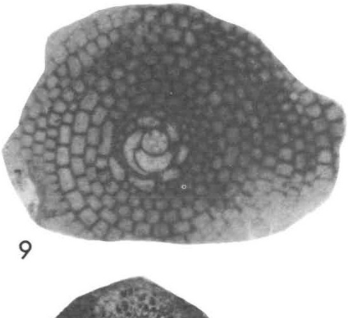
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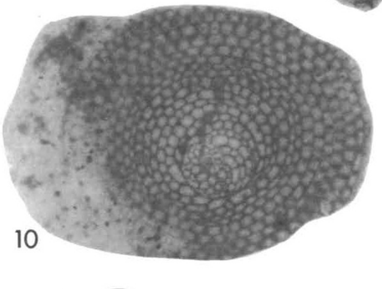
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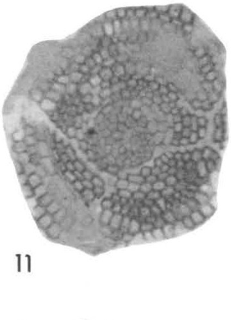
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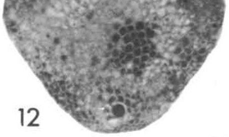
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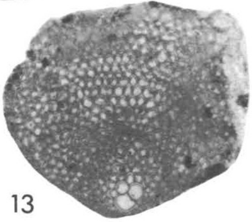
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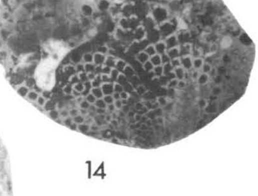
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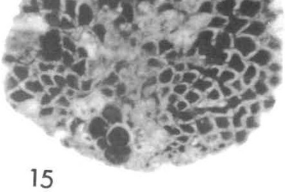
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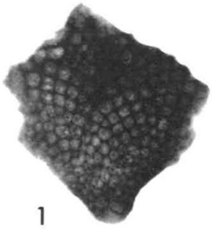
PLATE 17

Fig.	
1–11	**Miogypsina (Lepidosemicyclina) thecideaeformis** (Rutten). 1–8, equatorial sections; 9–11, vertical sections: 1, UWA75069—x15; 2, UWA75071—x15; 3, UWA75072—x15; 4, UWA75073—x25; 5, UWA75074—x20; 6, UWA75075—x20; 7, UWA75078—x20; 8, UWA75076, microspheric form—x15; 9, UWA75077—x20; 10, UWA75079—x20; 11, UWA75070, microspheric form—x15.
12–14	**Miogypsina (Lepidosemicyclina)** sp. cf. **M. thecideaeformis** (Rutten). 12, CPC15697: vertical section—x12; 13, CPC15698: off-centre vertical section—x15; 14, CPC15699: off-centre vertical section—x15.
15–17	**Miogypsina (Miogypsinoides) dehaarti** van der Vlerk. 15, UWA75083: equatorial section—x25; 16, UWA75085: equatorial section—x20; 17, UWA75084: vertical section—x40.
18	**Amphistegina bikiniensis** Todd & Post. UWA75087: vertical section—x40.
19–22	**Amphistegina hauerina** d'Orbigny. All vertical sections: 19, UWA75093—x25; 20, UWA75090—x45; 21, UWA75092—x25; 22, UWA75091—x50.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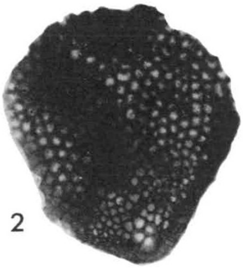
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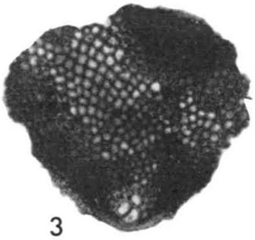
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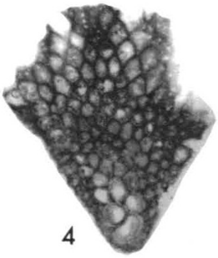
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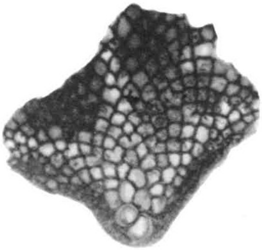
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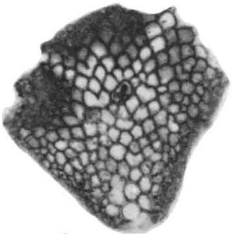
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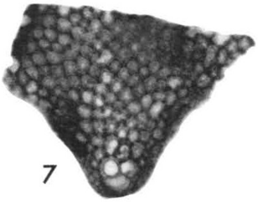
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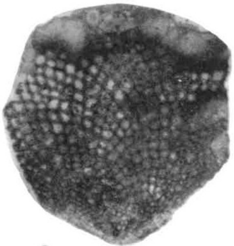
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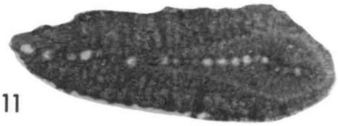
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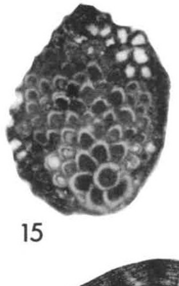
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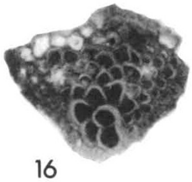
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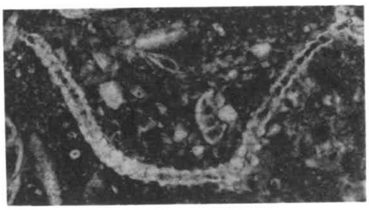
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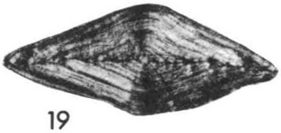
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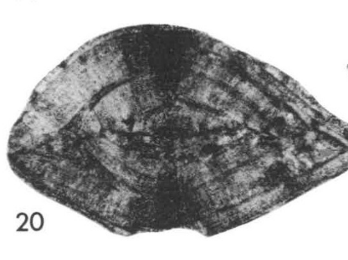
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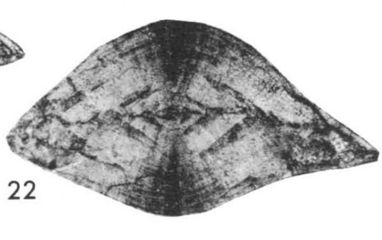
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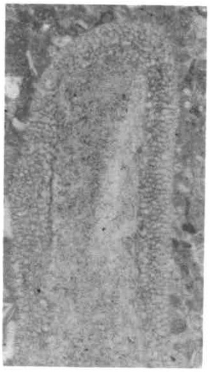
PLATE 18

Fig.	
1, 2	**Borodinia septentrionalis** Hanzawa. Both transverse sections: 1, CPC15700—x10; 2, UWA75094—x10.
3a–6	**Gypsina howchini** Chapman. Figs. 3, 4, equatorial sections; figs. 5, 6, vertical sections, 3, UWA75100: 3a—x15, 3b—detail of a, showing embryonic apparatus—x70; 4, UWA75103—x20; 5, UWA75101—x15; 6, UWA75102—x20.
7	**Gypsina globulus** (Reuss). UWA75097: vertical section—x20.
8, 9	**Gypsina mastaelensis** Bursch. 8, UWA75104: oblique vertical section—x40; 9, UWA75105: vertical section—x30.
10	**Biarritzina carpenteriaeformis** (Halkyard). UWA75111: longitudinal section—x30.
11–15	**Lepidocyclina (Eulepidina) badjirraensis** Crespin. All equatorial sections: 11, UWA75120—x12; 12, UWA75124, microspheric form—x10; 13, UWA75122—x12; 14, UWA75123—x12; 15, UWA75121—x16.
16	**Lepidocyclina (Eulepidina) ephippioides** Jones & Chapman. UWA75125: vertical section—x8.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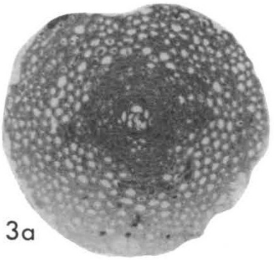
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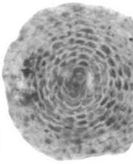
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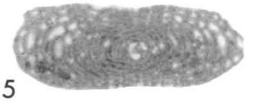
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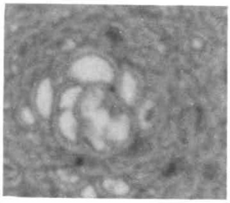
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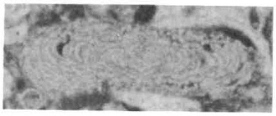
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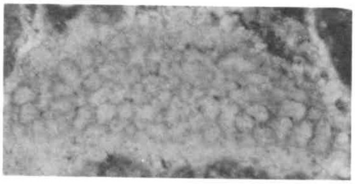
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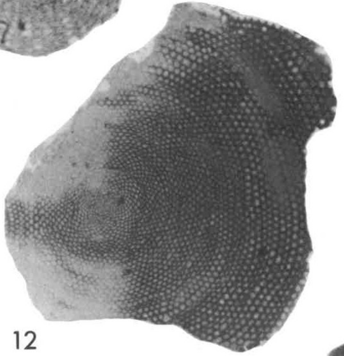
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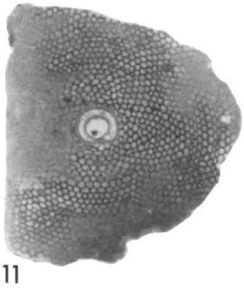
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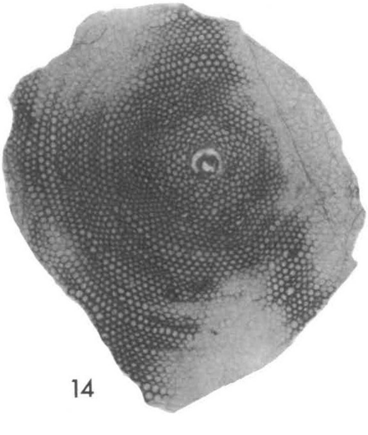
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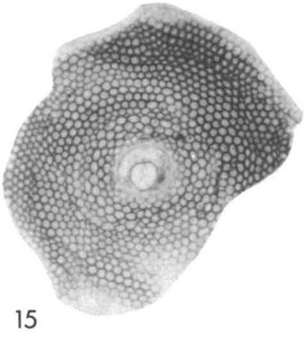
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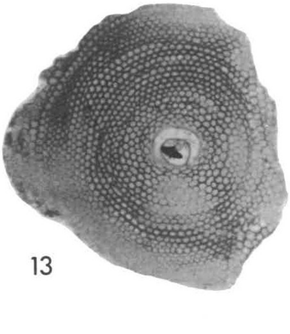
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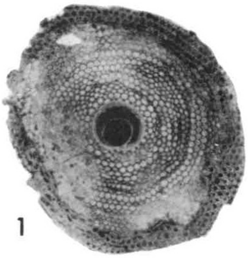
PLATE 19

Fig.

1–7 **Lepidocyclina (Eulepidina) ephippioides** Jones & Chapman.
Figs. 1–4, equatorial sections; figs. 5–7, vertical sections: 1, UWA75128—x8; 2, UWA75129—x10; 3, UWA75130—x10; 4, UWA75131, microspheric form—x10; 5, UWA75132—x10; 6, UWA75133, microspheric form—x7; 7, F64—x10.

8–15 **Lepidocyclina (Nephrolepidina) howchini howchini** Chapman & Crespin.
Figs. 8–12, equatorial sections; figs. 13–15, vertical sections: 8, UWA75153—x15; 9, UWA75151—x20; 10, UWA75149—x15; 11, UWA75150—x15; 12, UWA75152—x15; 13, UWA75155—x15; 14, UWA75156—x15; 15, UWA75154—x15.



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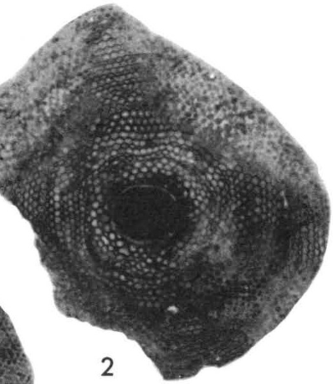

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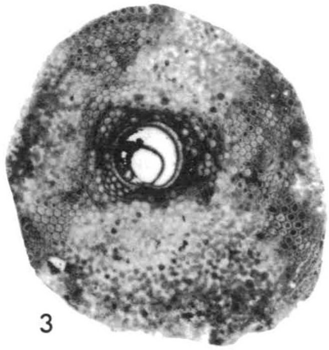

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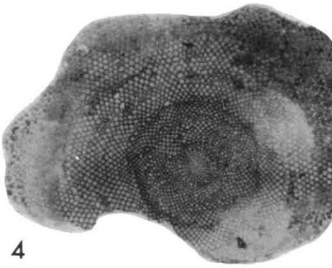

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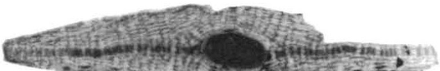

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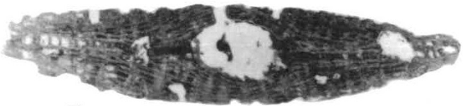

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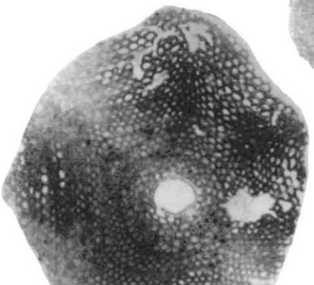

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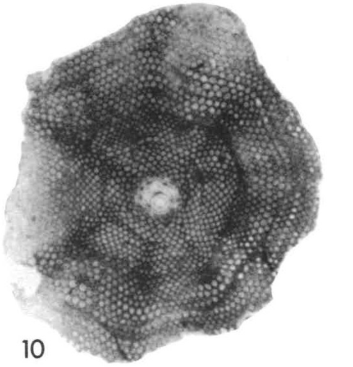

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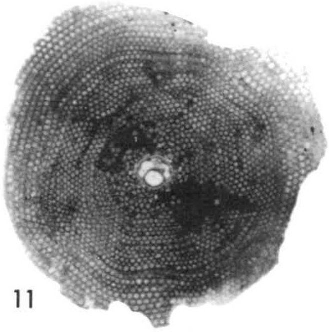

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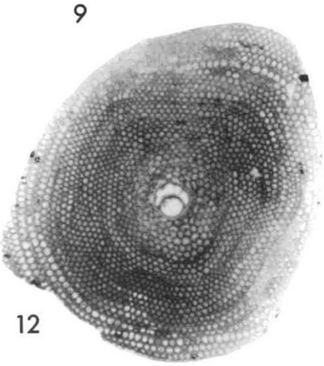

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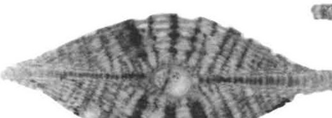

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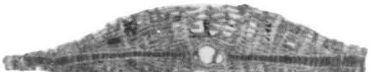

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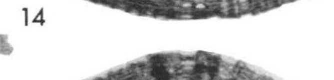

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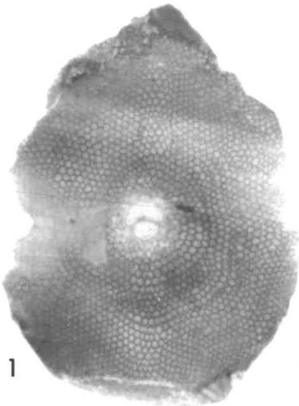
PLATE 20

Fig.	
1–12	**Lepidocyclina (Nephrolepidina) howchini howchini** Chapman & Crespin. Figs. 1–3, 7–12, equatorial sections; figs. 4–6, vertical sections: 1, UWA75157 x15; 2, UWA75158—x18; 3, UWA75159—x15; 4, UWA75161—x15; 5, UWA75160—x15; 6, UWA75162—x17; 7, CPC15702—x20; 8, CPC15705—x20; 9, CPC15703—x20; 10, CPC15706—x20; 11, CPC15704—x20; 12, CPC15707, microspheric form—x16.
13–16	**Lepidocyclina (Nephrolepidina) japonica** (Yabe). Equatorial sections: 13, UWA75234—x20; 14, UWA75237—x20; 15, UWA75235—x20; 16, UWA75236—x20.



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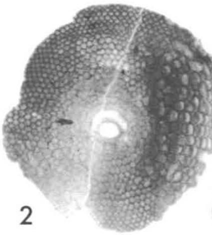

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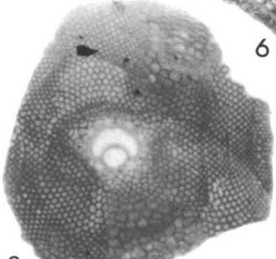

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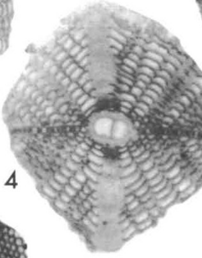

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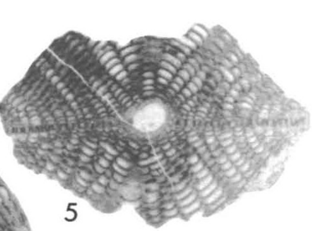

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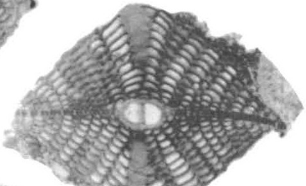

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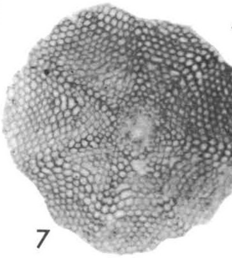

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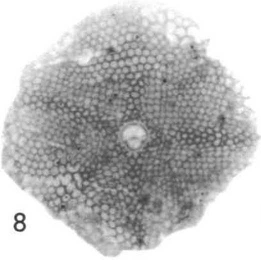

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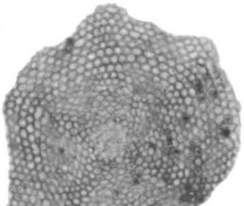

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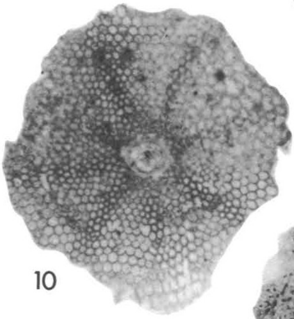

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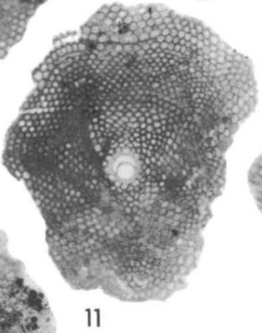

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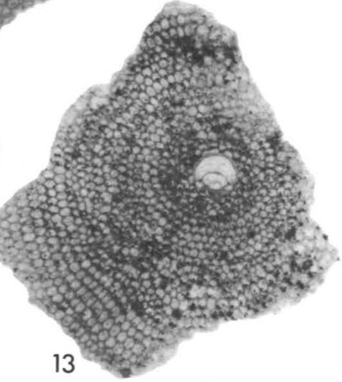

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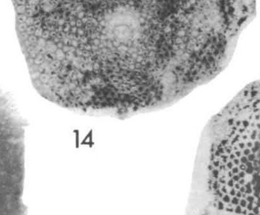

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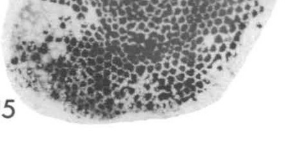

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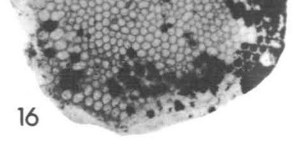

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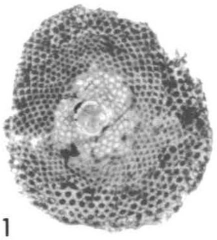
PLATE 21

Fig.

1–6 **Lepidocyclina (Nephrolepidina) howchini howchini** Chapman & Crespin.
Equatorial sections of topotypes: 1, CPC21580; 2, CPC21573; 3, CPC21575; 4, CPC21568; 5, CPC21578; 6, CPC21574. All x20.

7–13 **Lepidocyclina (Nephrolepidina) orakeiensis hornibrooki** Matsumaru.
Topotypes: 7–12, equatorial sections; 13, vertical section. 7, FP3211; 8, FP3210; 9, FP3209; 10, FP3212; 11, FP3208; 12, FP3207; 13, FP3213. All x20.

14 **Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis** (Karrer).
Equatorial section: CPC21563—x20.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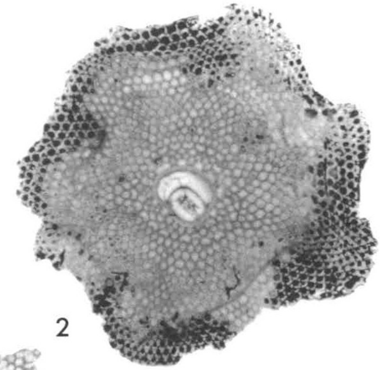
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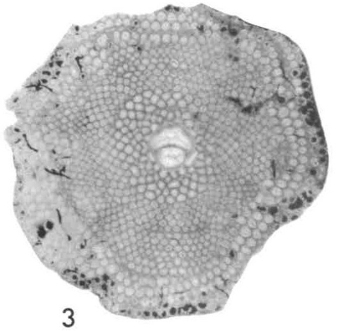
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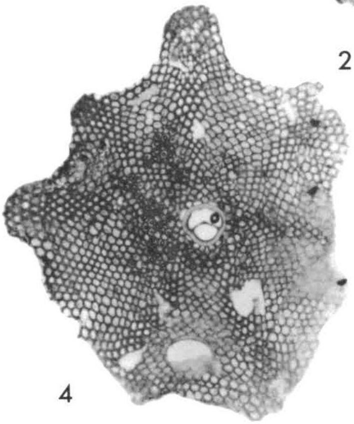
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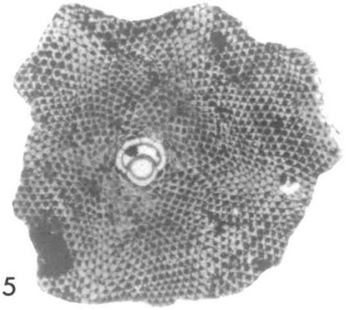
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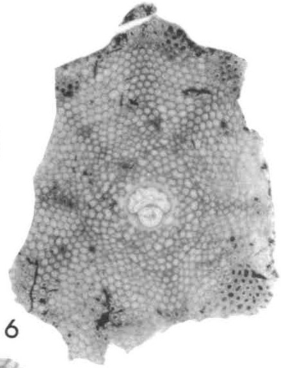
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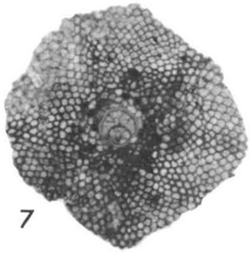
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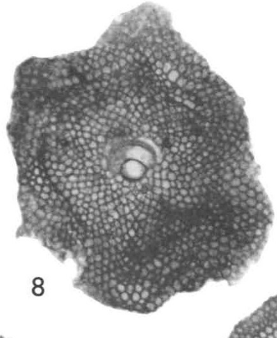
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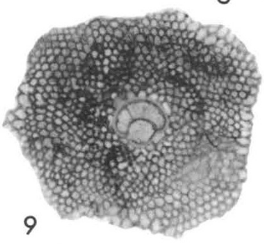
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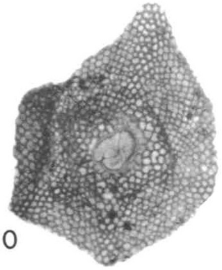
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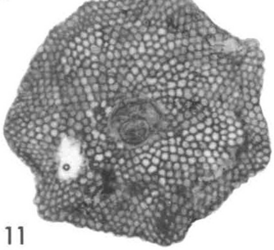
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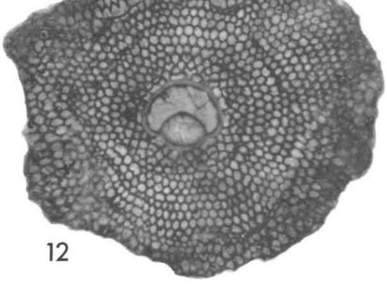
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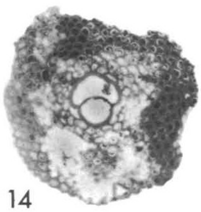
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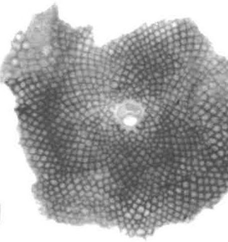
PLATE 22

Fig.	
1–13, 15–17	**Lepidocyclina (Nephrolepidina) howchini praehowchini** subsp. nov. Paratypes—figs. 1–6, 10–13, 15, equatorial sections; figs. 7–9, 16, 17, vertical sections: 1, UWA75173—x16; 2, UWA75175—x16; 3, UWA75178—x16; 4, UWA75176, microspheric form—x8; 5, UWA75177—x16; 6, UWA75174—x16; 7, UWA75180—x16; 8, UWA75179—x18; 9, UWA75181—x16; 10, UWA75224—x20; 11, UWA75228—x20; 12, UWA75226—x16; 13, UWA-75227—x20; 15, UWA75225—x20; 16, UWA75229—x20; 17, UWA75230—x20.
14	**Lepidocyclina (Nephrolepidina) sumatrensis** (Brady). UWA75242: equatorial section—x16.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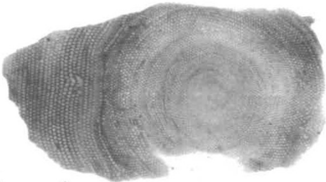
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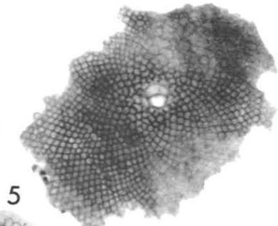
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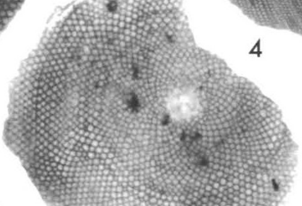
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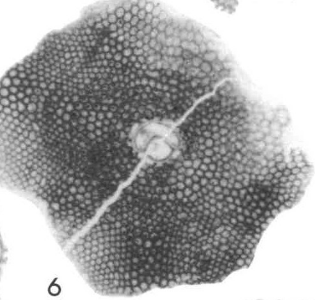
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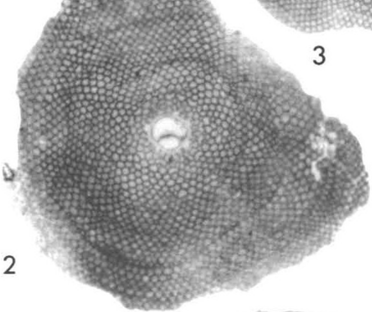
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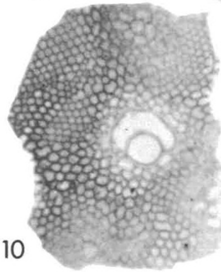
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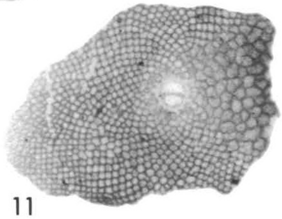
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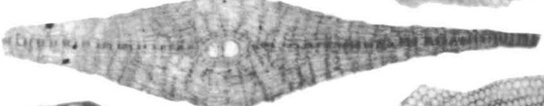
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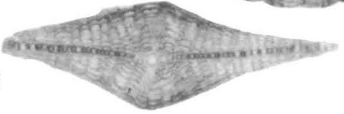
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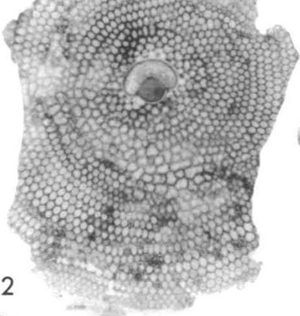
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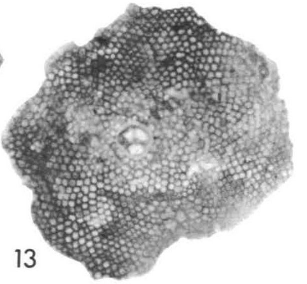
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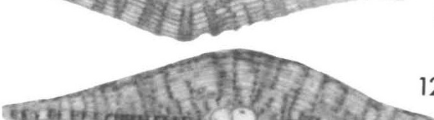
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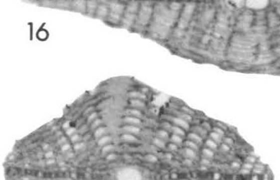
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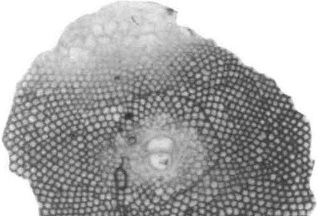
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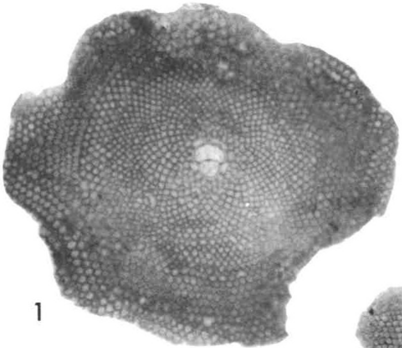
PLATE 23

Fig.

1–7 **Lepidocyclina (Nephrolepidina) sumatrensis** (Brady).
Figs. 1–4, equatorial sections; figs. 5–7, vertical sections: 1, UWA75243—x16; 2, UWA75244—x16; 3, UWA75246—x16; 4, UWA75245, microspheric form x16; 5, UWA75249—x20; 6, UWA75247—x16; 7, UWA75248—x20.

8–15 **Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis** (Karrer).
Figs. 8–11, equatorial sections; figs. 12–15, vertical sections: 8, F53—x20; 9, F54—x16; 10, F55—x16; 11, F57, microspheric form—x16; 12, F60—x20; 13, F58—x25; 14, F59—x16; 15, F61, microspheric form—x8.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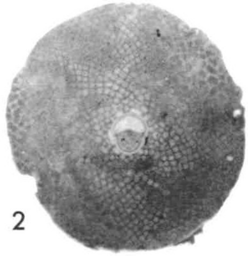
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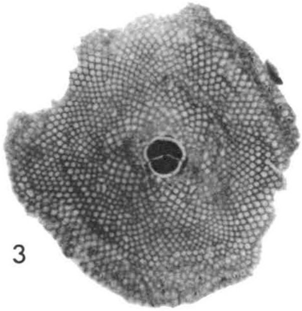
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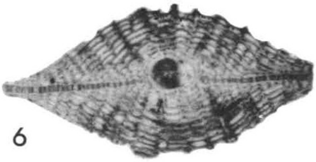
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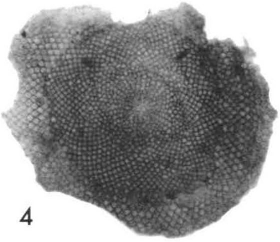
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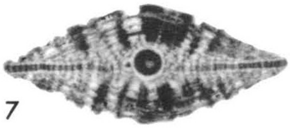
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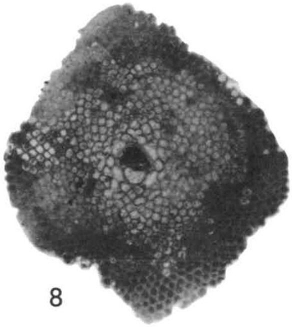
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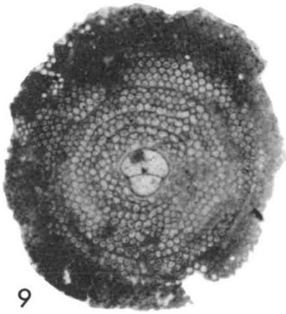
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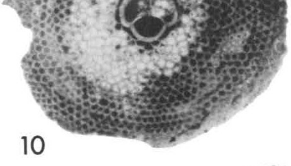
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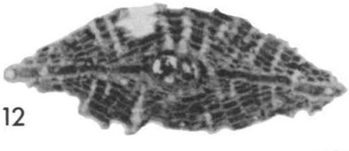
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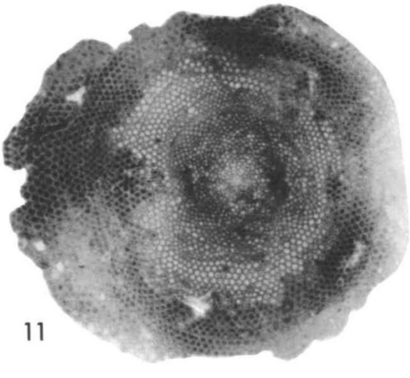
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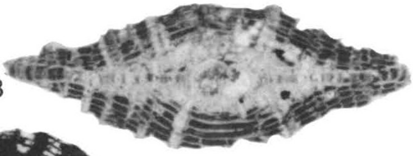
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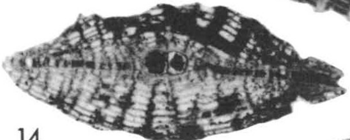
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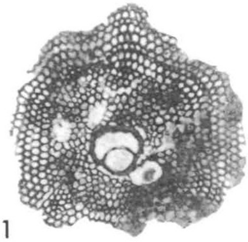
PLATE 24

Fig.	
1–13	**Lepidocyclina (Nephrolepidina) orakeiensis waikukuensis** subsp. nov. Paratypes—figs. 1–6, 8–12, equatorial sections; fig. 7, vertical section; fig. 13, external view: 1, F18—x16; 2, F19—x16; 3, F20—x16; 4, F21—x16; 5, F22—x16; 6, F23—x16; 7, F24—x25 8, F47—x16; 9, F46—x16; 10, F48—x16; 11, F25, microspheric form—x16; 12, F49—x16; 13, F17—x16.
14, 15	**Lepidocyclina (Nephrolepidina) orakeiensis orakeiensis** (Karrer). External views: 14, F81, microspheric form—x8; 15, F80—x15.
16–18	**Lepidocyclina (Nephrolepidina) japonica** (Yabe). External views; in fig. 18 the specimen is in glycerine. 16, UWA75232—x15; 17, UWA75233—x12; 18, UWA75231—x20. Note the thickened areas over the rays.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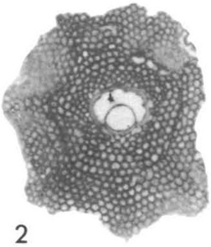
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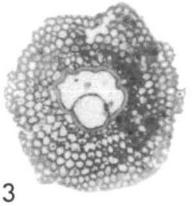
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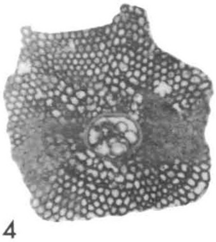
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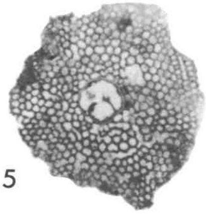
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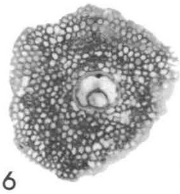
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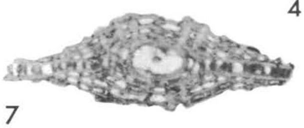
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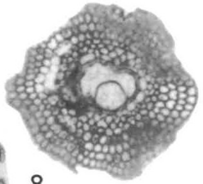
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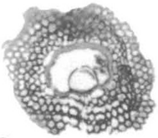
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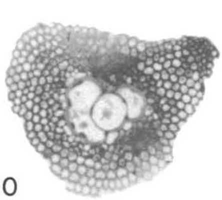
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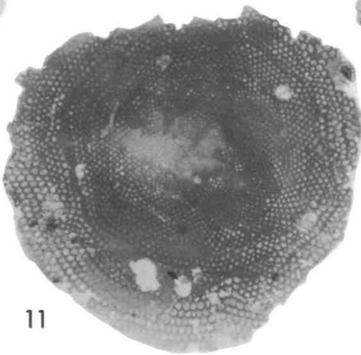
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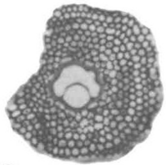
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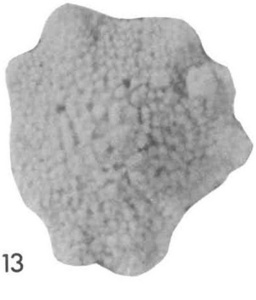
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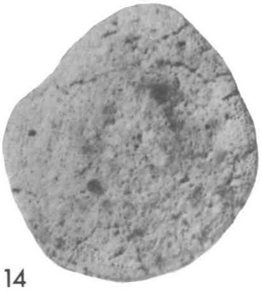
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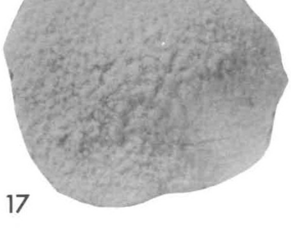
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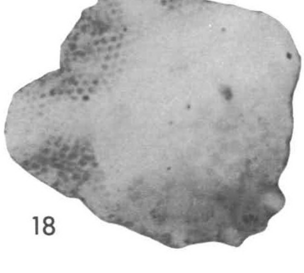
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PLATE 25

All are external views.

Fig.	
1–6	**Operculina complanata** (Defrance). 1, UWA75033—x10; 2, UWA75032—x10; 3, UWA75029—x14; 4, UWA75034—x10; 5, UWA75031—x10; 6, UWA75030—x11.
7	**Operculinella venosa** (Fichtel & Moll). UWA75038—x25.
8–10	**Cycloclypeus (Cycloclypeus) eidae** Tan. 8, UWA75046—x10; 9, UWA75048—x10; 10, UWA75047—x10.
11, 12	**Heterostegina borneensis** van der Vlerk. 11, UWA75059—x12; 12, UWA75058—x12.
13	**Heterostegina suborbicularis** d'Orbigny CPC15695—x30.
14	**Miogypsina (Lepidosemicyclina) thecideaeformis** (Rutten). UWA75068—x15.
15, 16	**Lepidocyclina (Eulepidina) badjirraensis** Crespin. 15, UWA75119—x6; 16, UWA75118—x1.5.
17	**Lepidocyclina (Eulepidina) ephippioides** Jones & Chapman. UWA75127—x5.

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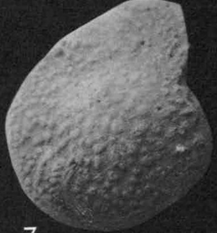

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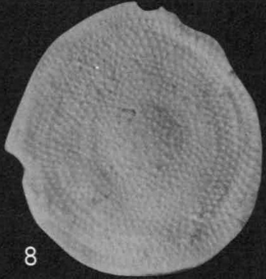

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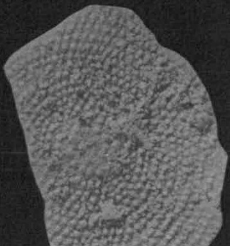

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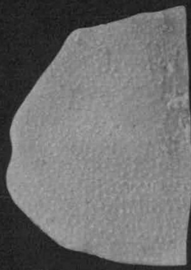

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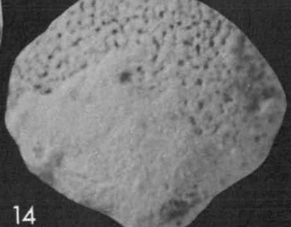

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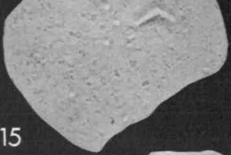

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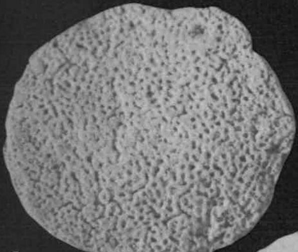
PLATE 26

All are external views.

Fig.	
1, 2	**Lepidocyclina (Eulepidina) ephippioides** Jones & Chapman. 1, F79—x5; 2, UWA75126—x4.
3–6	**Lepidocyclina (Nephrolepidina) howchini howchini** Chapman & Crespin. 3, UWA75147—x9; 4, UWA75146—x10; 5, UWA75148—x18; 6, UWA75145—x10.
7–14	**Lepidocyclina (Nephrolepidina) howchini praehowchini** subsp. nov. Figs. 7, 9–14, paratypes; fig. 8, holotype: 7, UWA75167—x10; 8, UWA75163—x10; 9, UWA75168—x12; 10, UWA75171—x10; 11, UWA75170, microspheric form—x7; 12, UWA75169—x12; 13, UWA75172, microspheric form—x8; 14, UWA75165—x10.
15, 16	**Lepidocyclina (Nephrolepidina) sumatrensis** (Brady). 15, UWA75240—x12; 16, UWA75241—x15.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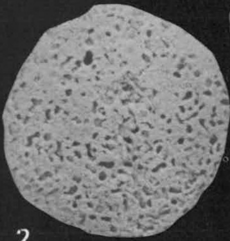
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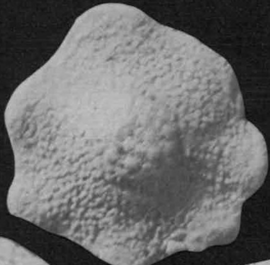
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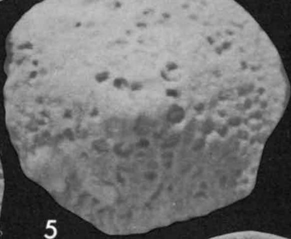
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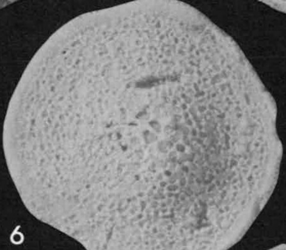
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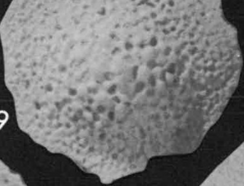
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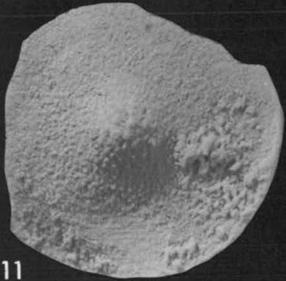
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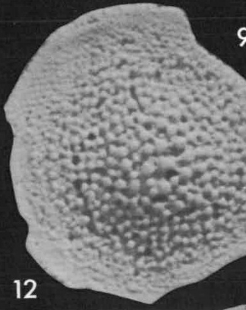
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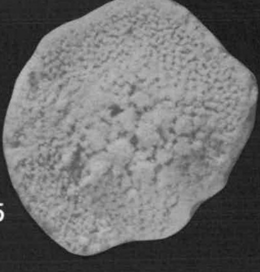
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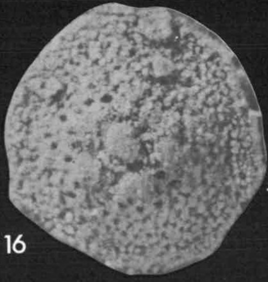
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