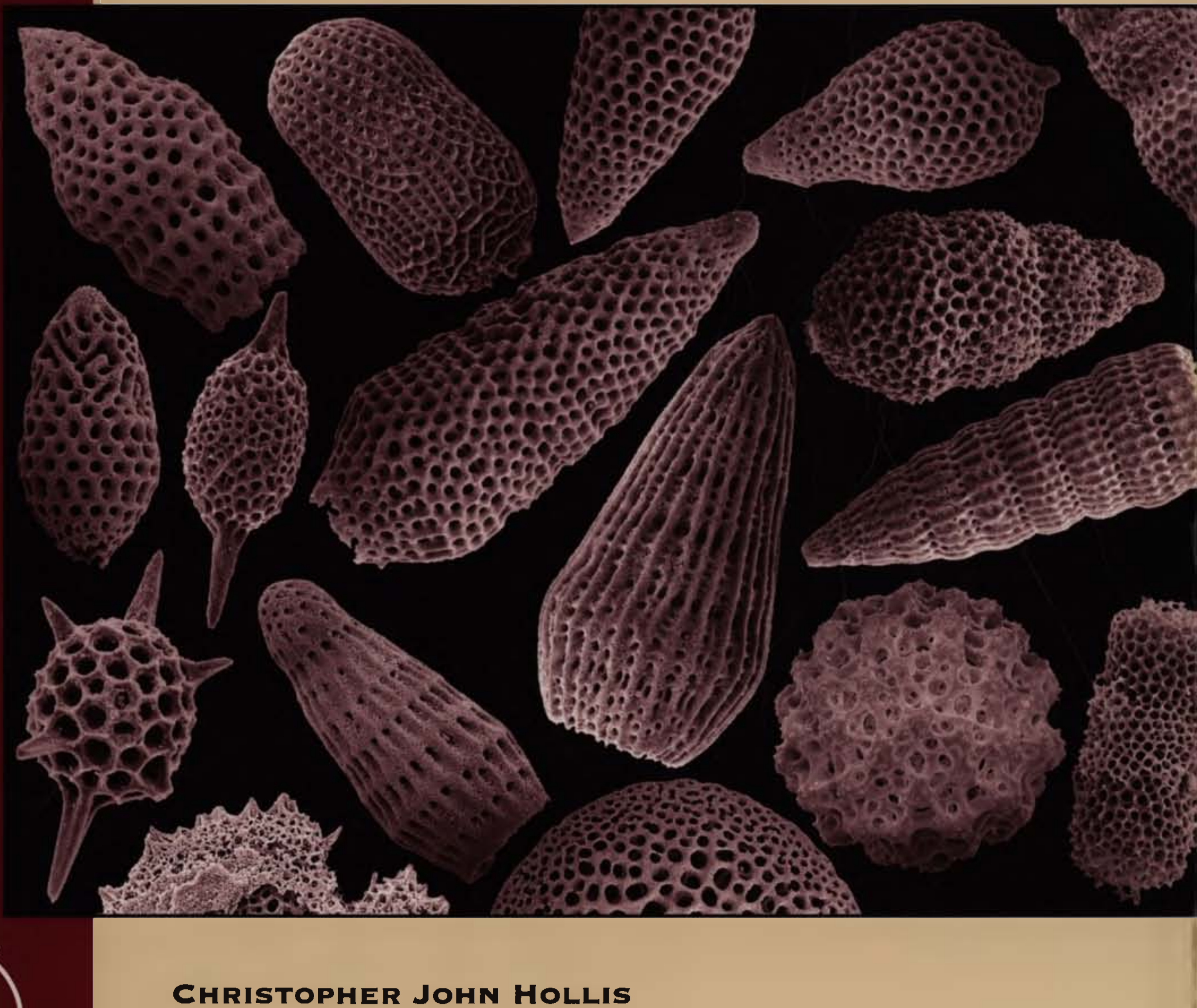
monograph 17

CRETACEOUS-PALEOCENE RADIOLARIA FROM EASTERN MARLBOROUGH, NEW ZEALAND



CHRISTOPHER JOHN HOLLIS

Institute of
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CRETACEOUS-PALEOCENE RADIOLARIA FROM EASTERN MARLBOROUGH, NEW ZEALAND

CHRISTOPHER JOHN HOLLIS

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Front cover Pseudo-scatter of digital images of radiolarians from Woodside Creek sample P30/f375 illustrates the striking feature of Paleocene assemblages from this section. Even at 31 m above the Cretaceous-Tertiary boundary, Paleocene index species such as *Buryella dumitrica* (top left), *Amphisphaera goruna* (bottom left), and *Spongurus* cf. *bilobatus* (bottom right) are accompanied by abundant Cretaceous survivors (remaining specimens).

CONTENTS

ABSTRACT

The pelagic lithofacies of the Mead Hill Formation, eastern Marlborough, New Zealand, contain the most complete record known of radiolarian evolution through the Cretaceous-Tertiary (K-T) transition. The K-T boundary is well-defined, both by microfossils and the "impact" signal of the boundary clay, and the earliest Paleocene record is relatively intact within a Late Cretaceous to Late Paleocene sequence of limestone, porcellanite, chert, and marl.

This monograph presents systematic descriptions of 98 radiolarian species or species groups, within 58 genera, which comprise the main elements in the radiolarian faunas of four Cretaceous-Paleocene sections in eastern Marlborough: Woodside Creek, Wharanui Point, Chancet Rocks, and Flaxbourne River. The distribution of these species is documented in secondary localities in inland Marlborough (Mead Stream), Wairarapa, Chatham Island, Lord Howe Rise (DSDP Site 208), and Campbell Plateau (DSDP Site 275).

Six new Cretaceous-Paleocene species are described: *Protoxiphotractus wilsoni, Lithomelissa? aitai, Botryostrobus? parsonsae, Phormostichoartus strongi, Eusyringium woodsidensis, Lithocampe wharanui.* Four new Paleocene species are described: *Haliomma teuria, Lithelius marshalli, Clathrocyclas australis, Buryella kaikoura.*

Improved knowledge on the stratigraphic distribution of the species treated, as well as improved foraminiferal age control at Flaxbourne River, are incorporated into revisions to previous radiolarian zonations for the New Zealand region.

No evidence is found for mass extinction of radiolarians across the Cretaceous-Tertiary (K-T) boundary in Marlborough. Estimates of species extinctions range from 0-8% of the total fauna. No species have last occurrences directly below the boundary, but five species are either restricted to the Cretaceous or have only isolated occurrences in the Paleocene, possibly due to reworking. Most Cretaceous survivors disappear in a relatively short interval in mid Early Paleocene (63.5-63 Ma) following a period of high siliceous plankton productivity. It is within this earliest Paleocene interval (65-63.5 Ma) that 60% of the recorded Paleocene species first appear, including the ancestors of several important early Tertiary lineages: *Amphisphaera aotea/goruna, Amphymenium splendiarmatum, Lithelius s.s., Amphicraspedum prolixum* gr., *Dorcadospyris, Dictyophimus,* and *Buryella.*

Keywords Radiolaria, taxonomy, biostratigraphy, Cretaceous-Tertiary boundary, Maastrichtian, Paleocene, Haumurian, Teurian, extinction, survival, diversification, Marlborough, New Zealand, southwest Pacific

CHAPTER 1. INTRODUCTION

1.1. SCOPE AND AIMS

This monograph is a taxonomic and biostratigraphic study of the radiolarian faunal succession in four well-known Cretaceous-Tertiary (K-T) boundary sections in eastern Marlborough: Woodside Creek, Wharanui Point, Chancet Rocks, and Flaxbourne River. To better delimit the geographic and stratigraphic distribution of the radiolarian species described here, faunas from additional localities within the New Zealand region (Fig. 1) have been examined or reassessed. These are inland Marlborough (Mead Stream), Wairarapa (Mara, Kaiwhata Stream), Chatham Island (Tioriori), and sedimentary sequences recovered by the Deep Sea Drilling Project (DSDP) from southern Campbell Plateau (DSDP Site 275) and northern Lord Howe Rise (DSDP Site 208).

The aims of the study are (1) to describe and illustrate the main radiolarian taxa present in the latest Cretaceous and Early Paleocene of eastern Marlborough, (2) to document the spatial and temporal distribution of these species within the New Zealand region and beyond, (3) to incorporate new findings in a revision of the local Cretaceous-Paleogene radiolarian zonation (Hollis 1993a; Strong *et al.* 1995) which may have application in other regions, and (4) to update the record of radiolarian survivorship and diversification through the Cretaceous-Tertiary transition (Hollis 1993b,1996) in relation to a revised and expanded faunal list.

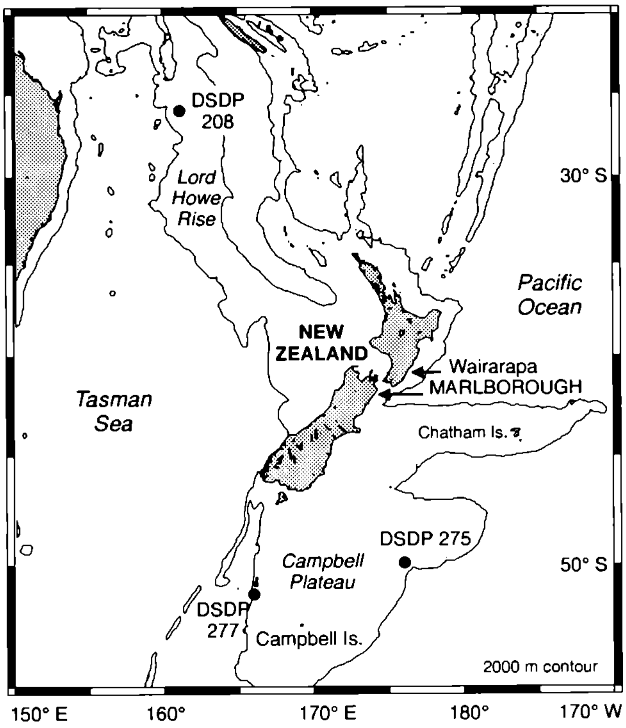

Figure 1 Map of New Zealand microcontinent showing location of eastern Marlborough study area and other localities examined.

1.2. PREVIOUS WORK

This monograph is based on the doctoral study of Hollis (1991) of radiolarians from the four primary sections, and the Cretaceous-Paleocene intervals at Mead Stream, inland Marlborough, and DSDP Site 208, northern Lord Howe Rise.

That study was the first to examine Late Cretaceous or Paleogene radiolarians from on-land New Zealand. It resulted in the first radiolarian zonation for latest Cretaceous to Late Paleocene (Hollis 1993a), and the first analysis of radiolarian faunal change across the K-T boundary (Hollis 1993b, 1996). Those studies led to more detailed analysis of the K-T transition (Hollis *et al.* 1995) and an integrated biostratigraphic study of radiolarians, foraminifera and dinoflagellates from Mead Stream (Strong *et al.* 1991, 1995).

Pessagno (1975) reported on latest Cretaceous radiolarians from DSDP Site 275, southern Campbell Plateau (Fig. 1). The Paleocene radiolarian assemblages from DSDP Site 208 were the subject of a short note by Dumitrica (1973), and several new species were later described by Petrushevskaya (1977). Later Paleogene radiolarian assemblages from the New Zealand region were described by Chen (1974: DSDP 274, Ross Sea) Petrushevskaya (1975: DSDP Sites 280 and 281, south Tasman Sea), and Caulet (1986: DSDP 592). Most recently, O'Connor completed a series of studies of Miocene-Oligocene radiolarians from Northland (O'Connor 1993,1994, in press, a,b), and is currently completing a study of radiolarians from the Late Eocene Oamaru Diatomite (Edwards 1991).

The only previous study of radiolarians from a K-T boundary section is that of Foreman (1968). In her monograph on late Maastrichtian radiolarians from California she recorded the progressive disappearance of selected Maastrichtian species across a K-T transitional interval within a corehole at Cima Hill, Fresno County. Although often cited as a guide to levels of radiolarian extinction at the boundary, this study was incomplete, as it did not establish the location of the boundary or describe the total radiolarian fauna.

1.3. LATE CRETACEOUS-PALEOGENE TIMESCALE

The timescale used in this monograph is shown in Figure 2. New Zealand stages are correlated with the geochronometric scale of Berggren *et al.* (1995) using the most reliable local datums (Edwards *et al.* 1988; Hornibrook *et al.* 1989). Standard abbreviations for these stages are shown in the figure. Lower case prefixes "e" and "l" refer to informal subdivisions "early" and "late".

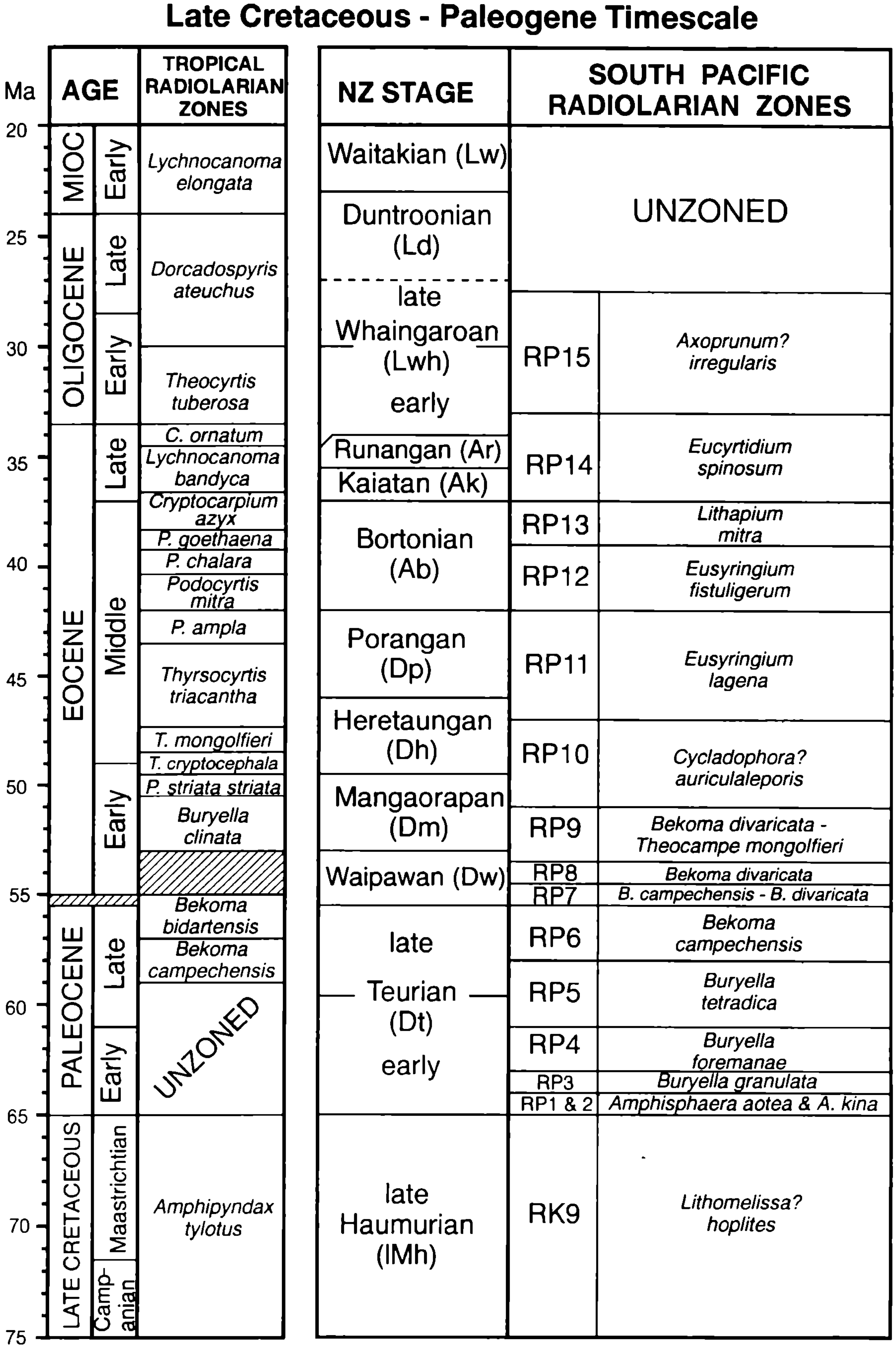

Figure 2 Latest Cretaceous-Paleogene timescale. Datums from Bolli *et al.* (1985) and Sanfilippo and Nigrini (in press) used to calibrate tropical radiolarian zonation to timescale of Berggren *et al.* (1995). Calibration with New Zealand stages based on Edwards *et al.* (1988) and Hornibrook *et al.* (1989). South Pacific radiolarian zonation (RK9, RP1-13) based on Hollis (1993) and Strong *et al.* (1995) as revised herein (Chapter 3), and Hollis *et al.* (1997). The latter study identified *the Eucyrtidium spinosum* and *Axoprunum? irregularis* zones of Takemura (1992) at South Campbell Plateau DSDP Site 277.

A twofold subdivision of the Teurian Stage is adopted, with the base of the late Teurian placed at the First Appearance Datum of nannofossil *Fasciculithus tympaniformis* (base of Nannofossil Zone NP5), an event considered relatively synchronous between high and low latitudes (Edwards *et al.* 1988; Berggren *et al.* 1995: 59.7 Ma). Correlation of radiolarian zones with the timescale is discussed in section 3.1.

1.4. SAMPLE COLLECTION AND PREPARATION

Rock names (Fig. 3) are based on the ternary scheme of Gilbert (1954) as modified by Compton 1962). Carbonate content is mainly a qualitative assessment based on reaction to hydrochloric acid, and comparison with samples for which X-ray diffraction and X-ray fluorescence analyses (Hollis *et al.* 1995) are available. Lithologies which contain more than 50% silica have previously been labelled "siliceous limestone" based on their appearance in the field (Strong 1977; Hollis 1993a) or "calcareous chert" based on their composition (Hollis *et al.* 1995). Here, "porcellanite" is used for highly siliceous rocks which, because of the presence of carbonate or terrigenous mud (Blatt *et al.* 1980), lack the vitreous lustre and conchoidal fracture of true chert or flint.

Sampling was constrained in most situations only by sample interval and general lithologic characteristics. Field examination of calcareous samples by etching with hydrochloric acid (Pessagno 1976) did not prove practicable, as radiolarians could not be easily distinguished from silicified foraminifera tests. In general, porcellanite or limestone was selected rather than chert nodules or marl/mudstone interbeds. Samples were processed by standard acid-leaching techniques for radiolarian extraction (e.g. Pessagno 1976; Sanfilippo & Riedel 1985).

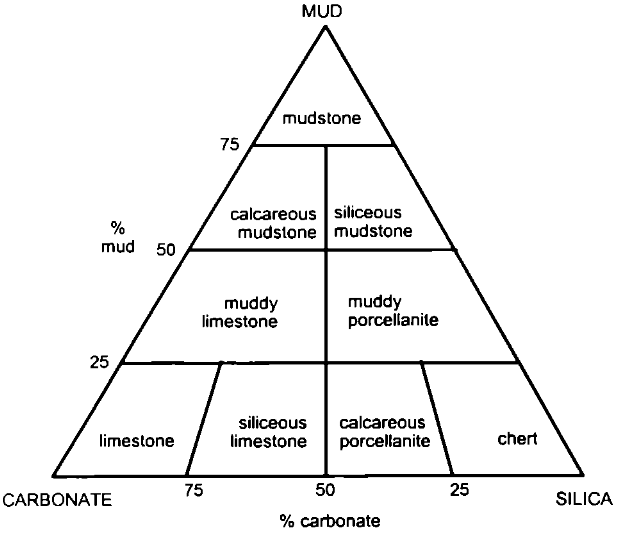

Figure 3. Classification of fine-grained sedimentary rocks

Abundance of radiolarians in processed samples is recorded in appendices 1 and 2 as follows: R (rare) < 20 specimens per picking tray (60 x 100 mm); F (few) = 20-200 per tray or < 50 specimens on a strewn slide (22 x 40 mm); C (common) > 200 per tray or 50-200 per slide; A (abundant) > 200 per slide. Grades of preservation are based on degree of recrystallisation, corrosion and breakage: P (poor) = tests highly recrystallised, infilled, surfaces corroded, delicate structures missing; M (moderate) = tests moderately recrystallised, partially infilled, surface features preserved, delicate structures often missing; G (good) = tests slightly recrystallised, internal and surface features well-preserved, delicate structures which are commonly present.

1.5. ILLUSTRATION AND CURATION

Plates were composed in CorelDraw 4.0[1]. All images are digitally captured and enhanced in PhotoStyler 2.0[2]. Transmitted light images were captured via video camera attached to a Leitz Ortholux microscope. Some scanning electron microscope (SEM) images were scanned from photographic negatives. Remaining SEM images were captured via an analog digital converter from a Philips PSEM500 scanning electron microscope.

Rock samples from the Flaxbourne River are deposited in the micropaleontology collection, Institute of Geological & Nuclear Sciences (IGNS), Lower Hutt. Rock samples from other primary sections, all processed residues, slides, SEM stubs, figured and type specimens are deposited at the University of Auckland. Samples from on-land sections are referred to in the text and figures by their number in the New Zealand Fossil Record File (Map sheet/fossil record number). To assist future location of figured specimens and type material, field numbers are also supplied in descriptions of new species, plate captions, and Appendices 1 and 2. DSDP samples are referred to in the standard format: Site-Core-Section, interval in centimetres.

1.6. ACKNOWLEDGMENTS

Graham Gibson and Jack Grant-Mackie initiated and supervised the doctoral study which is the basis of this work. Yoshiaki Aita helped to guide initial research, and has given unflagging support throughout the study. Jack Grant-Mackie, Akiko Nishimura, Ian Raine, George Scott, Percy Strong, Barry O'Connor, Paulian Dumitrica, and Annika Sanfilippo provided helpful reviews of all or parts of the manuscript. Thorough reviews of the systematics by the latter three were particularly valuable, and I regret that time has not permitted full consideration of some issues raised. Such work would be more appropriately followed up in future studies of specific lineages or families. Ian Raine, George Scott, and Wendy St George advised on digital imaging.

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[1] © Corel Corporation 1988-1993

[2] © Aldus Corporation 1993

Louise Cotterall drafted Figure 4. Anne Boersma and Gerta Keller provided the material from Indian Ocean ODP sites and Ecuador discussed in Chapter 4. Material examined from DSDP sites was either supplied directly by the Ocean Drilling Program (Site 208), or is housed in the DSDP/ODP Micropaleontological Reference Centre, IGNS, Lower Hutt (sites 275, 327A). Brent Jones assisted with sample preparation. The reference list was constructed using RADREFS[1], a computerised radiolarian reference library.

Margaret and David Parsons, Jock Clouston, and Herb Thomson kindly provided accommodation and access to sections in eastern Marlborough.

The manuscript was completed over several years while I was supported by a Japan Society for the Promotion of Science postdoctoral fellowship at Utsunomiya University in 1993, a New Zealand Science and Technology postdoctoral fellowship at the Institute of Geological & Nuclear Sciences at Lower Hutt between 1994 and 1996, and finally by the New Zealand Income Support Service in 1997. The New Zealand Lottery Grants Board contributed towards publication costs.

Final thanks go to my wife Anita Nicholls for her generous forebearance over the last few challenging months.

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[1] © A. Sanfilippo, G.W. Renz, C.A. Nigrini, and J.P. Caulet, 1990

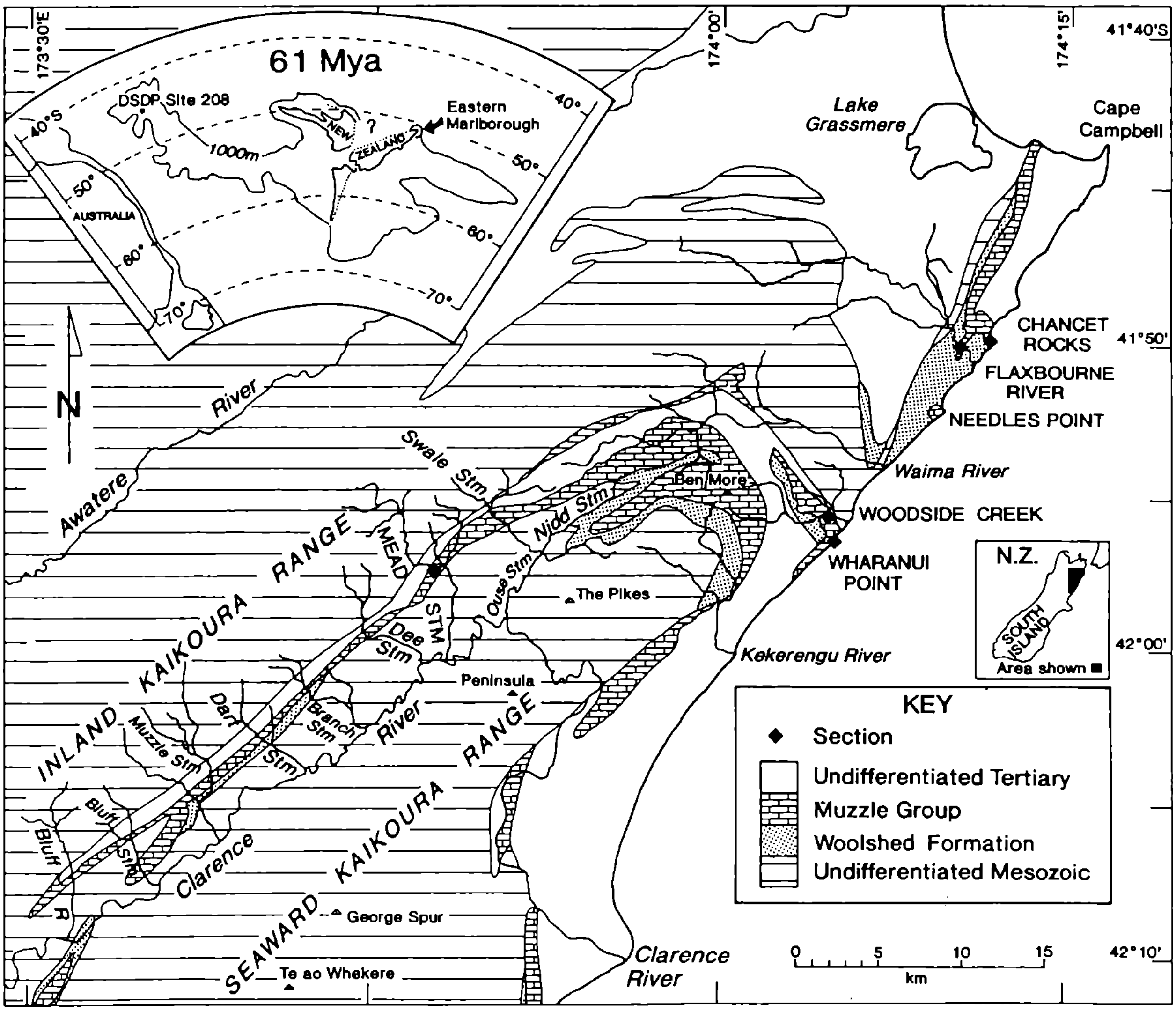

Figure 4 Simplified geological map of eastern Marlborough (after Lensen 1968), showing location of primary sections and Mead Stream. Inset shows position of the area on a Late Paleocene plate reconstruction (after Weissel *et al.* 1977).

CHAPTER 2. STRATIGRAPHY AND RADIOLARIAN OCCURRENCE

2.1. STRATIGRAPHIC OUTLINE

The four primary sections (Fig. 4) are all within Mead Hill Formation (latest Cretaceous-Paleocene), the lower of two formations which make up Muzzle Group (Reay 1993). The upper formation, Amuri Limestone (Paleocene-Eocene), achieves maximum thickness and is probably most complete at Mead Stream, inland Marlborough. Earlier indications that the boundary between Mead Hill Formation and Amuri Limestone may lie within the Woodside Creek section (Webb 1966; Strong 1977) and Chancet Rocks (Lewis & Laird 1980) are not supported by subsequent lithostratigraphic or biostratigraphic studies (Morris 1987; Hollis 1993a). It now appears that true Amuri Limestone does not outcrop in the vicinity of the primary sections.

Radiolarian zones (RK9, RP1-RP13) referred to in locality descriptions relate to the local latest Cretaceous to Middle Eocene radiolarian zonation (Hollis 1993a; Strong *et al.* 1995), and are applied in the revised sense outlined in Chapter 3 (Fig 2, 11).

2.2. PRIMARY SECTIONS

Only samples in which faunas have been examined are shown in figures 5-9. Location and other details of all samples collected from the four primary localities are given in Appendix 1. Occurrence of radiolarian species is summarised in Table 1 for the primary sections, and in Table 2 for secondary localities. Details of radiolarian distribution in the four primary localities are shown in Appendix 2.

2.2.1. Woodside Creek (Fig. 5)

The section is located in a small gorge approximately 1 km upstream of where the creek crosses State Highway One (P30/988190-990191*). The section youngs downstream, with an average strike and dip of 090°/45° N. The K-T boundary is located in a narrow cleft 50 m upstream of the gorge entrance. The base of the Mead Hill Formation is not well-exposed, but a conformable contact is inferred with underlying well-bedded calcareous mudstone of the Woolshed Formation. The upper contact with an Eocene volcanogenic sandstone appears to be faulted.

Mead Hill Formation is entirely late Haumurian (Maastrichtian: Webb 1966) and late Maastrichtian from 15 m below the K-T boundary (Strong 1977, 1981). It consists of pale medium-bedded (20-40 cm) siliceous limestone with rare dark grey chert nodules and thin marly interbeds. The upper seven metres is thick-bedded (40-100 cm), more calcareous, and lacks chert nodules.

Strong (1977, 1981) and Wilson (1978) located the boundary at a sharp contact between the thick-bedded Haumurian limestone and thin-bedded dark Teurian "limestone". The few centimetres of sediment marking the K-T transition have been subject to intense scrutiny since Alvarez *et al.* (1980) first identified the now-familiar geochemical signature of the 10-20 mm thick boundary clay. As well as anomalously high levels of iridium and other siderophilic elements (Alvarez *et al.* 1980; Brooks *et al.* 1986), the boundary clay contains "impact-shocked" mineral grains (Bohor *et al.* 1987), "soot" particles (Wolbach *et al.* 1988), fullerenes (Heymann *et al.* 1994), and carbon isotope anomalies (Hollander *et al.* 1993). Taken together, these features are convincing evidence for the global effects of an earth-impacting bolide at the end of the Cretaceous. These indicators of a relatively complete earliest Paleocene record conflict with evidence from foraminifera for a basal hiatus of 100-300 kyrs. (Strong 1977). This problem has been discussed at length by Hollis (1993a, 1996).

Above the boundary clay is a 2 m-thick dark-grey, finely laminated calcareous porcellanite, slightly enriched in organic material and clay. It grades into 6.5 m-thick medium-bedded (10-20 cm) medium-grey calcareous porcellanite. Both porcellanite units have numerous dark grey chert nodules and stringers, and thin softer mudstone interbeds. Foraminifera indicate that this lower interval is Early Paleocene. Foraminifera provide only broad age control for overlying Mead Hill Formation (Teurian or Teurian-Waipawan: unpublished data from NZ Fossil Record File).

The porcellanite grades into a 17.5 m-thick medium to thick-bedded, light grey to mauve siliceous limestone with very rare chert nodules and very thin marly interbeds. In the upper 10 m, bed thickness increases from 20-50 cm to 100-200 cm, and chert nodules and interbeds disappear. The overlying 7 m-thick unit consists of thick-bedded (50-100 cm), mauve, nonsiliceous limestone, and is in turn overlain by an 8 m-thick, medium-bedded (20 cm) mauve to yellow-brown, sandy limestone with rare tan chert nodules.

Of 85 samples examined, 8% were barren, while 35% contained common to abundant radiolarians. Preservation is poor to moderate in Cretaceous and basal Paleocene strata, moderate to good from 2-13 m above the K-T boundary, and generally good in the remaining Paleocene.

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* Grid reference on the NZMS 260 (*Infomap*) 1:50 000 topographic map series.

Table 1. Radiolarian occurrence in primary sections. Codes explained at base of facing page.

Primary sections	Woodside Creek						Wharanui Point			Chancet Rocks				Flaxbourne River			
Radiolarian zones	RK9	RP1	RP2	RP3	RP4	RP5	RK9	RP1	RP2	RP1	RP2	RP3	RP5	RK9	RP1	RP2	RP3
Cretaceo-Paleocene Spumellaria																	
Acanthocircus ellipticus	vr	vr	vr	vr	vr		vr	vr									vr
Amphibrachium aff. *sansalvadorensis*	vr	vr	vr	vr			vr										
Amphisphaera priva	r-f	r-f	f-r	f-r	f-r	f	r	r	vr		vr	vr	vr		vr	vr	vr
Amphymenium concentricum	vr																
Conocaryomma aff. *universa*	vr		vr	r	vr	vr											
Flustrella cretacea	vr	vr	vr	vr			vr										
Flustrella ruesti	vr	vr	vr	vr													
Heliodiscus spp.	vr	vr	f	r			vr										r
Heliosestrum spp.	vr	vr	f					f	f	r	f	r				vr	r
Lithelius? minor gr.	f-a	r	f-c	c	a	c	f	c	f	f	f	f	c	r	r	f	c
Lithomespilus coronatus	f	a	f	c-r	r	r	f	c	f	f	f	f	vr	f	f-a	f	f
Orbiculiforma renillaeformis s.l.	vr	vr	vr	vr	vr		vr							vr	vr	vr	
Orbiculiforma renillaeformis s.s.	vr	vr	vr	vr	vr		vr	vr			vr						
Patulibracchium spp.	r	r	vr	vr	vr		r	r							vr	vr	vr
Peritiviator cf. *labyrinthi*	vr	vr	vr				vr	vr									vr
Phaseliforma laxa	r	vr	vr	vr	r	r	vr	r			vr			vr	vr	vr	vr
Phaseliforma subcarinata	vr	vr	vr	r	r	r-f	vr					vr		vr		vr	
Protoxiphotractus wilsoni n.sp.	r	vr	f	f	f	f	f	r	r	r	vr		vr	r	r	r	r
Protoxiphotractus perplexus			vr		vr												
Prunobrachium kennetti	vr			is	is									vr			
Prunocarpus sp. A	vr	vr	vr	vr	vr	vr											
Spongodiscus communis			?	vr	vr												
Spongodiscus rhabdostylus	vr	vr	vr	r	vr	vr											
Spongotripus spp.	vr	vr	vr	vr	vr		vr										vr
Spongotrochus antiquus	r	f	c-f	a-f			r	r						f	f		vr
Spongotrochus cf. *polygonatus*	vr		vr	vr			vr										
Spongurus spongiosus	r	?		is													is
Stylosphaera pusilla	r-f	f	f	f-r	vr		f	f	vr	f	f-r			vr	r	f	f-r
Stylosphaera aff. *hastata*	vr	vr	r	r	vr			vr			vr					vr	r
Tholodiscus cf. densus	vr	vr	vr	r	vr	r		vr								vr	vr
Tholodiscus cf. *ocellatus*	vr	r	r	r	r	r	r	r	vr	vr	r	vr			vr	r	r-f
Cretaceo-Paleocene Nassellaria																	
Amphipyndax aff. *conicus*	f-r	r	r				vr	r			vr			r	vr		vr
Amphipyndax stocki gr.	a	c	c	c-a	c-a	a	a	c	c	f	f	c	f	f	f	f	f
Amphipternis alamedaensis	r-f	r	r	r	vr	r	r	vr	vr	r	r	f	vr	r	r	vr	r-f
Archaeodictyomitra cf. *lamellicostata*	r	r	r-f	r-f	f-r	f	vr	vr	r	r	r			vr	r		vr
Artostrobus pusillus	r	vr	r	vr	vr	vr	vr	vr	f	r	vr	f			r	r	f-c
Bathropyramis sanjoaquinensis s.l.	r	r	r	r	r-f	r	r	r	r		r	r	r			vr	r
Botryostrobus? parsonsae n.sp.	vr	vr	vr	r	vr	vr	vr	vr				r					vr
Cornutella californica	r	r	r	r	r	f	f	r	r	f-	f	r	r	vr	vr	vr	r-f
Cryptocarpium cf. *ornatum*	r	vr	vr	vr	vr		r	vr		vr	vr				vr	vr	vr
Cyrtocapsa campi	r	r	vr	vr	vr		r	r	r	r	vr			f	f	vr	vr
Cyrtocapsa livermorensis	r	r	r	r	vr		r	r	f		vr		vr	f	f	r	vr
Dictyomitra andersoni	c	c	c	c-f	f	c	c	c	f	f	f	f	r	c	c	f	r-f
Dictyomitra aff. *rhadina*	vr	vr	vr				vr	r	vr					r	vr	vr	vr
Dictyomitra multicostata	f	f	r	r	r	r	r	f-r	f	r	r	r	?	f	f	vr	vr
Eusyringium? woodsidensis n.sp.	r	vr	r	r	r	r	f	r	vr		vr	vr	r				vr
Lithocampe wharanui n.sp.	r	r	r-f	f	r	r	c	r	r	vr	r	vr	r		r	r	r
Lithocampe aff. *subligata*	vr	vr	vr	vr	vr												
Lithomelissa cf. *heros*	r	r	vr	vr	vr			vr		vr	vr			vr	vr	vr	vr
Lithomelissa? aitai n.sp.	f-r	f	f-r	r	r		r	r						f	f-r		vr
Lithomelissa? hoplites	r	vr	r	r			vr	vr			vr			r	vr		vr
Mita regina	r	r	r	r	r	r	f	f	r	r	vr			r	vr	vr	vr

Primary sections	Woodside Creek						Wharanui Point			Chancet Rocks				Flaxbourne River			
Radiolarian zones	RK9	RP1	RP2	RP3	RP4	RP5	RK9	RP1	RP2	RP1	RP2	RP3	RP5	RK9	RP1	RP2	RP3
Mita cf. *regina*	r	r	r	r	r	r	vr	r		vr	vr					vr	vr
Myllocercion acineton	c-f	c-f	f-r	r	r		f	c	f	c	r	vr	?	c	c	r	r
Myllocercion aff. *echtus*	c-f	c-f	f-r	r	r		r	f	r	vr	vr		?	f-c	f-c	r	r
Neosciadiacapsa jenkinsi	f-r	f-r	f	r	r		r	r	vr		vr	vr				r	r
Phormostichoartus? strongi n.sp.	vr		vr		vr		vr	vr					vr				vr
Siphocampe altamontensis	r	r	r	vr	vr		vr	vr	vr	r	r			vr	vr	vr	vr
Siphocampe cf. *altamontenis*	vr	vr	vr	vr	vr		f-r	r	r		vr					vr	vr
Stichomitra bertrandi	r	r	vr	vr	vr		r	r	r	r	r			f	f		vr
Stichomitra carnegiensis	r-f	f	f	r	r-vr	r	f	f	f	r	r			c-f	f	f	r
Stichomitra cf. *carnegiensis*				vr	r	r											
Stichomitra grandis	f	f	f-r	r	r		r	f	vr	r	r	r		f-a	c-f	f	r
Theocampe cf. *vanderhoofi*	f-a	f	f-r	r	r		r-f	c	r	c	r	vr		a	c-f	f	r
Theocapsomma amphora	r-f	f-r	r	r	r		r	r	r	r	r	r		f	r	vr	vr
Theocapsomma erdnussa	f	f	f	f-r	r	r	f	f	vr	r	r	vr		r	r-f	r	vr
Paleocene Spumellaria																	
Amphisphaera aotea		a-c	c-r		?			c-a	f	c	c-r				a-f	f	vr
Amphisphaera coronata s.l.					vr	r							f				
Amphisphaera kina			a	a-f	f-r	f			a		a	f	r			a	a
Amphisphaera goruna			r	vr	c-a	a							a			r	r
Amphisphaera macrosphaera			vr	r	vr	f							c				r
Amphymenium cf. *splendiarmatum*			r	f	r	r		vr							vr	r	f
Cladococcus? sp.					vr												
Haliomma teuria n.sp.			vr	r	?	?											
Haliomma gr. b			vr	r-f	c-a	c							c				vr
Hexadorium cf. *magnificum*			f	r												f	f-c
Lithelius aff. *foremanae*		vr	vr	vr	r	r		vr					r			vr	vr
Lithelius marshalli n.sp.			vr	f													
Lithelius cf. *hexaxyphophora*					vr	vr											
Lithelius? aff. *minor*		vr	r-f	r	r											r	f
Periphaena sp.					vr												
Saturnalis kennetti		vr	vr	vr	vr	vr							vr			r	r
Spongoprunum cf. *markleyense*			r	vr													r
Spongopyle cf. *insolita*					vr												
Spongotrochus cf. *glacialis*		r	f-c	f	vr												
Spongurus cf. *bilobatus*		vr	r-f	r	r			vr									r
Spongurus aff. *prolixum*			vr														
Stylodictya cf. *sexispinata*				vr	r	vr											
Stylosphaera minor				vr	r-f	f						r	f				
Palaeotetrapyle muelleri				?	vr												
Tholodiscus cf. *targaeformis*					r	vr											
Paleocene Nassellaria																	
Buryella dumitricai					f	vr							f				
Buryella foremanae					f-r	vr							f				
Buryella granulata				r-f	f-r	r					?	f	r			?	r-f
Buryella kaikoura n.sp.						f											
Buryella tetradica						c							c				
Clathrocyclas australis n.sp.			r	r	f-r	r							f				vr
Dictyophimus aff. *archipilium*		?		vr	r	r							c				
Dictyophimus aff. *pocillum*					vr	r							r				
Dorcadospyris aff. *confluens*			vr	vr	r								r				vr
Lithomelissa cf. *gelasinus*					vr												
Lithostrobus wero			r	r	r		?	?	vr		?	a	r			r	r-c
Codes for relative abundance over each zone:	vr (very rare) < 0.3%, r (rare) = 0.3-0.9%, f (few) = 1-2.9%, c (common) = 3-9.9%, a (abundant) > 10%; is = isolated occurrence, ? = uncertain identification																

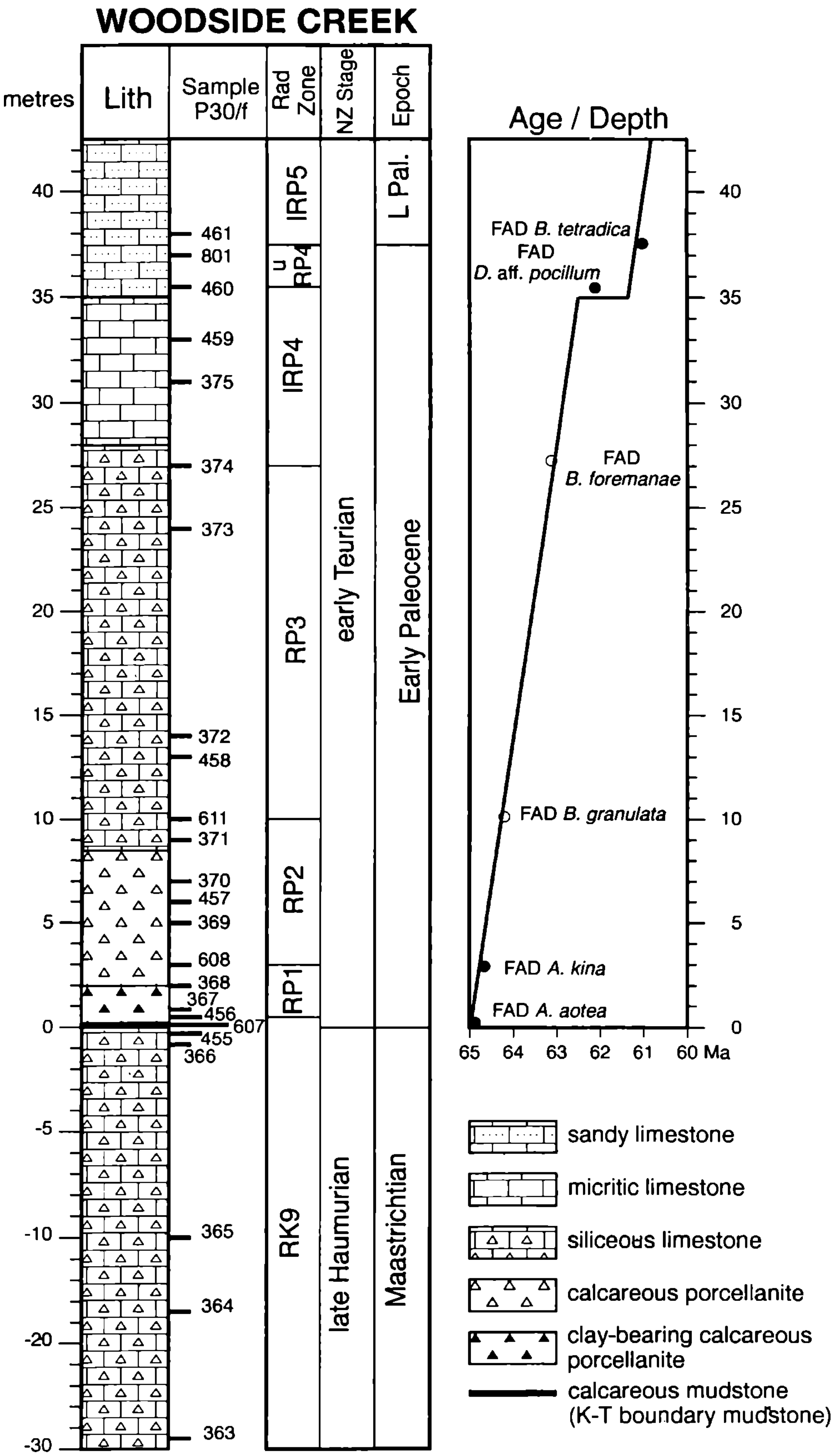

Figure 5 Stratigraphic column of Woodside Creek section showing lithologic units, location of examined samples, radiolarian zones, and age/depth plot. All units are within the Mead Hill Formation. Solid circles = dated events; open circles = interpolated events.

Radiolarian abundance is variable in the Cretaceous (5-500 radiolarians/g), low in the basal Paleocene (~5/g), high from 2-14 m above the K-T boundary (150-800/g) and moderate in the remaining Paleocene (30-250/g). Faunal character is outlined in Chapter 3.

The section is the stratotype of radiolarian zones RK9 and RP1-RP4 (Hollis 1993a). Location of some zonal boundaries has been revised in the course of the present study: RK9 extends up into the K-T boundary clay interval (P30/f607); the base of RP2 is lowered (P30/f608); base of RP3 is lowered (P30/f611), and the top of RP4 is raised (P30/801) to above the contact between the two uppermost units.

2.2.2. Wharanui Point (Fig. 6)

The section is located on the coast 200 m south of the mouth of Woodside Creek (P30/006186). It forms a low-lying stack which extends seawards as a small promontory. The 80 m-thick section has nearly vertical dip, strikes NE-SW and youngs seaward. Only a few metres of Paleocene strata are accessible at low tide. The base of Mead Hill Formation is obscured by sand. The K-T boundary was identified by Strong *et al.* (1988) at the base of a dark grey "limestone", primarily on lithostratigraphic grounds. Location was corroborated by a geochemical anomaly in a boundary clay at the base of this unit (*op. cit.*), and is supported by radiolarian biostratigraphy (Hollis 1993a).

Cretaceous strata consist of pale, medium to thick-bedded siliceous limestone with prominent large dark grey chert nodules in the lower part, and rare smaller nodules in the upper part. A more detailed description of the Cretaceous units is given by Strong *et al.* (1988). The latter reported late Haumurian foraminifera from the uppermost bed.

The Tertiary sequence begins with a moderately hard 2 cm-thick "boundary clay" which is overlain by a 1 m-thick dark-grey thin-bedded laminated calcareous porcellanite. The latter unit is overlain by at least 8 m of medium-bedded medium to light green-grey calcareous porcellanite.

Of ten samples collected for radiolarians, two were barren, while six contained common to abundant radiolarians. Recovery was poor in the uppermost Cretaceous sediments, but good in the lower part, with two samples yielding common moderately well-preserved radiolarians. Preservation was only moderate in the dark-grey porcellanite, but moderate to good in the overlying unit. Apart from a barren "boundary clay" sample, radiolarians were common in all Paleocene samples.

2.2.3. Chancet Rocks (Fig. 7)

The section is located within Chancet Rocks Scientific Reserve which is on the coast 2 km north of Ward Beach. Lewis & Laird (1980) outlined the geology of the reserve. Strong (1984) described the sequence in some detail, and identified the K-T boundary. The section sampled is a composite of two shore platform transects. The lower part was sampled in a transect 40 m south of the northern pinnacle (Grid ref. P29/094295; at location of photographs in Strong 1984; fig. 3, 4). The upper part was sampled in a transect directly seaward of the southern pinnacle (P29/094294). Although the geology is complex in places, both transects consist of beds of uniform near-vertical dip, striking NW and younging eastward towards the sea. A sharp basal contact of Mead Hill Formation on Woolshed Formation is exposed 15 m below the K-T boundary.

Cretaceous Mead Hill Formation consists of pale medium-bedded siliceous limestone with rare chert nodules. Latest Haumurian foraminifera have been recovered from the lower part (Strong 1984). The K-T boundary is placed at the base of a 15 cm-thick dark-grey laminated calcareous porcellanite which is enriched in iridium and other siderophiles (Brooks *et al.* 1986). Early Paleocene foraminifera occur 10 cm above the base of the overlying unit (Strong 1984), which is a 12 m-thick medium-bedded calcareous porcellanite grading up into siliceous limestone. Three prominent 20 cm-thick dark grey discontinuous nodular chert beds occur in the lower part of the unit (2.5, 3, and 4 m above base). The overlying unit is medium-bedded pink to white bioturbated limestone. The lower 10 m has intertwined networks of chertified burrows of the trace fossil *Thalassinoides*, previously misidentified as fossil sponges (Lewis & Laird 1980).

Of thirty samples examined, 37% were barren, while only 13% contained common to abundant radiolarians. Most Cretaceous samples were barren, and none was selected for faunal study. Radiolaria were common and of poor to moderate preservation in the lower Paleocene porcellanite, absent or very rare in the overlying 12 m of limestone, but common and moderately well-preserved in the upper 15 m.

Re-examination of samples resulted in identification of the base of Zone RP1 within the basal Paleocene dark porcellanite (P29/f500).

2.2.4. Flaxbourne River (Fig. 8)

The section is located about 2 km from the mouth of Flaxbourne River in a quarry on Chancet Station (P29/077297).

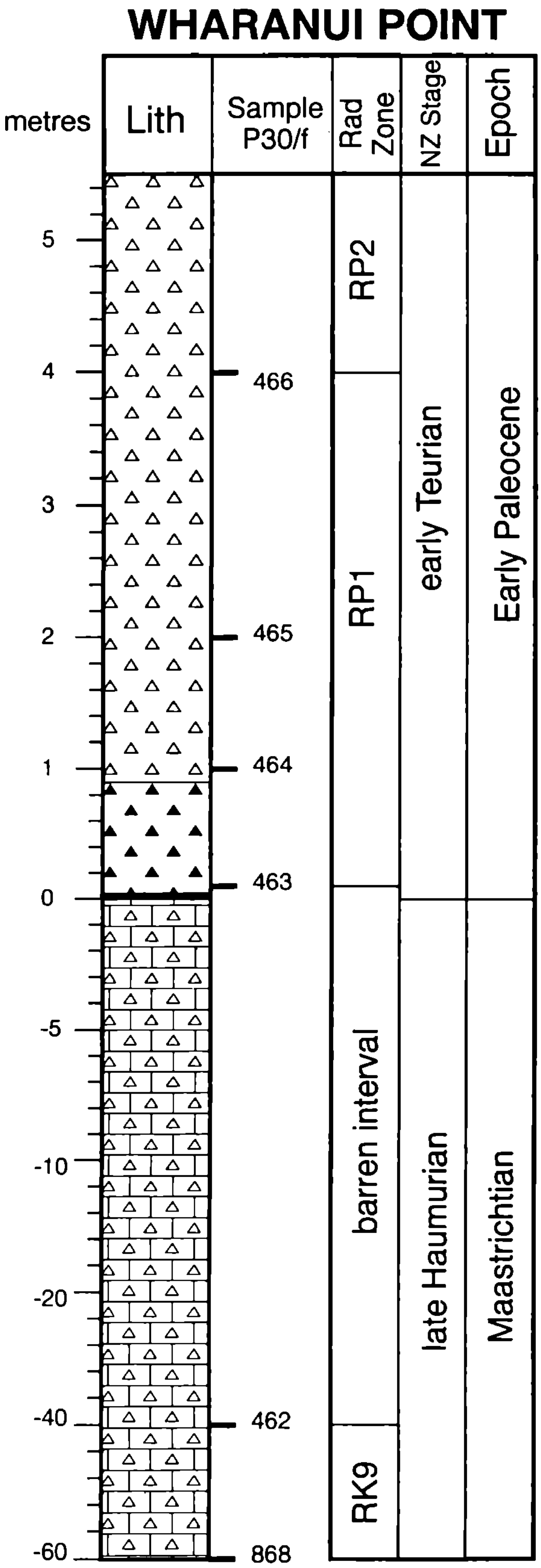

Figure 6 Stratigraphic column of Wharanui Point showing lithologic units, location of examined samples, and radiolarian zones. All units are within the Mead Hill Formation.

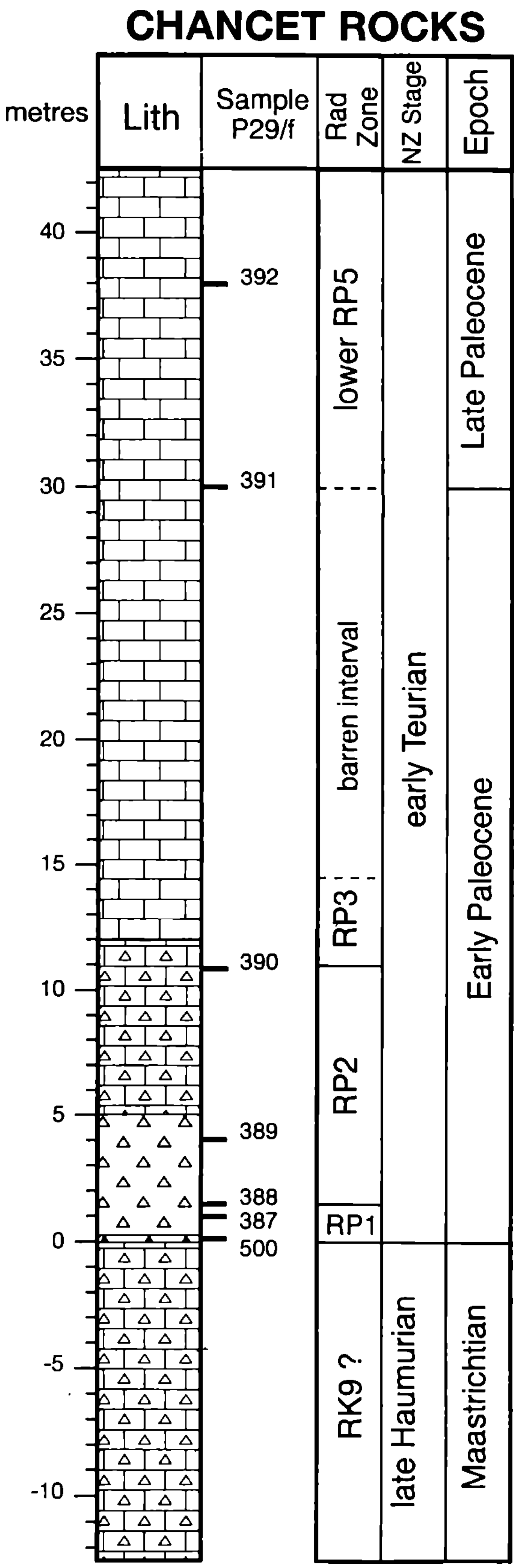

Figure 7 Stratigraphic column of Chancet Rocks showing lithologic units, location of examined samples, and radiolarian zones. All units are within the Mead Hill Formation.

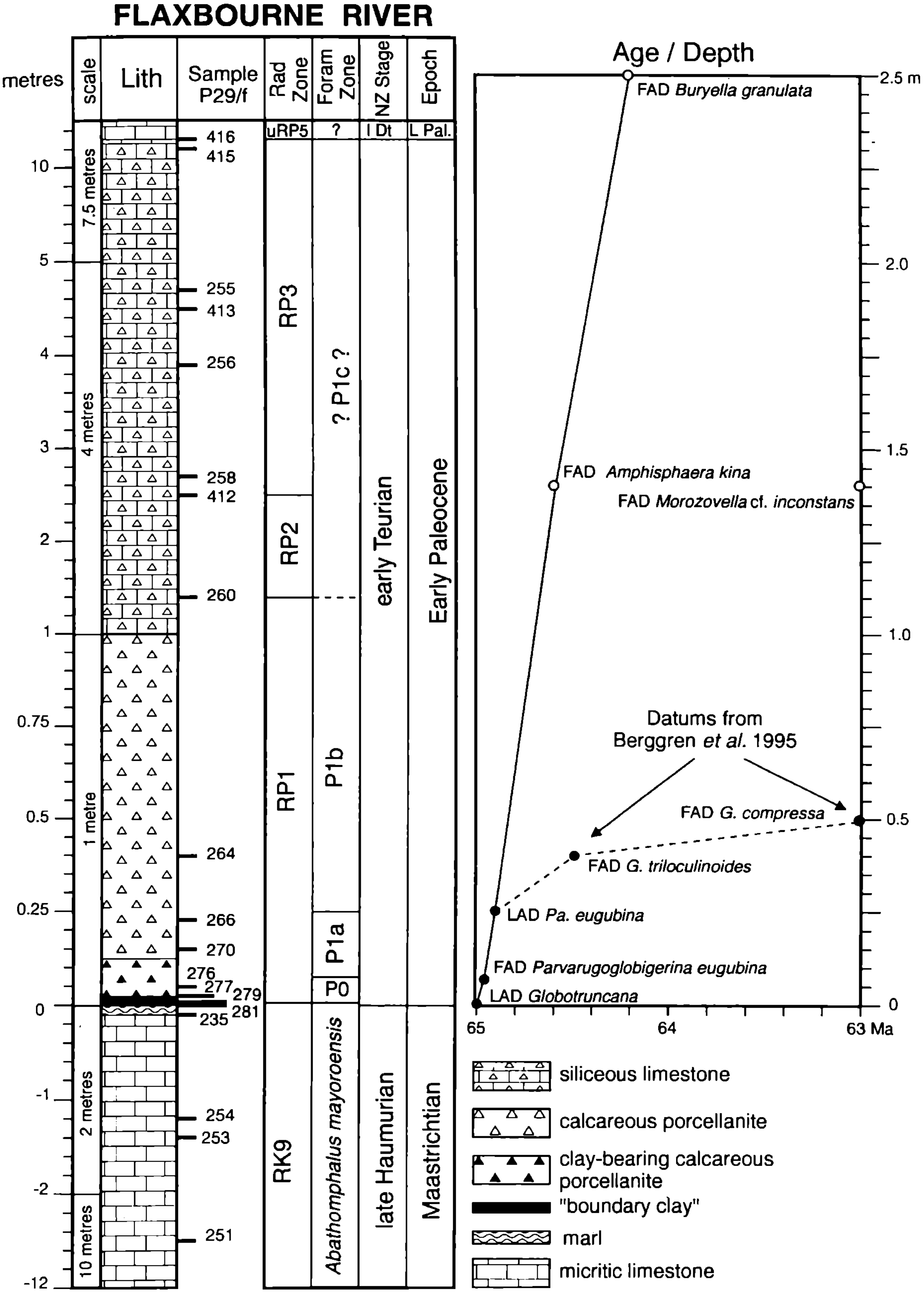

Figure 8 Stratigraphic column of Flaxbourne River section showing lithologic units, location of examined samples, radiolarian zones, foraminiferal zones (Strong pers. comm. *sensu* Keller 1993), and age/depth plot. Solid circles = dated events. All units are within the Mead Hill Formation.

All samples examined are splits of foraminiferal samples collected by C.P. Strong for a detailed study of the K-T boundary interval (Strong *et al.* 1987). As in other sections, the boundary is located at the base of a dark grey laminated interval. Pale Cretaceous limestone is capped by a 2-5 cm-thick undulating pale marl containing latest Cretaceous foraminifera. This is a lithology not represented at other sections, and suggests to Strong (pers comm.) that the K-T interval may be more complete at this section. The contact with the overlying 2 cm-thick boundary clay is sharp. The overlying succession consists of 10 cm-thick dark grey laminated calcareous porcellanite, 90 cm-thick thin to medium-bedded green-grey calcareous porcellanite, and 10 m-thick yellow-green medium-bedded siliceous limestone. Structural complications above this level obscure relations with overlying Upper Paleocene strata which yielded radiolarian assemblages correlated with upper RP5 (P29/f416-f419).

The foraminiferal zonation shown in Figure 8 is based on examination of 34 samples, including a very closely spaced suite of 20 samples spanning the first 50 cm of Tertiary strata (C.P. Strong pers. comm.). The Flaxbourne foraminiferal succession compares well with the sequence of foraminiferal events documented by MacLeod and Keller (1991). The following datums are used to define zone boundaries (after Keller 1988, 1993; MacLeod & Keller 1991; with age estimates from Berggren *et al.* 1995):

1. Top of *Abathomphalus mayoroensis* Zone: LAD (last appearance datum) of *A. mayoroensis* and *Globotruncana* spp. (65 Ma);

2. Base of P0: FAD (first appearance datum) of *Eoglobigerina* spp. (65 Ma);

3. Base of P1a: FAD of *Parvarugoglobigerina eugubina* (64.97 Ma);

4. Base of P1b: LAD of *P. eugubina* (64.9 Ma).

Good agreement between these datums and key radiolarian datums (FADs *Amphisphaera kina* and *Buryella granulata*) in this section is evident from the age/depth correlation line (Fig. 8) which indicates relatively continuous sedimentation over the first 2.5 m of the Paleocene at a rate of 3 mm/kyr (compacted). The first occurrences of other foraminifera are problematic. Berggren *et al.* (1995) located the FADs of *Globigerina triloculinoides* and *Globoratalia compressa* at 64.5 and 63 Ma respectively. If correct for Flaxbourne River, this would imply one or two major hiatuses between 0.25 and 0.5 m above the K-T boundary. However, MacLeod & Keller (1991) reported the FADs of both species below the LAD of *P. eugubina* (i.e. within Zone P1b), a finding compatible with the Flaxbourne River data. A doubtfully located P1b/P1c boundary, based on the first occurrence of a species similar to *Morozovella inconstans* in P30/f260, is also somewhat lower than indicated by the age/depth correlation line (Fig. 8).

Of 38 samples examined, radiolarians were common or abundant in 34%, while 8% of samples were barren. Radiolarians were common in all Cretaceous samples, few to rare in the first ten centimetres of Tertiary strata, and common to abundant in overlying Lower Paleocene sediments. Late Paleocene radiolarians were rare in the overlying limestone/marl sequence (*Buryella tetradica*, *Microsciadiocapsa* ? spp. and *Sethochytris babylonis* gr.).

2.3. SECONDARY LOCALITIES

Selected samples were examined from secondary localities (Fig. 1) in order to better delimit the geographic and stratigraphic distribution of species recorded from eastern Marlborough. The overall faunal composition of assemblages from these localities is not detailed here. Mead Stream faunas are described by Strong *et al.* (1991, 1995). Preliminary reports on the faunas of DSDP Sites 208 and 275 were made by Dumitrica (1973) and Pessagno (1975), respectively, but many species remain unrecorded. Faunal lists for Wairarapa and Chatham Island samples are available from the New Zealand Fossil Record File.

2.3.1. Mead Stream, inland Marlborough (Fig. 9)

A section in Mead Stream represents one of the most complete records of pelagic sedimentation in the New Zealand region. From the faulted base a 650 m thick sequence of limestone, porcellanite, chert, and marl ranges from late Haumurian to Bortonian (Maastrichtian to Middle Eocene) and is unconformably overlain by Oligocene clastic limestone. A suite of 50 radiolarian-bearing samples was examined as part of an integrated biostratigraphic study of foraminifera, radiolarians, and dinoflagellates (Strong *et al.* 1995). Subsequent sampling has improved foraminiferal age control from 360 to 440 m.

In Table 2, radiolarian samples have been grouped into six stratigraphic intervals based on radiolarian zones and foraminiferal and dinoflagellate age determinations (in terms of):

1. late Haumurian, RK9 (2 samples);
2. early Teurian, RP1-4 (9 samples);
3. late Teurian, upper RP5-6 (6 samples);
4. Waipawan, RP7-9 (11 samples);
5. Mangaorapan-Porangan, RP10-11 (12 samples);
6. Bortonian, RP12-13 (10 samples).

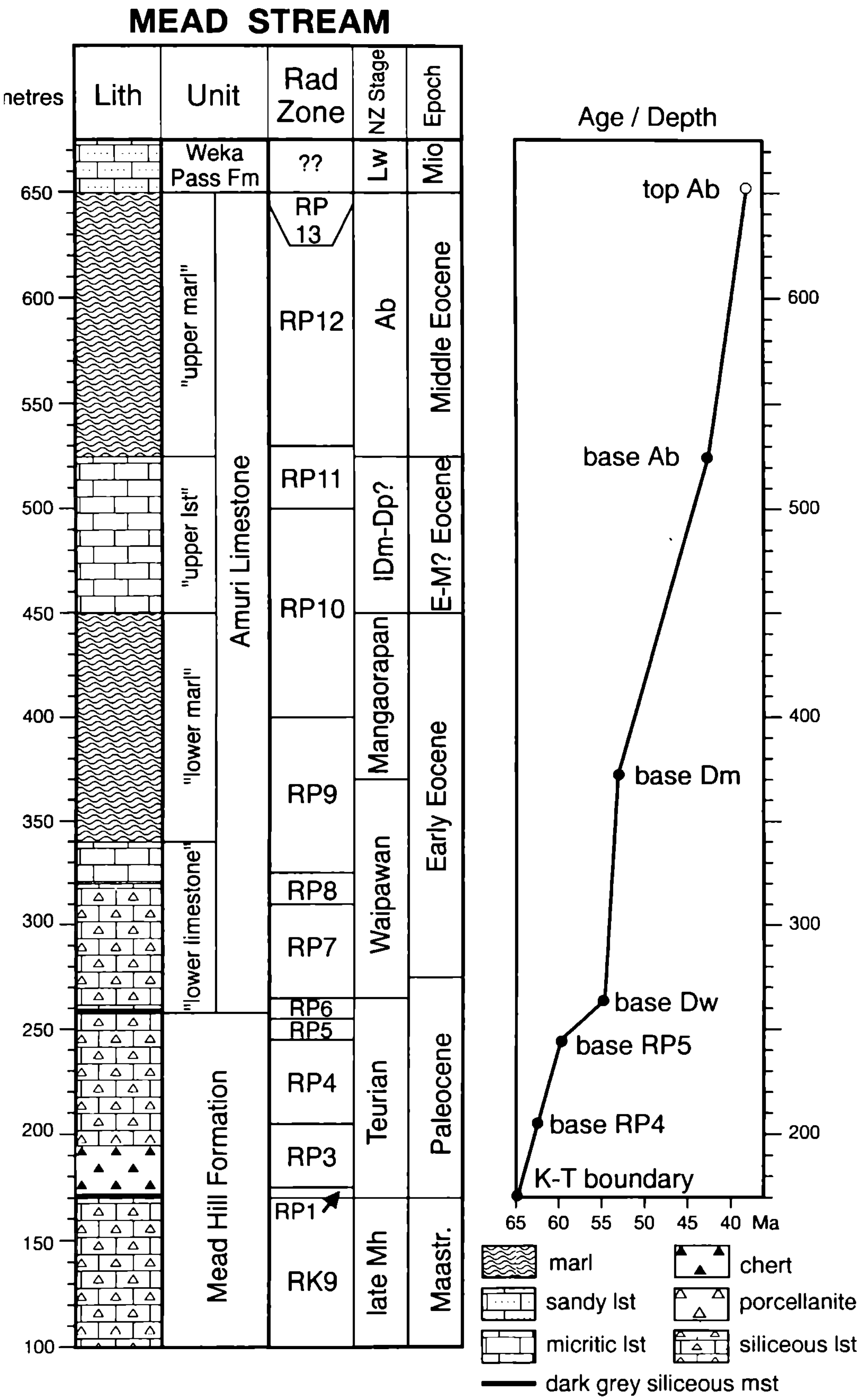

Figure 9 Stratigraphic column of Mead Stream section showing lithologic units, radiolarian zones, determinations based on foraminifera and dinoflagellates (Strong *et al.* 1995), and age/depth plot. Solid circles = dated event; open circles = age inferred (see Chapter 3).

Table 2. Occurrence of Marlborough radiolarians in secondary localities. Codes as for Table 1 (p. 7).

Locality	Mead Stream						Mara Quarry	Kaiwhata Stream	Tioriori Chatham Island	DSDP Site 275			DSDP Site 208				
Ref #, NZFR# or Core #	1	2	3	4	5	6	f199	f553	f616	5	2	1	34/33	33-1	31/30	30	30/29
Age	L Cret	Paleocene		Eocene			L Cret	E Pal	L Pal	L Camp-Maastr.			L Cret	Paleocene			
NZ Stage	Mh	eDt	IDt	Dw	Dm-p	Ab	Mh	eDt	IDt	Mh			Mh	eDt			IDt
Radiolarian Zone	RK9	RP1-4	RP5-6	RP7-8	9-10	11-13	RK9	RP4	RP5	RK9			RK9	RP2	RP4	IRP5	uRP5
Cretaceo-Paleocene Spumellaria																	
Amphisphaera priva	vr	vr					f			f	vr						
Amphymenium concentricum										vr	f	f	vr				
Conocaryomma aff. *universa*									is								
Hexadorium cf. *magnificum*							?										
Lithelius? minor gr.	r	c	c	f	f	f	f	c	f	c	c	f	c	a	a	a	a
Lithomespilus coronatus	vr	r	is				r		vr		vr				vr	vr	
Orbiculiforma renillaeformis s.l.							f		is	r	f	r			vr	vr	
Orbiculiforma renillaeformis s.s.	vr						f		is		f	r					
Patulibracchium spp.	vr						f				vr		vr				
Perítiviator cf. *labyrinthi*											vr	vr					
Phaseliforma laxa	vr						r			r	r	vr		vr			
Phaseliforma subcarinata							r	vr	is		r			vr			
Protoxiphotractus wilsoni n.sp.							f			vr							
Prunobrachium kennetti	r-f						vr		is		vr	vr					
Prunocarpus wilsoni n.sp.											f						
Spongodiscus rhabdostylus							r										
Spongurus spongiosus											vr						
Stylosphaera pusilla	vr	vr					r				r	r	vr	vr			
Tholodiscus cf. *densus*							vr				r	r					
Tholodiscus cf. *ocellatus*		vr									r	vr	vr	f	r	vr	
Cretaceo-Paleocene Nassellaria																	
Amphipternis alamedaensis		r	vr	vr	vr	vr	vr	f			vr	vr	vr	f	vr	vr	vr
Amphipyndax stocki gr.	r	r	vr				c	r	vr	c	f	f	c	c	vr	vr	vr
Archaeodictyomitra cf. *lamellicostata*							r		is		r	r	vr	vr	vr		vr
Artostrobus pusillus										r			vr	vr	vr		
Bathropyramis sanjoaquinensis s.l.		r	r				r		r			r			r	r-f	f
Cornutella californica		vr	vr	vr	vr	vr	r	vr	r		r	r	vr	vr	r	r	r
Cryptocarpium? cf. *ornatum*	vr		?						?		vr	vr	vr		vr		
Cyrtocapsa campi	vr	vr															
Cyrtocapsa livermorensis	vr	vr					vr			vr	vr				vr		
Dictyomitra andersoni	r	f-r	vr				f		vr	f	r	f	f	f	vr		
Dictyomitra multicostata							r				r		vr	vr	vr		is
Eusyringium woodsidensis n.sp.							r		vr					vr	vr		vr
Lithocampe wharanui n.sp.		vr	vr				r		r	f	vr			vr	vr	vr	vr
Lithocampe aff. *subligata*							vr										
Lithomelissa cf. *heros*	r	vr	is									vr	f	vr	vr	vr	
Lithomelissa? aitai n.sp.	r-f	r					r		?		c	f	vr	vr	vr		
Lithomelissa? hoplites	vr												r				
Lithomelissa? polycyrtis		vr					r		?		f	f	r				
Mita regina	vr	vr					r		is	vr	vr	r	vr	vr	vr		
Mita cf. *regina*	vr	vr					r						vr				
Myllocercion acineton	r-f	f-r					vr			?	vr	r	f		vr		
Myllocercion aff. *echtus*	vr	r												vr			
Neosciadiacapsa jenkinsi	r	vr					f		vr	vr	c	f					
Phormostichoartus? strongi n.sp.							vr			vr	f	f					
Siphocampe altamontensis	vr	vr									vr	r					
Siphocampe cf. *altamontensis*							vr			vr	vr						
Stichomitra bertrandi	vr	vr					vr				vr	vr	r		vr		
Stichomitra carnegiensis	vr	f-r	is				f		?				c	r	vr		?
Stichomitra cf. *carnegiensis*							f		vr		?						
Stichomitra grandis	r-f	r					r		?			vr	c				?
Theocampe cf. *vanderhoofi*	a-f	c-r	is				vr				f	f	f		vr		
Theocapsomma amphora	vr	vr					r			r			vr	r	vr	vr	
Theocapsomma erdnussa	vr	vr					r					vr			?		?
Paleocene Spumellaria																	
Amphisphaera aotea		f-vr															
Amphisphaera coronata s.l.		r	f	f-c	f-c	f-c			f							f	f
Amphisphaera kina		f-r	f-r											c	vr		vr
Amphisphaera goruna		vr-f	f	f-r					f					vr	f	f	f-r
Amphisphaera macrosphaera		r	r-f	r	r	vr		c	f						r	f	f
Haliomma teuria n.sp.							?								*		
Haliomma gr. b		r-f	f-c	f-c	f-c	f-c		f	f						c	c	c
Lithelius aff. *foremanae*		vr												vr	vr	vr	
Periphaena sp.				r	r	r			vr							vr	vr
Saturnalis kennetti		vr	vr											vr	vr		
Stylosphaera minor		r	r	r	r	vr			r						r-f	f	f-r
Tholodiscus cf. *targaeformis*		vr	vr												vr	r	r
Paleocene Nassellaria																	
Buryella dumitricai		f-c	r	vr				f	r						c	vr	vr
Buryella foremanae		f-r	r												c	vr	vr
Buryella granulata		c-f	f-r	vr					f						a	r	r
Buryella kaikoura n.sp.									r								f
Buryella tetradica			c	c-f	f-vr				c			??				a	a
Clathrocyclas australis n.sp.		r	vr					c	r					vr	f	f	f-vr
Dictyophimus aff. *archipilium*		vr	vr												f	f	c-f
Dictyophimus aff. *pocillum*			vr					vr							vr		
Dorcadospyris aff. *confluens*		vr	r						r						f	f	f
Lithostrobus wero		f-r	r					f						r	vr	vr	vr

2.3.2. *Mara quarry, Wairarapa*

A single dolomitic concretion (U25/f199) collected by Moore (1988) from a quarry (grid ref. U25/836555) within Whangai Formation (Haumurian-Teurian) yielded a diverse, well-preserved radiolarian assemblage similar to the most diverse Haumurian assemblages of Marlborough and DSDP Site 275 (see below). A late Campanian-Maastrichtian age is inferred because all primary index species for the Paleocene are absent. The presence of at least one species (*Stichomitra* cf. *carnegiense* and also possible *Saturnalis kennetti*) elsewhere known only from the Paleocene is not considered to be a reliable indicator of age, but rather to reflect the very high diversity of the assemblage (Hollis 1990). A very diverse Late Cretaceous assemblage in a different geographic and environmental setting to the Marlborough Cretaceous assemblages has the potential to contain species which do not appear until the Paleocene in Marlborough.

2.3.3. *Kaiwhata Stream, Wairarapa*

A calcareous concretion (T27/f553) collected from Whangai Formation in Kaiwhata Stream (T27/547045) yielded a well-preserved Early Paleocene fauna which is correlated with Zone RP4. Some 2.5 km upstream (T27/568036), siliceous mudstone from Whangai Formation yielded poorly preserved Campanian-Maastrichtian assemblages.

2.3.4. *Tioriori, Chatham Island*

Sea cliffs at Tioriori, northern Chatham Island, provide a valuable record of Cretaceous-Eocene sedimentation in the outer Chatham Rise (Campbell *et al.* 1993; Hollis 1995). Schist basement is overlain by Late Cretaceous-Paleocene Takatika Grit which consists of highly phosphatised bands of reworked marine reptile bones (E. Fordyce, pers. comm.), diatomite nodules, and other cobble-sized clasts bound in a cemented sandstone matrix. Overlying this formation is the Tutuiri Greensand (Paleocene-Eocene). The basal unit is a 1.5 m thick biosiliceous sandstone rich in sponge spicules, radiolarians, and diatoms. A suite of samples was collected from both formations at the type locality of Takatika Grit (CH/363777).

Only sparse Late Cretaceous radiolarians were recovered from the grit (CH/f617, f618), but very rich and extremely well-preserved radiolarian faunas were recovered from the basal Tutuiri Greensand (CH/f613-f616). All four samples are correlated with upper Zone RP5 (Late Paleocene) based on the co-occurrence of *Buryella tetradica*, *B. pentadica,* and *Microsciadiocapsa*? sp. Several Cretaceous "survivor" species occur in low numbers within this interval, including species known to range into RP5 elsewhere (*Amphipyndax stocki*, *Archaeodictyomitra* cf. *lamellicostata*, *Eusyringium woodsidensis* n.sp.) as well as others known only from the earlier Paleocene (*Orbiculiforma renillaeformis s.s.*, *Prunobrachium kennetti*). Given the coarse texture of this unit, it is possible that some radiolarians may be reworked. Nearby radiolarian-rich Cretaceous deposits are a potential source of reworked specimens (e.g. DSDP Site 275).

2.3.5. *DSDP Site 275, southeastern Campbell Plateau*

DSDP Site 275 was drilled in a water depth of 2 800 m at latitude 50°26.34' S and longitude 176°18.99' E. Three samples were examined from the biosiliceous facies in cores 1 to 5 (275-1-1, 102-104 cm; 275-2-3, 100-102 cm; 275-5-1, 43-45 cm). In an earlier study of the radiolarians from this site, Pessagno (1975) suggested a late Campanian age for this interval, based on the presence of *Phaseliforma* which was thought to have died out in the late Campanian. The genus is now known to range into the Paleocene, and the age of the interval is broadened to late Campanian-Maastrichtian (Hollis 1993a). Apart from a record of a species similar to *Lithostrobus wero* in sample 275-1, CC (Petrushevskaya 1977, pl. 3, fig. u), no Paleocene index species has been observed. Radiolarian assemblages are considerably more diverse than indicated in Pessagno's (1975) original report. In addition to numerous and as yet undocumented spumellarians, the interval has many species in common with Marlborough (see Table 2).

2.3.6. *DSDP Site 208, northern Lord Howe Rise (Fig. 10)*

DSDP Site 208 was drilled in a water depth of 1545 m at latitude 26°06.61' S and longitude 161°13.27' E. Fourteen samples were examined from the Maastrichtian-Eocene interval. Faunal data were combined with those provided by Dumitrica's (1973) study of four core-catcher samples to assist in defining zones RK9-RP5 (Hollis 1993a). The site was designated as type section for Zone RP5. In Table 2 radiolarian occurrences are grouped as follows:

1. Maastrichtian, RK9: 208-34-3, 100-102 cm; 208-33-2, 108-110 cm;
2. Basal Paleocene, RP2: 208-33-1, 60-62 cm; 208-33-1, 40-42 cm;
3. Early Paleocene, RP4: 208-32, CC; 208-31, CC; 208-31-3, 101-102; 208-31-2, 28-30 cm; 208-30, CC; 208-30-6, 98-100 cm;
4. Late Paleocene, lower RP5: 208-30-3, 101-102cm; 208-30-2, 31-33 cm;
5. Late Paleocene, upper RP5: 208-30-1, 24-26cm; 208-29, CC; 208-29-6, 128-130 cm; 208-29-4, 28-30 cm; 208-29-3, 101-103 cm.

Eocene sample 208-29-1, 65-67 cm is not shown.

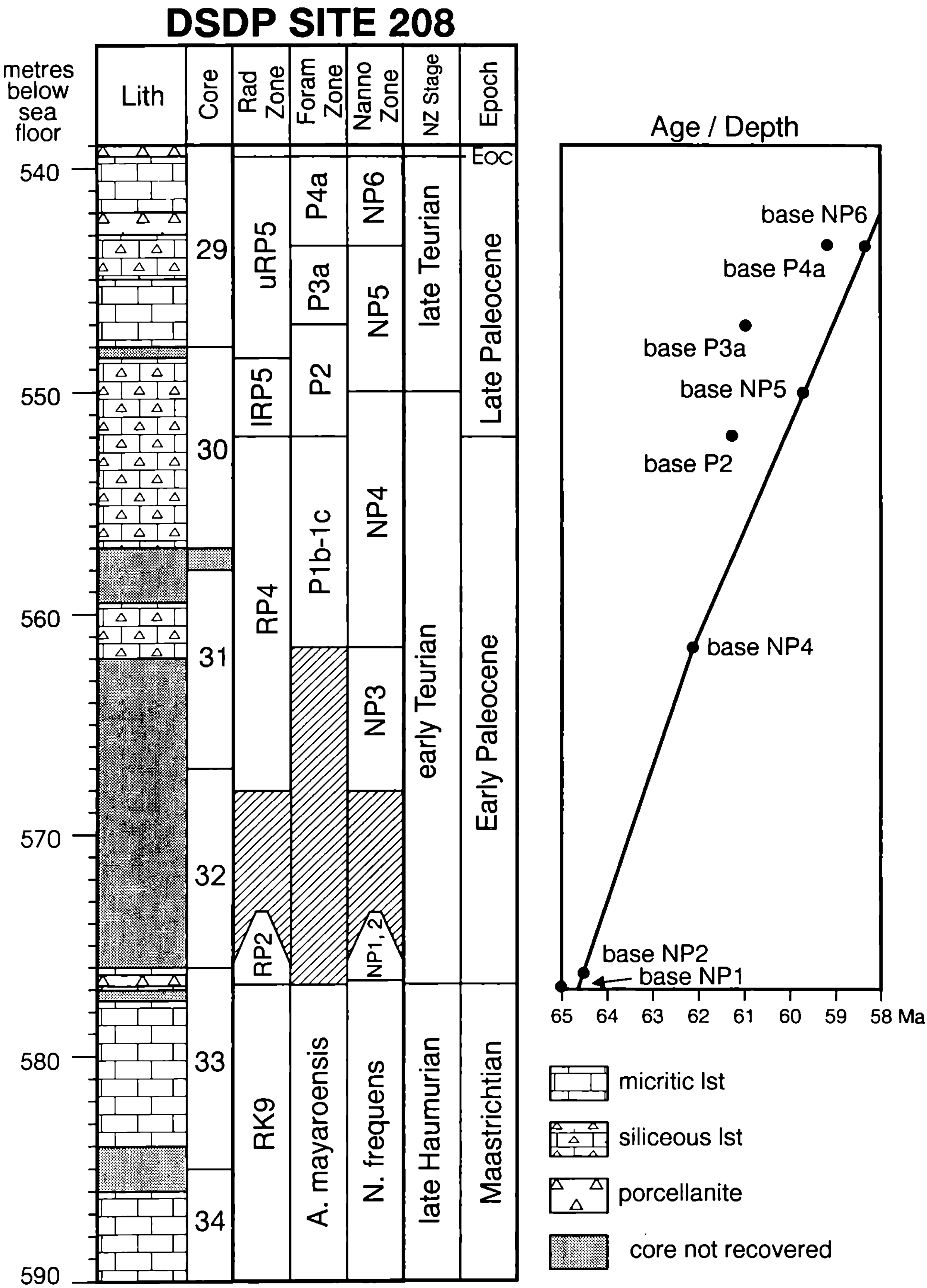

Figure 10 Stratigraphic column of DSDP Site 208 showing lithologic units, radiolarian zones, foraminiferal zones (Webb 1973), and nannofossil zones (Burns *et al.* 1973; Edwards 1973). Location approximate for base of zones RP4 and NP3 which occur in 208-32-CC (only part of Core 32 recovered). In age/depth plot, solid circles = dated event.

CHAPTER 3. BIOSTRATIGRAPHY

3.1. CORRELATION OF RADIOLARIAN ZONES WITH PALEOGENE TIMESCALE (Figs. 2, 11)

Three methods have been employed to calibrate radiolarian zones with the revised Paleogene timescale (Berggren *et al.* 1995).

1. Direct dating of radiolarian events by accompanying fossils: foraminiferal dating of RK9/RP1 and RP1/RP2 boundaries at Flaxbourne River (C.P. Strong pers. comm.); nannofossil dating of basal RP2 and interval from lower RP4 to upper RP5 at DSDP Site 208 (Burns *et al.* 1973; Edwards 1973); foraminiferal and dinoflagellate dating of RP6 to RP13 at Mead Stream (Strong *et al.* 1995).
2. Adoption of ages for radiolarian events established elsewhere: RP5/RP6 boundary and first approximation of ages for RP8-RP12 at Mead Stream.
3. Interpolation based on age/depth plots is used to locate RP2/RP3 and RP3/RP4 boundaries at Woodside Creek and to constrain events within the RP4-RP5 interval at Site 208.

Foraminifera were not used for correlation at Site 208. Those foraminiferal events present at Site 208 (Webb 1973) are consistently diachronous with respect to nannofossil datums, and the latter are considered more reliable (Burns *et al.* 1973).

Microfossil zones are referred to simply by their codes below: P0-P4 = foraminiferal zones (Berggren *et al.* 1995); NP1-NP6 = nannofossil zones (Martini 1971); RK9, RP1-RP13 = radiolarian zones as described here. All radiolarian zones described here are biozones in the sense of Salvador (1994). In future work it is recommended that these zones be distinguished from the standard tropical chronozones (Riedel & Sanfilippo 1978) by the insertion of "(sp)", i.e. "South Pacific", within the alphanumeric code, e.g. Zone RP(sp)1. FAD, LAD = first appearance datum, last appearance datum.

3.2. RADIOLARIAN ZONATION

3.2.1. Latest Cretaceous to Late Paleocene (Fig. 11)

The zonation introduced here is a substantial revision of the initial radiolarian zonation for the K-T transition of the New Zealand region (Hollis 1993a). Revisions are the result of a thorough re-examination of the radiolarian faunal succession of eastern Marlborough, improved foraminiferal age control at Flaxbourne River (C.P. Strong pers. comm.), and a reassessment of age control at DSDP Site 208 (Burns *et al.* 1973). Changes are made to the location of some zonal boundaries at the Woodside Creek stratotype (zones RK9-RP5), many new faunal events are recognised within the zones, and correlation with other fossil groups is improved. Results of preliminary studies of material from DSDP Site 327A (South Atlantic Ocean) and ODP Site 752B (South Indian Ocean) and the "via Perimetral" K-T boundary section in Ecuador (Keller *et al.* 1997) are also used to trace the geographic extent of Paleocene zones.

Ranges of Tertiary-restricted species arranged in order of first appearance are shown in Figure 12, and ranges of Cretaceous-Tertiary species arranged in order of last appearance are shown in Figure 13.

RK9, *Lithomelissa? hoplites* Interval Zone (Hollis 1993a, emend. herein)

DEFINITION: Interval from the FAD of *Orbiculiforma renillaeformis* to the FAD of *Amphisphaera aotea*. The base may be recognised by the secondary datums: FAD *Lithomelissa? hoplites* and FAD *L.? polycyrtis*.

STRATOTYPE: Mead Hill Formation, Woodside Creek; interval from 30 m below K-T boundary to top of boundary mudstone (WO28-WO51).

EVENTS: Although the base has not been identified in the southwest Pacific, by definition it is assumed to coincide with a late Campanian faunal event which includes the earliest occurrences of *L.? hoplites*, *L.? polycyrtis* (California and tropical Atlantic: Foreman 1968, 1977, 1978; Petrushevskaya & Kozlova 1972), *O. renillaeformis s.s.*, *Stylosphaera pusilla*, *Theocampe* cf. *vanderhoofi*, *Siphocampe altamontensis*, *Theocapsomma amphora*, *T. erdnussa*, and *Amphipternis alamedaensis* (California and tropical Pacific: Campbell & Clark 1944a; Foreman 1968; Pessagno 1976; Empson-Morin 1981).

Several species known only from the southwest Pacific may first appear within the zone, but as yet no intrazonal events have been identified. The top of the zone coincides with a change from nassellarian to spumellarian dominance in all Marlborough sections and DSDP Site 208 but in contrast to the K-T transition in California (Foreman 1968) the K-T boundary is not marked by any radiolarian extinctions.

FAUNAL CHARACTER: In all southwest Pacific localities examined, the zone is dominated by nassellarians. Diversity is moderate to high. Common species include *Amphipyndax stocki* gr., *Theocampe* cf. *vanderhoofi*, *Myllocercion acineton*, *Dictyomitra andersoni*, *Stichomitra grandis*, *S. carnegiensis*, and *Lithomespilus coronatus*.

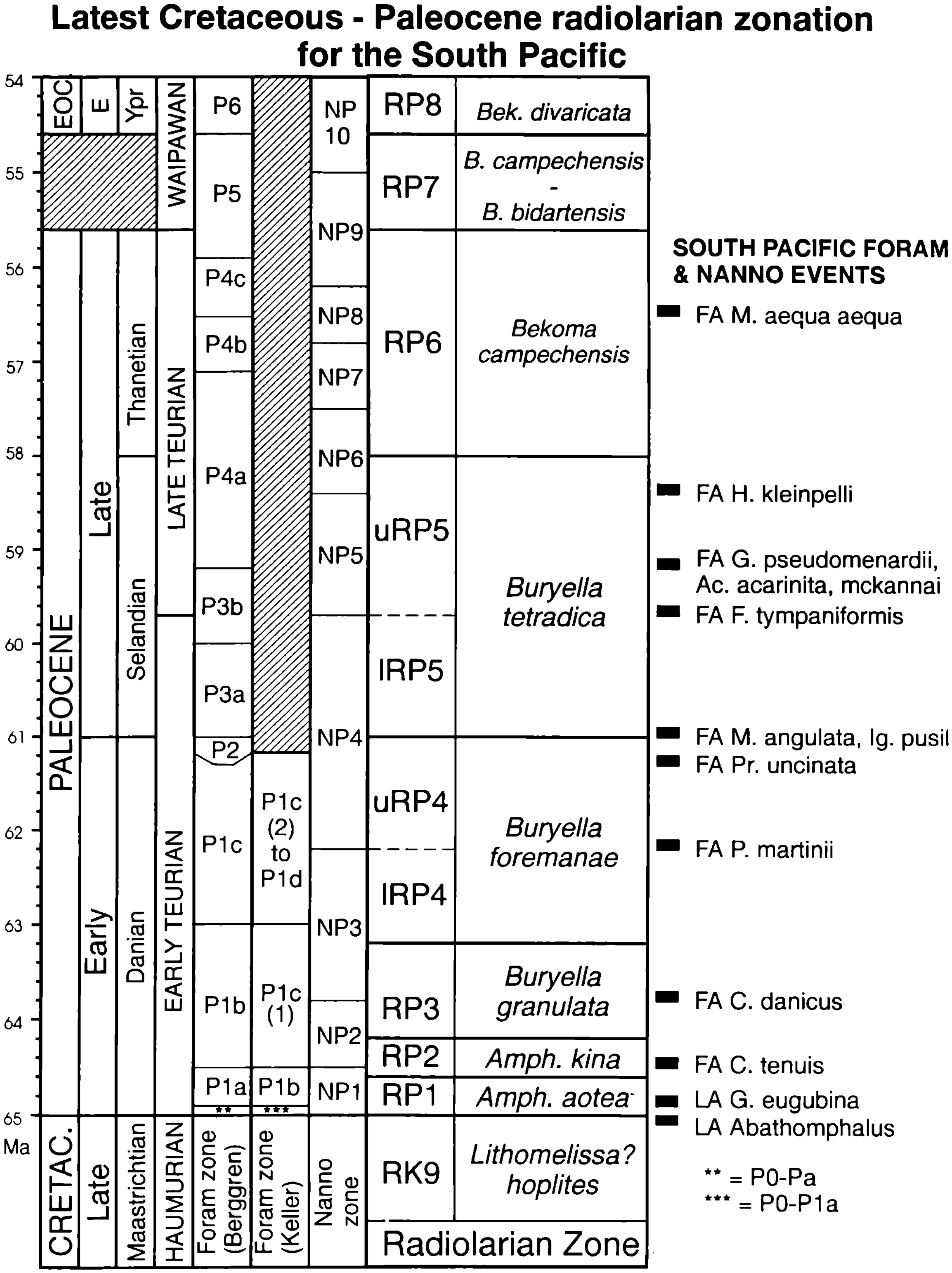

Figure 11 Latest Cretaceous-Paleocene radiolarian zonation. See explanation in text (Section 3.1).

WOODSIDE CREEK RANGE CHART (1): PALEOCENE RADIOLARIANS BY FIRST APPEARANCE

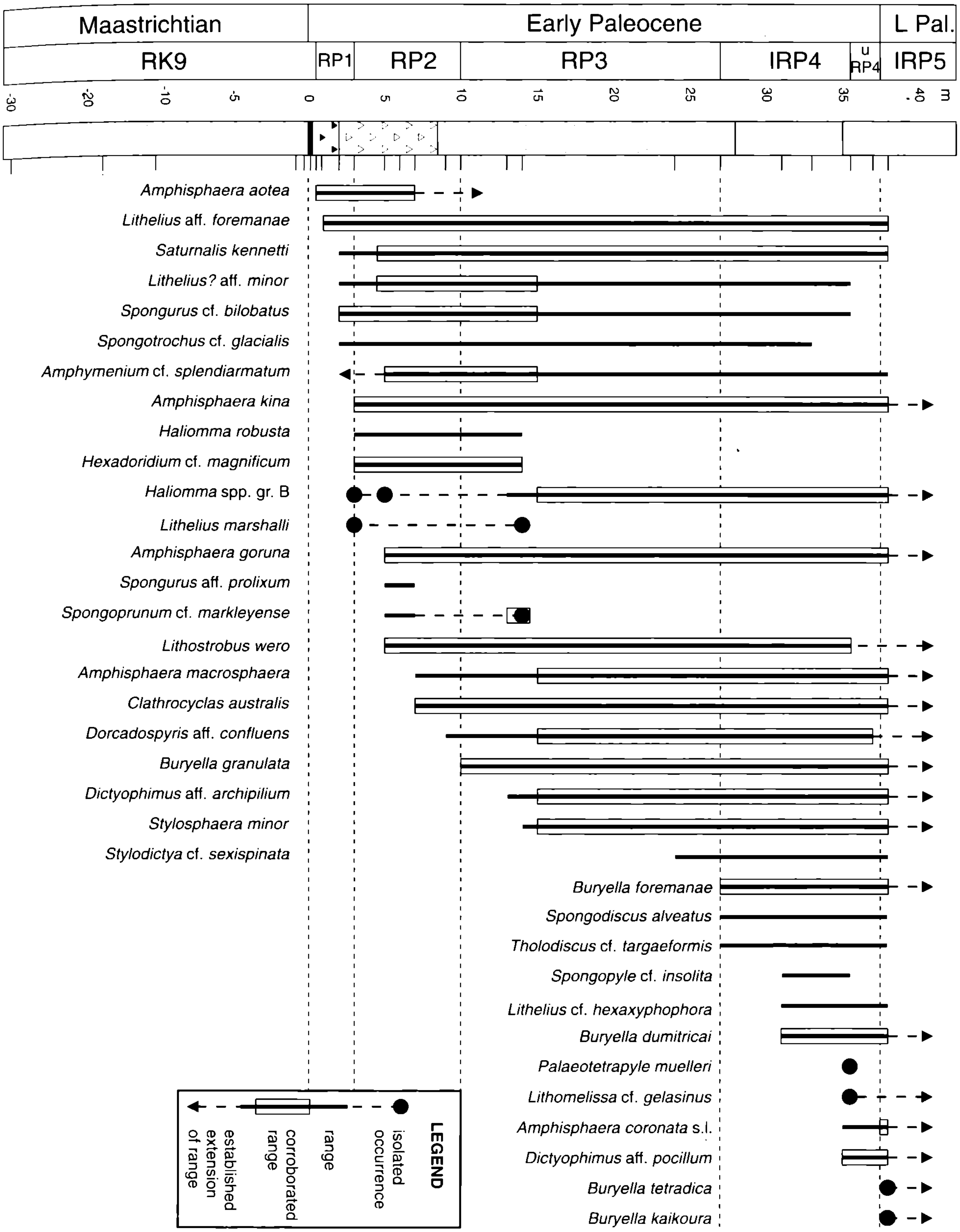

Figure 12 Ranges of Paleocene radiolarians at Woodside Creek, in order of first appearance.

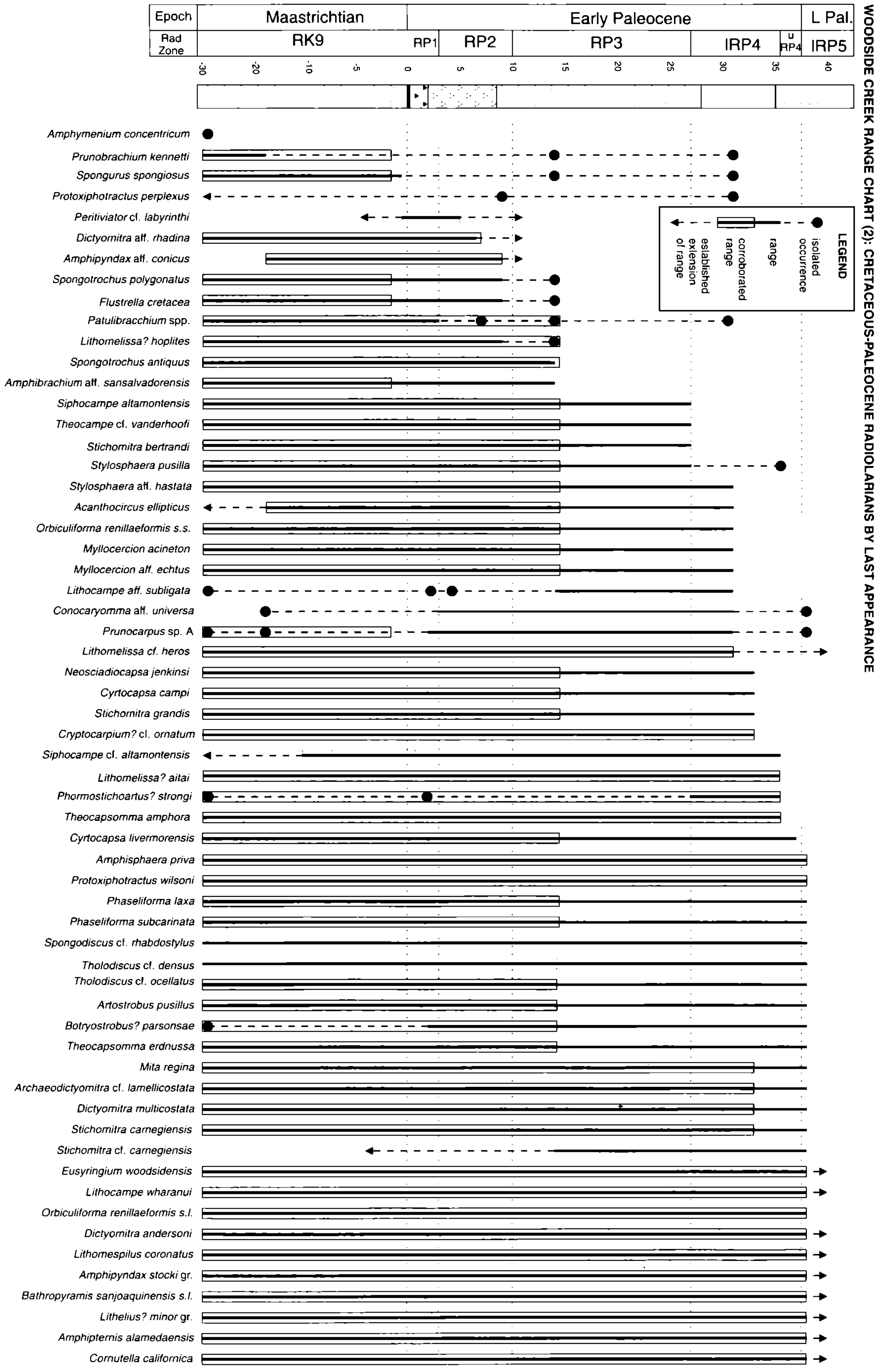

Figure 13 Ranges of Cretaceous-Paleocene radiolarians at Woodside Creek, in order of last appearance.

REMARKS: The definition is revised to accommodate localities where *O. renillaeformis* is present but the rarer and less widely occurring *L.? hoplites* is absent. The original name is retained to avoid confusion with the Californian *Orbiculiforma renillaeformis* Zone (Pessagno 1976), the base of which is defined as the LAD of the Phaseliformidae (see below).

In the absence of any radiolarian extinctions at the K-T boundary in Marlborough, this zone effectively spans the boundary. Although *A. aotea* usually occurs in the lowermost Paleocene samples examined, it is now evident that earliest Paleocene faunas within the first few millimetres of Tertiary sediment at Woodside Creek and Flaxbourne River lack *A. aotea*, and are in other respects largely indistinguishable from latest Cretaceous faunas. The boundary between the RK9 and RP1 appears to lie within the K-T boundary clay at Flaxbourne River; *A. aotea* first appears 3 mm above the base of the boundary clay.

CORRELATION: The zone is correlated with the late Campanian to Maastrichtian *Amphipyndax tylotus* Zone of Foreman (1977), based on the presence of *L.? hoplites*. Apart from an isolated occurrence in samples dredged from the Tonga Trench (Ballance *et al.* 1989), *A. tylotus* has not been recorded in the latest Cretaceous of the Southwest Pacific. The zone is also correlated with upper *Patulibracchium dickinsoni* and *O. renillaeformis* Zones of California (Pessagno 1976). The boundary between these two zones is defined as the LAD of the Phaseliformidae, and is clearly not valid in the southwest Pacific where the genus *Phaseliforma* ranges into the Paleocene.

AGE RANGE: Haumurian to earliest Teurian, late Campanian to earliest Paleocene.

GEOGRAPHIC EXTENT: Marlborough, Wairarapa, DSDP Sites 275 and 208, California.

RP1, *Amphisphaera aotea* Interval Zone (Hollis 1993a)

DEFINITION: Interval from the FAD of *Amphisphaera aotea* to the FAD of *A. kina*.

STRATOTYPE: Mead Hill Formation, Woodside Creek; 0.5-2 m above the K-T boundary.

EVENTS: *A. aotea* is the only Tertiary species in the lower part of the zone. *Amphymenium* cf. *splendiarmatum*, *Lithelius* aff. *foremanae*, *Lithelius*? aff. *minor*, *Saturnalis kennetti*, *Spongurus* cf. *bilobatus*, and *Spongotrochus* cf. *glacialis* first appear in the upper part of the zone. No LAD is noted.

FAUNAL CHARACTER: Actinommid spumellarians are dominant, particularly *A. aotea*, *Lithomespilus coronatus*, and *Stylosphaera pusilla*. Diversity is low. Common nassellarians are: *Amphipyndax stocki* gr., *Dictyomitra* spp., *Myllocercion* spp., and *Theocampe* cf. *vanderhoofi*.

CORRELATION: *A. aotea* first appears in lowermost foraminiferal zone P0 at Flaxbourne River, 3 mm above the base of the K-T boundary clay.

AGE: Earliest Teurian, earliest Paleocene (P0 to P1a).

GEOGRAPHIC EXTENT: Correlative faunas lacking high numbers of Cretaceous "survivors" occur in earliest Paleocene tuff in southern Indian Ocean ODP Site 752B (11R-2, 115 cm to 11R-1, 130 cm; NP1) and are used to define the base of the Paleocene in the "via Perimetral" K-T boundary section in Ecuador (Keller *et al.* 1997).

RP2, *Amphisphaera kina* Interval Zone (Hollis 1993a)

DEFINITION: Interval from the FAD of *Amphisphaera kina* to the FAD of *Buryella granulata*.

STRATOTYPE: Mead Hill Formation, Woodside Creek, 3-9 m above the K-T boundary.

EVENTS: *Haliomma teuria* n.sp., *Amphisphaera goruna*, *Spongoprunum* cf. *markleyense*, *Spongurus* aff. *prolixum*, and *Lithostrobus wero* first appear in lower RP2; *L. wero* occurs more regularly from upper RP2. *Amphisphaera macrosphaera*, *Clathrocyclas australis* n.sp., and *Dorcadospyris* aff. *confluens* first appear in upper RP2. No LAD is noted.

FAUNAL CHARACTER: Actinommid spumellarians continue to dominate the fauna, but other spumellarian families increase in abundance (phacodiscids, litheliids, spongurids and spongodiscids). Diversity is moderate to high, and common species include: *Amphisphaera kina*, *Lithelius minor* gr., *Spongotrochus* spp., *Amphipyndax stocki* gr., and *Dictyomitra andersoni*.

CORRELATION: *A. kina* first appears in an interval correlated with upper P1a to P1b at Flaxbourne River and in CP1a at DSDP Site 208.

AGE: Early Teurian, early Early Paleocene (P1a to P1b; NP1 to NP2).

GEOGRAPHIC EXTENT: Marlborough and DSDP Site 208. Correlative faunas lacking high numbers of Cretaceous "survivors" occur in southern Atlantic DSDP Site 327A (9-6, 108-115 cm; Paleocene; pers. obs. DSDP/ODP Micropaleontological Reference Centre Collection), southern Indian Ocean ODP Site 752B (11R-1, 130 to 10R-6, 86 cm; NP1; pers. obs.), and comprise all but the very base of the Paleocene interval in the "via Perimetral" K-T boundary section in Ecuador (Keller *et al.* 1997).

RP3, *Buryella granulata* Interval Zone (Hollis 1993a)

DEFINITION: Interval from the FAD of *Buryella granulata* (= *Stichomitra granulata* in Hollis 1993a) to the FAD of

Stratotype:: Mead Hill Formation, Woodside Creek; 10-24 m above K-T boundary.

Events: *Dictyophimus* aff. *archipilium* and *Stylosphaera minor* first appear in lower RP3. *Stylodictya* cf. *sexispinata* first appears in upper RP3. *Amphisphaera macrosphaera* and *Haliomma* spp. gr. B, both of which occur sporadically lower in the Paleocene become common in RP3. *Dictyomitra* aff. *rhadina*, *Amphisphaera aotea*, *Amphibrachium* aff. *sansalvadorensis*, *Spongotrochus antiquus*, *Lithomelissa*? *hoplites*, and *Amphipyndax* aff. *conicus* last appear in lower RP3.

Faunal character: RP3 faunas show a progressive transition from actinommid-dominated faunas of RP1-2 to the more balanced faunas, with respect to spumellarian versus nassellarian abundance, of RP4-5. Spumellarians decline in abundance concomitant with an increase in Paleocene nassellarians (*Lithostrobus wero*, *Buryella granulata*) and *Amphipyndax stocki* gr.

Correlation: The boundaries of this zone have poor direct fossil control. Age of the lower boundary is based on the age/depth plot at Woodside Creek (Fig. 6).

Age: Early Teurian, middle Early Paleocene (lower NP3).

Geographic extent: Marlborough. Not confirmed at Site 208 because the interval between RP2 and RP4 was lost during drilling. Correlative faunas occur in Hokkaido (Iwata & Tajika 1986, 1992; Hollis 1993a), and southern Indian Ocean ODP Site 752B (10R-5, 68 cm to 10R-3, 111 cm; NP2).

RP4, *Buryella foremanae* Interval Zone (Hollis 1993a)

Definition: Interval from the FAD of *Buryella foremanae* to the FAD of *B. tetradica*.

Stratotype: Mead Hill Formation, Woodside Creek; 27-37 m above K-T boundary. DSDP Site 208 is designated parastratotype because it is considered to contain a more complete record of upper RP4.

Events: *Buryella dumitricai*, *Spongodiscus alveatus*, and *Tholodiscus* cf. *targaeformis* first appear in lower RP4. *Amphisphaera coronata s.l.*, *Lithomelissa* cf. *gelasinus*, and *Dictyophimus* aff. *pocillum* first appear in upper RP4. Numerous Cretaceous survivor species last appear in RP4. In lower RP4 these include: *Acanthocircus ellipticus*, *Patulibracchium* spp., *Orbiculiforma renillaeformis* s.s, *Siphocampe altamontensis*, *Theocampe* cf. *vanderhoofi*, *Myllocercion acineton*, *M.* aff. *echtus*, *Neosciadiocapsa jenkinsi*, *Cyrtocapsa campi*, *Stichomitra bertrandi*, and *S. grandis*. *Stylosphaera pusilla*, *Lithomelissa*? *aitai* n.sp., *Phormostichoartus*? *strongi* n.sp., *Siphocampe* cf. *altamontensis* and *Theocapsomma amphora* last appear in upper RP4. *Orbiculiforma renillaeformis s.l.*, *Lithomelissa* cf. *heros*, and *Cyrtocapsa livermorensis* last appear in RP4 at Woodside Creek, but have isolated occurrences in other localities in RP5.

Faunal character: Spumellarians remain abundant, with litheliids and actinommids common. Diversity is high, and common species are *Amphipyndax stocki* gr., *Amphisphaera goruna*, *Buryella dumitricai*, *Dictyomitra andersoni* and *Clathrocyclas australis* n.sp.

B. foremanae and *B. dumitricai* are never abundant at Woodside Creek. Both species and *B. granulata* are common to abundant in RP4 at Site 208.

Correlation: Age of the lower boundary is estimated by interpolation between datums on the age/depth plot for DSDP Site 208 (Fig. 10). It is assumed that *B. foremanae* first appears directly below Core 31, which is the highest location possible for the event recorded by Dumitrica (1973) within 32-CC, the only material retrieved from Core 32. The resulting minimum age estimate is consistent with a constant rate of sedimentation through the Early Paleocene at Woodside Creek (Fig. 5). The upper boundary is within middle NP4 at Site 208, approximately at the Early/Late Paleocene boundary.

A distinctive intrazonal event, the FAD of *Dictyophimus* aff. *pocillum*, occurs close to the NP3/NP4 boundary at Site 208, and is used to divide the zone into lower and upper parts. Because the event occurs near the top of the zone at Woodside Creek, the upper part of RP4 is thought to be missing in this section. A sharp lithologic break directly below the event suggests an intrazonal hiatus (see Fig. 5).

Age: Early Teurian, late Early Paleocene (upper NP3 to mid NP4).

Geographic extent: Marlborough, Wairarapa, DSDP Site 208. Correlative faunas occur in Russia (*Buryella*? *alifera* Zone of Kozlova 1984, 1993), Hokkaido (Iwata and Tajika 1986, 1992; Hollis 1993a), southern Atlantic DSDP Site 327A (8-5, 77-84; Paleocene; pers. obs., DSDP reference collection), and southern Indian Ocean ODP Site 752B (9R-1, 89 cm to 5R-3, 109 cm; NP3; pers. obs.).

RP5, *Buryella tetradica* Interval Zone (Hollis 1993a)

Definition: Interval from the FAD of *Buryella tetradica* to the FAD of *Bekoma campechensis*.

Stratotype: DSDP Site 208-30-3, 101-103 cm to 29-3, 101-103 cm. Uppermost Mead Hill Formation, Mead Stream section, is designated parastratotype because it contains the boundary between RP5 and RP6.

Events: *Buryella kaikoura* n.sp. first appears in lower RP5. *Microsciadiocapsa*? sp. (see Strong *et al.* 1995) and *Buryella pentadica* first appear in upper RP5. Numerous

Cretaceous survivors last appear in the zone, notably: *Amphisphaera priva, Protoxiphotractus wilsoni* n.sp., *Phaseliforma* spp., *Theocapsomma erdnussa, Archaeodictyomitra* cf. *lamellicostata, Mita regina, Eusyringium? woodsidensis* n.sp., and *Lithocampe wharanui* n.sp.

FAUNAL CHARACTER: Site 208 faunas are dominated by litheliids, eucyrtids, and actinommids. Common species include: *Lithelius? minor* gr., *Buryella tetradica, Dictyophimus* spp., *Amphisphaera coronata s.l., A. macrosphaera, A. goruna,* and *Buryella granulata. Buryella kaikoura* is common in the upper part of the zone. Similar faunas were encountered at Chancet Rocks, but those at Woodside Creek differ by containing abundant *Amphipyndax stocki* gr. and common archaeodictyomitrids.

CORRELATION: *B. tetradica* first appears approximately at the Early/Late Paleocene boundary at Site 208 (mid NP4). Although only a maximum age limit can be determined for the top of RP5 (lower NP6), this is close to the minimum age limit provided by the FAD of *Bekoma campechensis* in tropical and North Atlantic (Foreman 1973a; Nishimura 1987). Site 208 faunas show no evidence for the diachronous early occurrence (upper NP4) of *B. campechensis* reported by Nishimura (1992) for North Atlantic DSDP Site 384.

RP5 is divided into lower and upper parts based on the FAD of *Microsciadiocapsa?* spp. This event occurs 1.5 m above the NP4/NP5 boundary and is used as an approximate guide to the early/late Teurian boundary. This event is the basis for inferring that only the lower part of RP5 is preserved at Woodside Creek and Chancet Rocks, and that only upper RP5 has been identified at Flaxbourne River, Mead Stream, and Tioriori (Chatham Island).

AGE RANGE: Late early to early late Teurian, early Late Paleocene (mid NP4 to mid NP6).

GEOGRAPHIC EXTENT: Marlborough, Chatham Island, and DSDP Site 208. Correlative faunas occur in southern Atlantic DSDP Site 327A (8-3, 77-84 cm to 5-1, 50-57 cm; Late Paleocene; pers. obs., DSDP reference collection) and ODP Site 752B (5R-2, 116 to 5R-1, 131 cm; NP4; pers. obs.). The zone is distinguished from correlative assemblages in the tropical Atlantic (Foreman 1973a) and Russia (= *Buryella tetradica* [assemblage] Zone of Kozlova 1984, 1993) by the absence of *Phormocyrtis striata exquisita* and *Bekoma* spp.

3.2.2. Late Paleocene to Middle Eocene (Fig. 2)

The following zones were established in an integrated biostratigraphic study of foraminifera, radiolarians, and dinoflagellates of the Late Cretaceous to Eocene sequence at Mead Stream (Strong *et al.* 1995). None of these zones has been identified in eastern Marlborough, due to lack of suitable exposure, but because they are referred to throughout the text a brief summary is warranted. Moreover, subsequent consideration of the Mead Stream radiolarian succession in relation to the present study has highlighted a need to revise some aspects of this zonation. In particular, although it was possible to relate the Mead Stream succession to tropical and Northern Hemisphere zonations, significant discrepancies are evident in both taxa present and their ranges. To advance their utility in the New Zealand region, it is considered appropriate that these zones be treated as part of a new southern high-latitude zonation. Seven new biostratigraphic zones are erected, and one other is treated as a loose equivalent to the northern hemisphere zone with which it is correlated. For further details, including taxonomic notes, refer to Strong *et al.* (1995). See also Hollis *et al.* (1997).

RP6, *Bekoma campechensis* Range Zone (*s.l.* Nishimura 1987)

DEFINITION: Total range of *Bekoma campechensis. Corythomelissa adunca,* and *Lychnocanoma auxilla* first appear in lower RP6. *Amphisphaera kina, Dictyomitra andersoni, Lithostrobus wero,* and *Stichomitra carnegiensis* last appear in the zone.

REFERENCE SECTION: Mead Stream (Fig. 9), uppermost Mead Hill Formation, and lowermost Amuri Limestone (basal "lower limestone"; 257.4 - 262 m above base of Muzzle Group).

AGE : Latest Teurian, late Late Paleocene.

REMARKS: Adopted in the original (Nishimura 1987) rather than emended sense (Nishimura 1992). In the latter study of North Atlantic DSDP Site 384, an extremely well-preserved and rich radiolarian succession was shown to include a very early appearance of *B. campechensis* (nannofossil zone NP4), and the only known record of the evolutionary transition from *B. campechensis* to *B. bidartensis* (NP8). In other areas the first event occurs later (NP5-NP6), and there is no overlap between the ranges of these two species (Foreman 1973a; Nishimura 1987). At Mead Stream the stratigraphic gap between the LAD of *B. campechensis* and the FAD of *B. bidartensis* is an interval of at least 40 m, including four samples with distinctive faunas, and is described as a new zone below.

RP7, *Bekoma campechensis-B. bidartensis* Interval Zone, new zone

DEFINITION: Interval from the LAD of *B. campechensis* to the FAD of *B. bidartensis. Amphicraspedum prolixum* gr., *Axoprunum pierinae, Sethochytris babylonis* gr., and *Phormocyrtis striata exquisita* first appear in lower RP7.

STRATOTYPE: Mead Stream (Fig. 9), lower Amuri Limestone ("lower limestone"; 262-308 m).

AGE: Earliest Waipawan, latest Paleocene-Early Eocene.

REMARKS: RP6-7? in Strong *et al.* (1995), see remarks under RP6.

RP8, *Bekoma divaricata* Interval Zone, new zone

DEFINITION: Interval from first morphotypic appearance of *B. bidartensis* to the LAD of *B. divaricata. Phormocyrtis striata striata, Podocyrtis papalis,* and *P. aphorma* first appear in lower RP8. *Bekoma bidartensis* last appears in lower RP8. *Amphisphaera goruna, Microsciadiocapsa*? sp., *Corythomelissa adunca,* and *Phormocyrtis striata exquisita* last appear in upper RP8. RP8 includes the last common occurrence of *Buryella tetradica.*

STRATOTYPE: Mead Stream (Fig. 9), lower Amuri Limestone ("lower limestone"; 308 - 324 m).

AGE: Middle Waipawan, early Early Eocene.

REMARKS: Although primary index species suggest a correlation with the *Bekoma bidartensis* and *Buryella clinata* Zones of tropical and northern areas (Sanfilippo *et al.* 1985; Nishimura 1987), foraminiferal and dinoflagellate age control at Mead Stream indicate that RP8 spans a significantly earlier and more narrow time interval. *B. clinata* has not been encountered in the southwest Pacific, but elsewhere the top of the *B. clinata* zone is marked by the evolutionary transition from *Phormocyrtis striata exquisita* to *P. s. striata* and the LADs of *Bekoma bidartensis* and *B. divaricata.*

RP9, *Bekoma divaricata-Theocampe mongolfieri* Interval Zone, new zone

DEFINITION: Interval from the LAD of *Bekoma divaricata* to the FAD of *Theocampe mongolfieri. Theocampe urceolus* first appears in RP9. *Phormocyrtis striata striata* is the only member of this species present.

STRATOTYPE: Mead Stream (Fig. 9), middle Amuri Limestone ("lower marl"; 324 - 400 m).

AGE: Late Waipawan to middle Mangaorapan, middle Early Eocene.

REMARKS: Although primary index species suggest a correlation with the *Phormocyrtis striata striata* and *Theocotyle cryptocephala* Zones of tropical and northern areas (Sanfilippo *et al.* 1985; Nishimura 1987), foraminiferal and dinoflagellate age control at Mead Stream indicate that RP9 spans a significantly earlier time interval.

RP10, *Cycladophora*? *auriculaleporis* Interval Zone, new zone

DEFINITION: Interval from the FAD of *Theocampe mongolfieri* to the FAD of *Eusyringium lagena. Cycladophora*? *auriculaleporis* first appears in lower RP10. *Buryella tetradica, Podocyrtis papalis,* and *Phormocyrtis striata striata* are restricted to isolated occurrences from mid RP10.

STRATOTYPE: Mead Stream (Fig. 9), middle Amuri Limestone ("lower marl" to "upper limestone"; 400 - 500 m).

AGE: Late Mangaorapan to middle Heretaungan, late Early to early Middle Eocene.

REMARKS: Equivalent to RP11 in Strong *et al.* (1995), and appears to span a slightly earlier interval than the tropical *T. mongolfieri* Zone. *T. mongolfieri* first appears in early Middle Eocene in low latitudes (Sanfilippo *et al.* 1985).

RP11, *Eusyringium lagena* Interval Zone, new zone

DEFINITION: Interval from the FAD of *Eusyringium lagena* to the FAD of *E. fistuligerum. Cryptocarpium ornatum, Eucyrtidium* cf. *cheni, Phormocyrtis ligulata, Theocyrtis* aff. *tuberosa,* and *Theocampe amphora* first appear in lower RP11. *Lithapium anoectum* and *Lychnocanoma bellum s.s.* first appear in upper RP11.

STRATOTYPE: Mead Stream (Fig. 9), upper Amuri Limestone ("upper limestone"; 500 - 530 m).

AGE: Late Heretaungan to Porangan, middle Middle Eocene.

REMARKS: Equivalent to RP12 in Strong *et al.* (1995). Approximate age equivalent of the tropical *Thyrsocyrtis triacantha* Zone (Sanfilippo *et al.* 1985).

RP12, *Eusyringium fistuligerum* Interval Zone, new zone

DEFINITION: Interval from the FAD of *Eusyringium fistuligerum* to the FAD of *Lithapium mitra. Lophocyrtis (Lophocyrtis)* cf. *jacchia* and *Lophocyrtis (Paralampterium) longiventer* first appear in lower RP12.

STRATOTYPE: Mead Stream (Fig. 9), upper Amuri Limestone ("upper marl"; 530 - 645 m).

AGE: Early to middle Bortonian, late Middle Eocene.

REMARKS: Equivalent to lower RP13 in Strong *et al.* (1995). Appears to span a later interval than in low latitudes where *E. fistuligerum* first appears in mid Middle Eocene (base of *Podocyrtis ampla* Zone; Riedel and Sanfilippo 1978).

RP13, *Lithapium mitra* Interval Zone, new zone

DEFINITION: Interval from the FAD of *Lithapium mitra* to the FAD of *Eucyrtidium spinosum* Takemura. *Eusyringium lagena* last appears within RP13.

STRATOTYPE: Mead Stream (Fig. 9), uppermost Amuri Limestone ("upper marl"; 654-650 m). The top of the zone has not been identified at the stratotype, but has been identified at southern Campbell Plateau DSDP Site 277 (Hollis *et al.*, 1997).

AGE: Late Bortonian, latest Middle Eocene.

REMARKS: Equivalent to upper RP13 in Strong *et al.* (1995). Appears to span a later interval than in low latitudes where *L. mitra* first appears in the mid Middle Eocene (*Podocyrtis mitra* Zone; Riedel & Sanfilippo 1978). The top of this zone marks the base of Takemura's (1992) Late Eocene *Eucyrtidium spinosum* Zone.

CHAPTER 4. CRETACEOUS-TERTIARY TRANSITION

4.1. INTRODUCTION

A detailed paleoenvironmental analysis of the radiolarian faunal succession across the K-T boundary in Marlborough was presented by Hollis (1996). The broad population trends identified in that study have not been significantly affected by nomenclatural reassignments effected in the present study, so no further discussion is offered here. The following discussion is restricted to updating details of faunal turnover in relation to a revised and expanded faunal list. Comparisons are made between the faunas from the K-T transition of eastern Marlborough and those of inland Marlborough (Mead Stream), DSDP Sites 208 (Lord Howe Rise) and 327A (southern Atlantic Ocean), ODP Site 752B (southern Indian Ocean), California (Foreman 1968), and Ecuador (Keller *et al.* 1997).

Because of the high natural diversity of radiolarian populations, the species considered here represent only the most distinctive taxa and at least 50% of the total Marlborough fauna remains undifferentiated below the level of family. The taxa identified consist of 107 species or species groups representing 62 genera within 17 families. The following are not described in the systematic section because either they are very rare or not present at Woodside Creek: *Lithomelissa*? *polycyrtis* (Campbell & Clark) (Mead Stream, DSDP 208), *Siphocampe argyris* Foreman (Woodside Creek), *S. bassilis* Foreman, and *Theocampe lispa* Foreman (both at Wharanui Point).

The Marlborough fauna includes 70 "Cretaceous" species or species groups (with the undifferentiated genera *Heliodiscus*, *Heliosestrum*?, and *Patulibracchium* each counted as a single species) within 46 genera. These are species which originate in the Cretaceous and may range into the Tertiary. The "Tertiary" component consists of 37 species, within 24 genera (including undifferentiated members of the genus *Prunopyle*), restricted to the Tertiary.

4.2. K-T BOUNDARY EXTINCTIONS

Estimates of radiolarian extinction levels across the K-T boundary in Marlborough vary according to how isolated occurrences, and uncorroborated or partly corroborated species ranges, are assessed (Table 3). A minimum estimate for species-level extinctions is 0-1.4%. Only one species, *Amphymenium concentricum*, lacks a Paleocene record, but it is very rare in the Late Cretaceous, last appearing 30 m below the boundary at Woodside Creek.

A great range of estimates is possible if varying degrees of reworking are considered. Firstly, if it is assumed that the four species which have only isolated occurrences in the Paleocene are reworked, extinctions increase to 7.6% for species and to 6.5% for genera. Excluded from these calculations are five species recorded only in Paleocene strata in Marlborough, but known elsewhere in the Cretaceous (Foreman 1968; Pessagno 1976; this study).

A further 18 Cretaceous species occur consistently in the Paleocene at Woodside Creek, but are absent or sporadic elsewhere. This may be evidence for persistent reworking through Paleocene strata exposed in Woodside Creek. If this view is accepted, extinction levels rise to 35.4% for species and 28.3% for genera. However most of these species are rare, and their more consistent occurrence at Woodside Creek may simply reflect the high number of samples examined from the section.

Sixteen Cretaceous species occur consistently in the Paleocene of three or more sections in Marlborough, but are absent or sporadic elsewhere. It is very unlikely that Paleocene records of these species are due to persistent reworking in several sections. Instead, they are accepted as real survivors and their rarity elsewhere in the Paleocene is thought to have a paleoenvironmental cause.

Twenty six Cretaceous species occur consistently in Paleocene rocks throughout the New Zealand region. There is little doubt that these species survived into the Paleocene. Many also occur in the Early Paleocene of California (Foreman 1968), Russia (Kozlova 1984), or Hokkaido (Iwata & Tajika 1986).

In summary, there is little evidence for major radiolarian extinctions at the K-T boundary in the four primary sections. Species-level extinction may be lower than 2%, and is unlikely to be higher than 10%.

Faunal discontinuities are evident in other K-T boundary sections. Of 37 Cretaceous species at Mead Stream, six last occur at the K-T boundary, and an additional nine have only isolated occurrences in the Paleocene (i.e. potential local extinction level of 40%). Similarly, of 34 Cretaceous species at DSDP Site 208, six last appear at the boundary, and an additional nine are restricted to isolated occurrences in the Paleocene (potential local extinction level of 44%). Similar or greater faunal discontinuities are evident in other regions. In the "via Perimetral" K-T boundary section in Ecuador (Keller *et al.* 1997), 21 radiolarian species either have their last occurrences at the boundary or have only isolated occurrences in the Paleocene.

Estimates for species extinction range from 43-78%, depending on how one accounts for the additional 17 rare species that disappear within the latest Cretaceous. In the Californian Cima Hill core sequence described by

Table 3. Paleocene occurrences of Cretaceous Radiolaria. Codes explained below.

	Paleocene range in NZ region						Paleocene beyond NZ
Cretaceous species with:	WO	WH	CH	FX	MD	208	
consistent Paleocene range throughout SW Pacific							
Lithomespilus coronatus	5	2	5	3	4	IS	ATL, ECD
Stylosphaera pusilla	4	2	2	3	3	IS	
Lithelius? minor gr.	5	2	5	3	13	5	ATL, ECD
Orbiculiforma renillaeformis s.l.	4	KK		2	6	4	RUS
Spongotrochus antiquus	3	IS		3	6	g	
Tholodiscus cf. *ocellatus*	5	2	3	3	3	5	ECD
Lithomelissa? aitai n.sp.	4	1		3	3	4	
Lithomelissa cf. *heros*	4	IS	2	3	3	4	cf. CAL?, ECD
Artostrobus pusillus	5	2	3	3	3	4	ATL, ECD
Theocampe cf. *vanderhoofi*	4	2	3	3	3	IS	cf. CAL?
Myllocercion acineton	4	2	3	3	3	4	CAL?
Myllocercion aff. *echtus*	4	2	2	3	3	2	
Theocapsomma amphora	4	2	3	3	IS	4	CAL?, ECD
Amphipyndax stocki gr.	5	2	5	3	6	5	CAL, RUS, JAP
Amphipternis alamedaensis	5	2	5	3	13	5	CAL, ATL, JAP
Archaeodictyomitra cf. *lamellicostata*	5	2	2	3		4	
Dictyomitra andersoni	5	2	5	3	6	5	CAL?, RUS, JAP, ECD
Dictyomitra multicostata	5	2	3	3		2	CAL, JAP
Mita regina	5	2	2	3	3	4	JAP
Bathropyramis sanjoaquinensis s.l.	4	2	5	3	6	5	JAP
Cornutella californica	5	2	5	3	13	5	CAL, ATL, RUS, JAP
Cyrtocapsa campi	4	2	2	3	3		CAL?
Lithocampe wharanui n.sp.	5	2	5	3	IS	5	
Stichomitra bertrandi	4	2	2	3	3	IS	CAL?, RUS, JAP?
Stichomitra grandis	4	2	3	3	3	KK	CAL?, RUS, JAP
Stichomitra carnegiensis	5	2	2	3	3	4	
consistent Paleocene range in eastern Marlborough							
Amphisphaera privus	5	2	5	3	IS		JAP
Protoxiphotractus wilsoni n.sp.	5	2	5	3			
Stylosphaera aff. hastata	4	IS	IS	3			
Heliodiscus spp.	3	KK		3			
Heliosestrum? spp.	2	2	3	3			
Phaseliforma laxa	5	1	IS	3	KK	IS	JAP
Siphocampe altamontensis	4	2	2	3	IS		
Siphocampe cf. *altamontenis*	4	2	IS	3			JAP
Cryptocarpium? cf. ornatum	4	1	2	IS	KK	IS	cf. CAL, ATL
Theocapsomma erdnussa	5	2	3	3	IS	?	
Amphipyndax aff. *conicus*	2	1	IS	3			
Dictyomitra aff. *rhadina*	2	2		3			
Mita cf. *regina*	5	1	2	3	IS	KK	
Neosciadiacapsa jenkinsi	4	2	3	3	IS		
Cyrtocapsa livermorensis	4	2	3	3	IS	IS	CAL?, JAP
Eusyringium woodsidensis n.sp.	5	2	5	3		IS	
consistent Paleocene range at Woodside Creek							
Conocaryomma aff. *universa*	4						
Prunocarpus sp. A	4						
Acanthocircus ellipticus	4	IS		3			
Peritiviator cf. *labyrinthi*	2	IS		3			
Phaseliforma subcarinata	5	KK	IS	IS		IS	
Orbiculiforma renillaeformis s.s.	4	1	IS		KK		
Amphibrachium aff. *sansalvadorensis*	3	IS					
Patulibrachium spp.	2	IS		3	KK	KK	JAP
Spongodiscus rhabdostylus	5						
Spongotripus spp.	4	KK		IS			
Spongotrochus polygonatus	3	KK					
Flustrella cretacea	3						
Flustrella ruesti	3						
Tholodiscus cf. *densus*	5	IS		3			
Lithomelissa? hoplites	2	IS	IS	IS	KK	KK	JAP
Botryostrobus? parsonsae n.sp.	4	IS	IS	IS			
Phormostichoartus? strongi n.sp.	4	IS	IS	IS			
Lithocampe aff. *subligata*	4						
only Cretaceous or isolated Paleocene occurrences							
Acanthocircus campbelli	IS	KK					
Amphymenium concentricum	0					KK	
Prunobrachium kennetti	IS			KK	KK		
Spongurus spongiosus	IS			IS			
Theocampe lispa		2					
only Paleocene occurrences in Marlborough							
Protoxiphotractus perplexus	IS						JAP
Lithomelissa? polycyrtis					IS	KK	
Siphocampe argyris	IS						
Siphocampe bassilis		IS					
Stichomitra cf. *carnegiensis*	5					?	

Codes for occurrence KK = restricted to Cretaceous, 1-6 = upper range limit (RP1-6), IS = isolated Paleocene occurrence, ? = uncertain identification.
In NZ region: WO = Woodside, WH = Wharanui, CH = Chancet, FX = Flaxbourne, MD = Mead Stm, 208 = DSDP Site 208.
Beyond NZ: CAL? = K-T transition interval in California, CAL = definite Paleocene (Foreman 1968); ECD = Ecuador (Keller et al. 1997); JAP = Hokkaido, Japan (Iwata &Tajika 1986, 1992); ATL = Atlantic (Petrushevskaya & Kozlova 1972; Foreman 1973a; Sanfilippo & Riedel 1973); RUS = Russia (Kozlova 1984).

Foreman (1968), 13 species have their last occurrences at the probable boundary, with a further 20 absent from the confirmed Paleocene 3 m above (species extinction = 34-87%). Examination of reference slides (DSDP/ODP Micropaleontological Reference Centre) from the K-T transition in south Atlantic DSDP Site 327A indicates that 70% of Cretaceous species last occur at the boundary. Radiolarian assemblages from the K-T transition in south Indian Ocean ODP Site 752B consist of a sparse spumellarian-dominated Cretaceous fauna and a gradually diversifying Paleocene fauna. Although most Cretaceous elements persist into the earliest Paleocene, few of the common Cretaceous survivors of Marlborough occur.

These sparse and scattered records of radiolarians from well-defined K-T boundary sections do not provide a comprehensive global picture. Nevertheless, available evidence indicates that the high degree of continuity in radiolarian faunas through the K-T transition of Marlborough is extraordinary if not unique. Elsewhere, radiolarians like their foraminiferal cousins appear to have been adversely affected to varying degrees by events at the K-T boundary, which resulted in at least 300 kyrs of very low oceanic productivity (Zachos *et al.* 1989). Radiolarian survival in Marlborough is linked with evidence for a reverse trend towards a peak in siliceous plankton productivity ~500 kyrs after the K-T boundary event (Hollis *et al.* 1995). A discrepancy between the faunal continuity observed in coastal Marlborough and the discontinuity noted at Mead Stream may be explained by poor preservation and patchy recovery of earliest Paleocene faunas at the latter section. A 25 m-thick basal Paleocene chert unit signals very high siliceous productivity (Hollis *et al.* 1995), but the process of chertification appears to have destroyed or rendered unidentifiable most of the siliceous microfossils.

4.3. PALEOCENE EXTINCTIONS

A similar radiolarian survivorship pattern is observed through the earliest Paleocene (Zones RP1-RP3) in all Marlborough sections (Figs. 14-16). Numbers of Cretaceous survivor species show an initial short-lived reduction over a 5-10 cm interval directly above the K-T boundary (uppermost RK9 to lowermost RP1) prior to returning to approximately Cretaceous numbers over the RP1-RP3 interval. At Woodside Creek, only three species disappear over the RP1-RP2 interval, and only nine disappear over the RP1-RP3 interval (Fig. 13). Even at Mead Stream, one RP3 sample contains only seven species fewer than the richer of two late Cretaceous samples (Fig. 14). High numbers of Cretaceous species over the RP1-RP3 interval reflects a peak in overall diversity which, with other factors such as a high diatom/radiolarian ratio, is indicative of a thriving siliceous plankton community in Marlborough following the K-T boundary event (Hollis *et al.* 1995). Although species numbers are high, the relative abundance of all but two Cretaceous taxa decreases over this interval (Figs. 15, 16), due to an influx of new Tertiary spumellarians including *Amphisphaera aotea* and *A. kina*. Cretaceous actinommids *Lithomespilus coronatus* and *Stylosphaera pusilla* also increase in abundance over the RP1-RP2 interval.

Above mid RP3, radiolarian survivorship at Woodside Creek exhibits quite a different pattern to that observed elsewhere. RP4 is characterised by high numbers of Cretaceous species in lower samples (47 species persist into lowest RP4), with progressive last appearances of 21 species within the zone (Figs. 13, 15). Despite this relatively high rate of disappearance in RP4, 25 species range into RP5 at Woodside Creek. Relative abundance of most Cretaceous taxa declines gradually from RP3 to RP5 (Fig. 15). Exceptions are *Lithelius? minor* gr., which is common in Cretaceous and Paleocene assemblages in all sections examined, and *Amphipyndax stocki* gr., which is common to abundant throughout the Woodside Creek and Wharanui sections. Based on Empson-Morin's (1984) report of predominant *Amphipyndax* and *Dictyomitra* in Campanian assemblages from the neritic Texan shelf, Hollis (1996) interpreted the high abundance of *A. stocki* gr. and associated taxa in Woodside Creek assemblages as due to a shallow depositional setting relative to Flaxbourne, Chancet, and Mead sections.

The record from upper RP3 to lower RP5 is not well-represented in the other primary sections: Wharanui extends no higher than lower RP2, Flaxbourne has a discontinuity between mid RP3 and upper RP5, and Chancet samples are barren of radiolarians from RP3 to RP5. Nevertheless, available data indicate that the numbers of Cretaceous species and their abundance decline much more rapidly through the RP3-RP5 interval than at Woodside Creek. Only 12 Cretaceous species range into RP5 at Chancet Rocks, and no more than eight occur from upper RP4-RP6 at Mead Stream and DSDP 208 (Fig. 14). In RP3 Woodside and Flaxbourne samples have similar relative abundances of Cretaceous species, excluding *Amphipyndax stocki* gr., but above this level the combined abundance of Cretaceous taxa, excluding *Lithelius? minor* gr., is 6% in Chancet RP5 assemblages, 3-6% in Mead RP4-RP6 assemblages, and <4% in RP4-RP5 assemblages from DSDP Site 208.

A speculative explanation for the unique survivorship record at Woodside Creek, incorporating both taphonomic and environmental factors, is given by Hollis (1996).

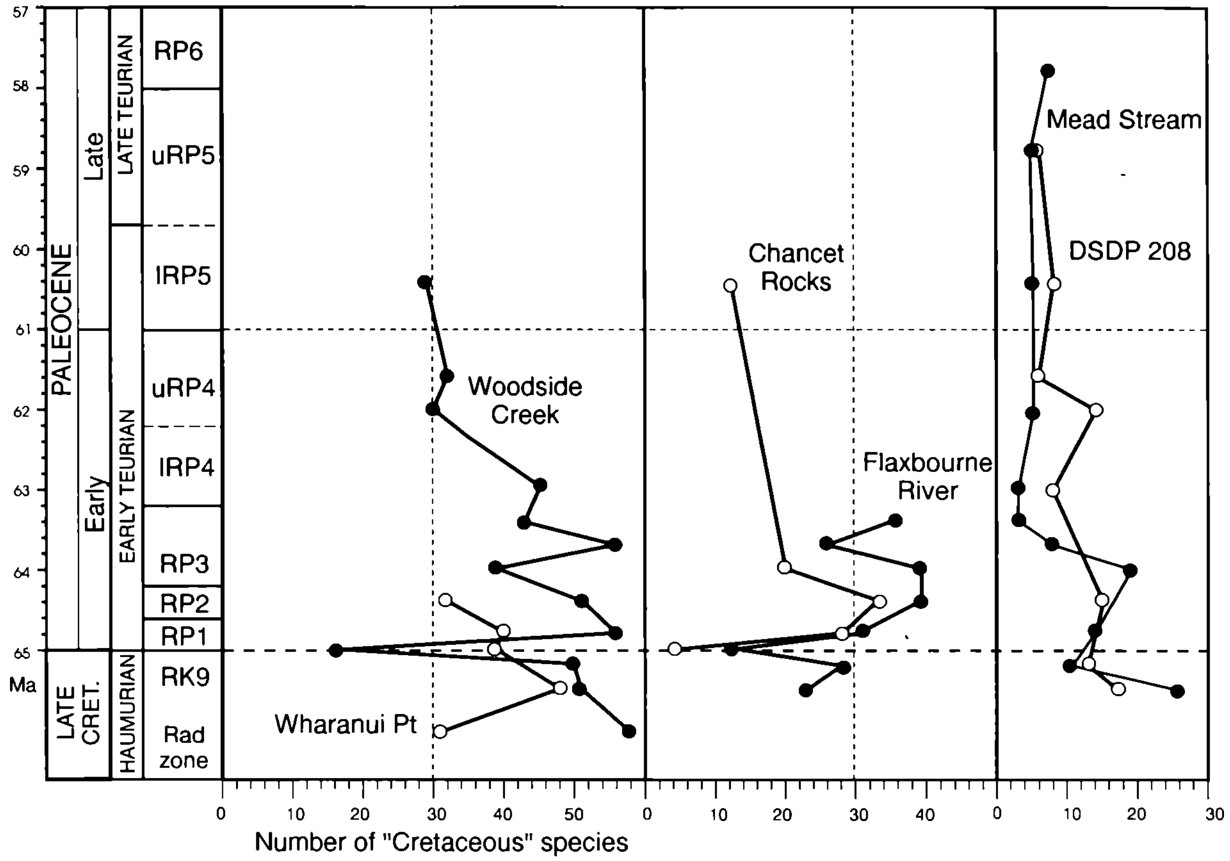

Figure 14 Cretaceous-Paleocene radiolarian survivorship through the K-T transition in the southwest Pacific. Data points represent the highest number of Cretaceous-Paleocene ("Cretaceous") species within an individual sample in a given time interval (lowest, upper, and uppermost RK9; K-T boundary; RP1; RP2; lower, mid, upper RP3; lower, mid, upper RP4; lower, upper RP5, lower RP6.

4.4. PALEOCENE DIVERSIFICATION

Initial diversification within Paleocene radiolarian faunas in Marlborough is correlated with indicators of increasing siliceous productivity. The appearance and rapid rise in abundance of *Amphisphaera aotea* coincides with an influx of diatoms, and a 10-20% increase in bulk rock silica (Hollis *et al.* 1995). Peak diatom/radiolarian ratios and silica values between upper RP1 and lower RP2 coincide with a burst of diversification within the actinommids, sponguriids and litheliids (Figs. 12, 15; 16). This includes: (1) evolutionary appearances of *Amphisphaera kina* and *A. goruna*; (2) the first members of the long-ranging species complexes—*Lithelius s.s.*, *Amphymenium splendiarmatum*, *Spongurus bilobatus*, and *Amphicraspedum prolixum* gr.; (3) short-lived blooms of new species—*Spongotrochus* cf. *glacialis*, *Haliomma teuria* n.sp., *Lithelius marshalli* n.sp., and *Spongoprunum* cf. *markleyense*.

This initial bloom of spumellarians was followed by the progressive appearance of a group of distinctive nassellarians (mid RP2 to lower RP3) including: (1) the suggested ancestral species of the genus *Buryella*—*Lithostrobus wero*, and *Buryella granulata*; (2) the first spyrid—*Dorcadospyris* aff. *confluens*; (3) and the first member of the genus *Dictyophimus*—*D.* aff. *archipilium*. General features of the tests of new radiolarian species from this interval suggest rapid population expansion in a setting in which demand for silica was great. Tests are small, or have large, open pores, and are somewhat irregular. Skeletal elements tend to be thin, spumellarian spines tend to irregularly distributed, and dominant nassellarians have numerous small segments. Approximately 70% of the 37 "Tertiary" species first appear within 1 Myrs of the K-T boundary (RP1 to lowest RP3). Diversification declines markedly in upper RP3 concurrently with, or as a result of, decline in productivity.

Another cluster of speciation events occurs in RP4. The suggested descendant of *Buryella granulata*—*B. foremanae*—gave rise to *B. dumitricai*, and may also be the direct ancestor of the two four-segmented species of *Buryella* in RP5, *B. tetradica* and *B. kaikoura* n.sp. First occurrences of several species in upper RP4 may be partly an effect of improved assemblage preservation. *Spongopyle* cf. *insolita*, *Palaeotetrapyle muelleri*, and *Lithomelissa* cf. *gelasinus*, in particular are delicate forms unlikely to be distinguished, if preserved at all, in poorly

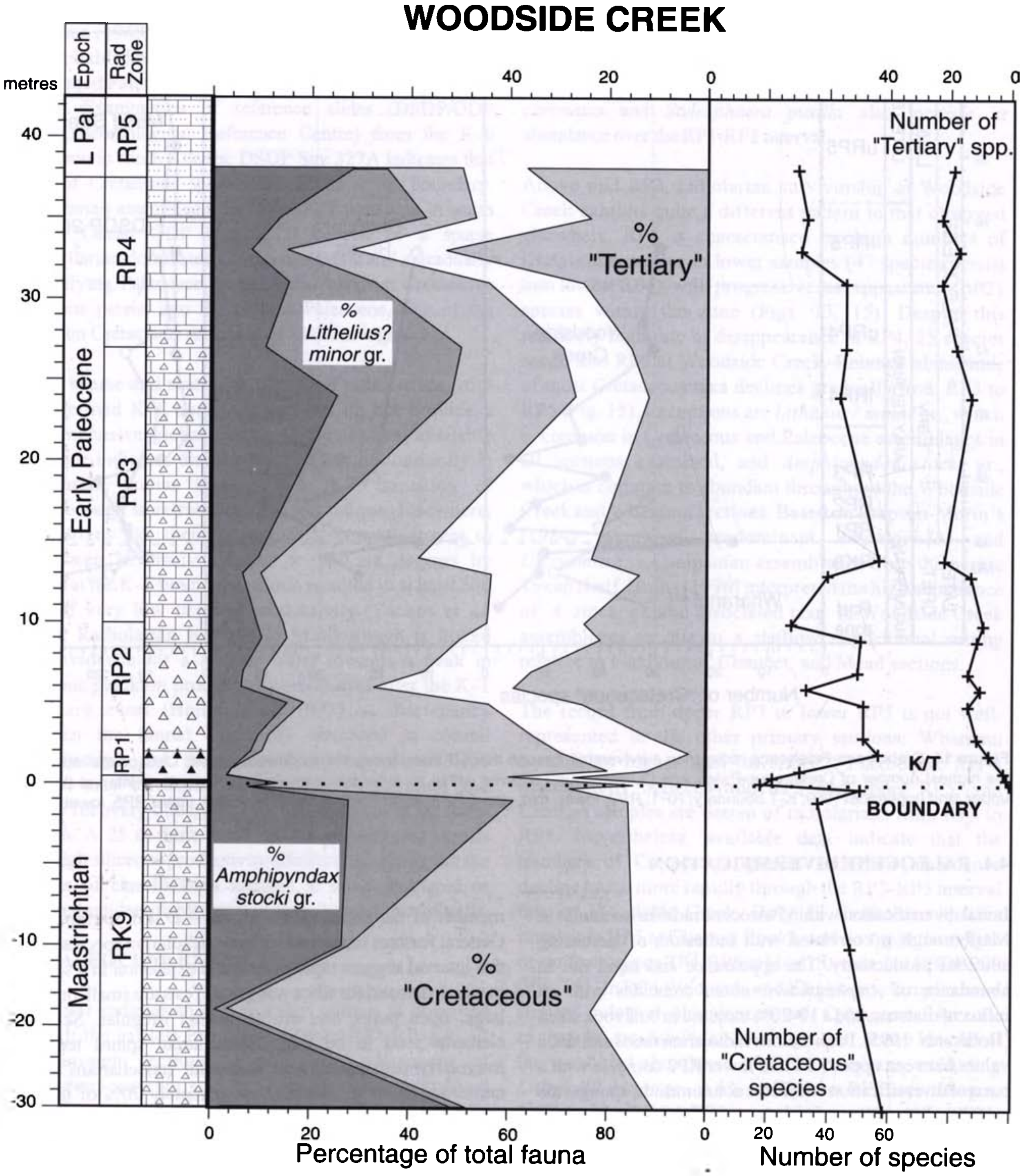

Figure 15 Trends in relative abundance and numbers of species at Woodside Creek within Cretaceous-Paleocene ("Cretaceous") and Paleocene-restricted ("Tertiary") taxa. *Amphipyndax stocki* gr. and *Lithelius minor* gr. are significant elements of the "Cretaceous" fauna as discussed in the text.

preserved material. Otherwise, faunas of RP4 and lower RP5 are dominated by species in which the tests are large and well-organised, skeletal elements tend to be thickened, spumellarian spines are regularly arranged, and nassellarians have few large segments with regularly arranged pores. These features are indicative of a slow population turnover in a setting in which demand for silica was relatively low.

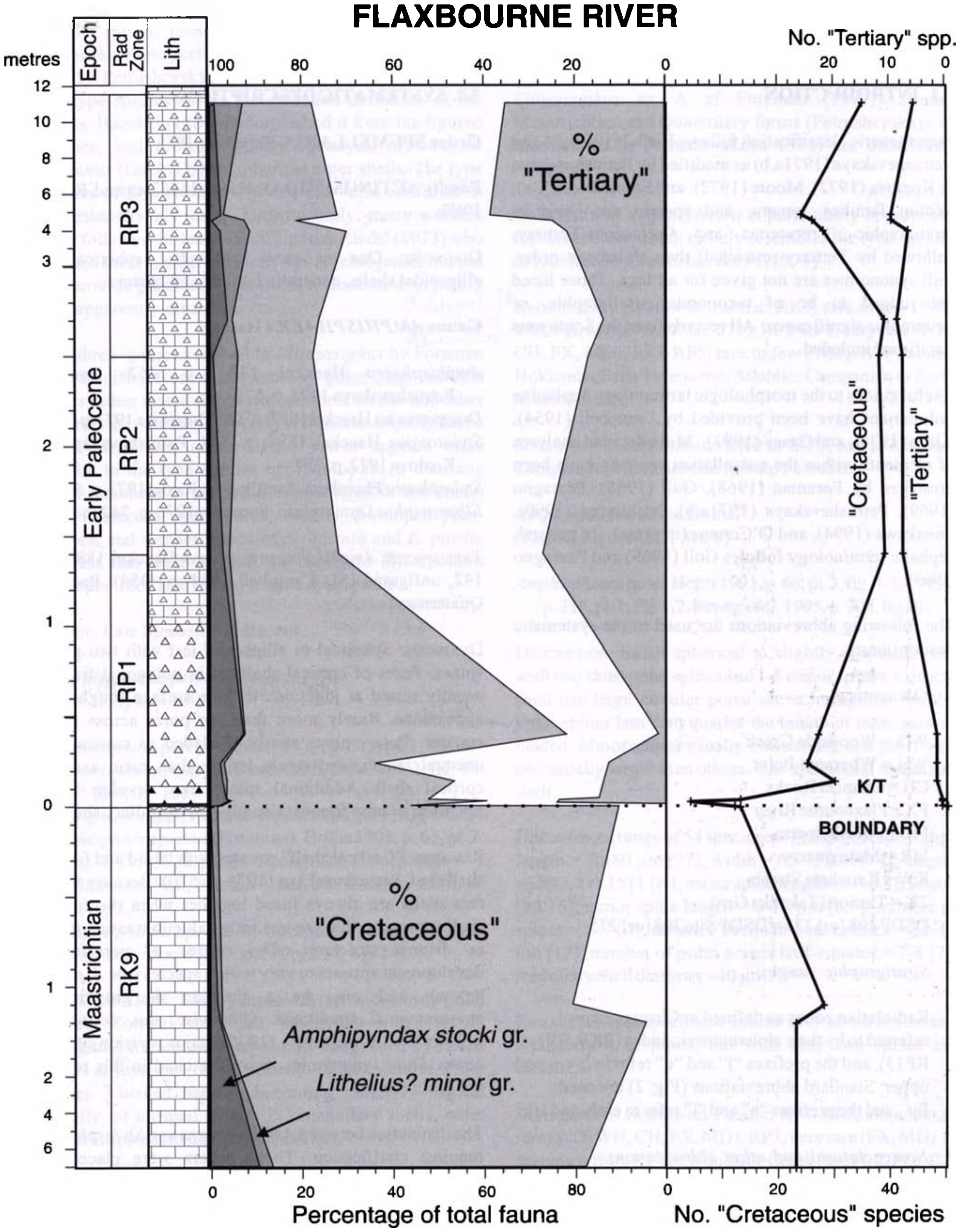

Figure 16 Trends in relative abundance and numbers of species within Cretaceous-Paleocene ("Cretaceous") and Paleocene-restricted ("Tertiary") taxa at Flaxbourne River.

CHAPTER 5. SYSTEMATIC PALEONTOLOGY

5.1. INTRODUCTION

Suprageneric classification follows Riedel (1967a,b) and Petrushevskaya (1971a,b) as modified by Petrushevskaya & Kozlova (1972), Moore (1972), and Foreman (1973a). Within families, genera, and species are listed in stratigraphic (Cretaceous and Cretaceous-Tertiary, followed by Tertiary-restricted) then alphabetic order. Full synonomies are not given for all taxa. Those listed are judged to be of taxonomic, stratigraphic, or geographic significance. All records from the Southwest Pacific are included.

Useful guides to the morphologic terminology applied to radiolarians have been provided by Campbell (1954), Kling (1978), and Casey (1993). More detailed analyses of elements within the nassellarian cephalis have been presented by Foreman (1968), Goll (1968), Pessagno (1969), Petrushevskaya (1971a,b), Nishimura (1990), Funakawa (1994), and O'Connor (in press). In general, cephalic terminology follows Goll (1968) and Pessagno (1969).

The following abbreviations are used in the systematic descriptions:

1. *Occurrence:*

   WO = Woodside Creek
   WH = Wharanui Point
   CH = Chancet Rocks
   FX = Flaxbourne River
   MD = Mead Stream
   MR = Mara quarry
   KW = Kaiwhata Stream
   TK = Tioriori (Takatika Grit)
   DSDP 208 [or] 275 = DSDP Site 208 [or] 275

2. *Stratigraphic range:*

   Radiolarian zones as defined in Chapter 3 are referred to by their alphanumeric codes (RK9, RP1-RP13), and the prefixes "l" and "u" refer to lower and upper. Standard abbreviations (Fig. 2) are used for , and the prefixes "e" and "l" refer to early and late.

3. *Nomenclatural and other abbreviations:*

   OD = original designation,
   SD = subsequent designation
   ICZN = International Code of Zoological Nomenclature.

5.2. SYSTEMATIC DESCRIPTIONS

Order SPUMELLARIA Ehrenberg 1875

Family ACTINOMMIDAE Haeckel 1862, emend. Riedel 1967b

Diagnosis: One or more concentric spherical to ellipsoidal shells, generally latticed and spinose.

Genus *AMPHISPHAERA* Haeckel

Amphisphaera Haeckel 1881, p. 452. Emend. Petrushevskaya 1975, p. 570.
Druppatractus Haeckel 1887, p. 324. Dumitrica 1973, p. 787.
Stylatractus Haeckel 1887, p. 328. Petrushevskaya & Kozlova 1972, p. 519.
Stylosphaera Ehrenberg. Sanfilippo & Riedel 1973, p. 519.
Ellipsoxiphus Dunikowski. Foreman 1978, p. 742 (*part.*).

Type species: *Amphisphaera neptunus* Haeckel 1887, p. 142, unfigured (SD Campbell 1954, p. D54). Pacific, Quaternary.

Diagnosis: Spherical to ellipsoidal test with two polar spines. Pores of cortical shell set in polygonal frames usually raised at junctions to give surface roughened appearance. Rarely more than ten pores across half-equator. Polar spines sturdy, 3-bladed to conical, of unequal length, and rarely longer than main axis of cortical shell. Additional spines may develop from junctions of pore frames. Usually two medullary shells.

Remarks: "Cortical shell" equates with "third and fourth shells" of Petrushevskaya (1975, p. 570). Because these two shells are always fused together when the fourth shell is present, there seems little value in treating them as distinct structures. The degree of pore-frame development appears to vary within species (see *A. priva* below), and may be a function of growth or environmental conditions. Otherwise, this definition follows Petrushevskaya's (1975) major revision of this genus. Only synonymies in studies cited in this report are listed above.

The distinction between *Amphisphaera* and *Stylosphaera* requires clarification. These genera were placed in different families in the largely geometric classification system of Haeckel (1887) because of a supposed difference in the number of shells (three in *Amphisphaera*, two in *Stylosphaera*). Modern workers include 2-4 shelled species in the same genus, but continue to use these names for two morphological groups; one with relatively few pores set in well-developed frames and with short sturdy polar spines, the other with numerous pores set in weakly developed frames and relatively long, slender spines. These equate with *Amphisphaera* and *Stylosphaera* respectively in the sense of Petrushevskaya (1975). Petrushevskaya's view is followed here because the type species fulfils the emended definition of the genus. Haeckel (1887) distinguished it from the figured species, and probable junior synonym, *Stylatractus neptunus* Haeckel by its spherical outer shells. The type species of *Stylosphaera*—*S. hispida*—also conforms to Petrushevskaya's usage. Unfortunately, many workers have followed the lead of Sanfilippo & Riedel (1973) who applied these names in exactly the reverse sense, but did not provide emended definitions or discussion to justify this apparently erroneous usage.

The three species ascribed to *Ellipsoxiphus* by Foreman (1978) differ from that genus by possessing multiple shells rather than a single latticed shell. In this and other respects they are more properly referred to *Amphisphaera* or *Stylosphaera*. *Ellipsoxiphus privus* appears more similar to the type species of *Amphisphaera* than any other members of the genus encountered in this study. The numerous small pores, weakly developed pore-frames, and slender spines of *E. hastata* and *E. pusilla* suggest that their original allocation to *Stylosphaera* (Campbell & Clark 1944a) is more appropriate.

RANGE: Late Mesozoic to Recent.

Amphisphaera priva (Foreman)
(Plate 1, Figures 1-4)

Ellipsoxiphus sp. A., Foreman 1977, p. 315, pl. 1, fig. 4.
Ellipsoxiphus privus Foreman 1978, p. 743, pl. 2, fig. 14, 15 (non fig. 16).
Stylosphaera spp., Iwata & Tajika 1986, pl. 4, fig. 9-12.
Amphisphaera privus (Foreman). Hollis 1991, p. 65, pl. 2, fig. 7-15; 1993a, p. 324. Strong *et al.* 1995, p. 205.
? *Stylatractus*? sp., Petrushevskaya & Kozlova 1972, pl. 4, fig. 3,4.
? *Amphisphaera* sp. aff. *Stylatractus neptunus* Haeckel. Petrushevskaya 1975, p. 570, pl. 28, fig. 2-6.

DESCRIPTION: Large ellipsoidal test with sturdy polar spines. Cortical shell has subcircular pores set in polygonal frames. Surface usually roughened by raised nodes at junctions of pore frames, rarely smooth. Polar spines 3-bladed basally, becoming smoothly conical distally, of unequal length. 2-3 medullary shells; outer shells ellipsoidal, innermost spherical.

DIMENSIONS: (range of 22 specimens [mean]): cortical shell length = 105-170 µm [137], width = 85-140 µm [115], length/width = 1.08-1.33 [1.19]; spine length = 40/65-100/140 µm [70/98]; distance between pore centres = 10-25 µm [15]; number of pores across half-equator = 8-20 [9]; outer medullary shell length = 69-86 µm [76].

REMARKS: Foreman's (1978) definition is applied in a restricted sense to exclude smaller narrowly ellipsoidal forms allocated to *Protoxiphotractus wilsoni* n.sp. below. In this sense, *A. priva* is equivalent to *Ellipsoxiphus* sp. A of Foreman (1977). Similar Maastrichtian and Quaternary forms (Petrushevskaya & Kozlova 1972; Petrushevskaya 1975) are uncertainly included.

Relocation to *Amphisphaera* is particularly appropriate for this species which closely resembles the type species as redefined by Petrushevskaya (1975).

DISTRIBUTION: Southwest Pacific: RK9, rare to few (WO, WH, FX, MD, MR, DSDP 275); RP1-RP3, very rare (WH, CH, FX, MD); RP1-RP5, rare to few (WO). NW Pacific: Hokkaido, Early Paleocene. Atlantic: Campanian to Early Maastrichtian.

SOUTHWEST PACIFIC RANGE: RK9 to lRP5, Mh to eDt, late Campanian-Maastrichtian to Late Paleocene.

Amphisphaera aotea Hollis
(Plate 2, Figures 1-3, ?4a, b)

Amphisphaera aotea Hollis 1991, p. 66, pl. 3, fig. 1-3; 1993a, p. 316, pl. 1, fig. 1,2. Strong *et al.* 1995, p. 208, fig. 8E.

DESCRIPTION: Small spherical to slightly ellipsoidal test with two short polar spines and 1-5 minor spines. Cortical shell has large circular pores set in hexagonal frames. Polar spines less than quarter the length of main axis, 3-bladed. Minor spines usually clustered at one pole, with one usually larger than others. One spheroidal medullary shell.

DIMENSIONS: (range of 54 specimens [mean]): cortical shell length = 70-80 µm [77], width = 65-75 µm [74], length/width = 1-1.15 [1.04]; major spine length = 5/10-15/20 µm [10/15]; minor spine length = 5-10 µm [6.5]; number of spines = 3-7 [4]; distance between pore centres = 12-15 µm [12]; number of pores across half-equator = 7-8 [7]; medullary shell diameter ~40 µm.

REMARKS: Some specimens similar to *A. aotea* in size and arrangement of pores, but with only two spines are included.

DISTRIBUTION: Southwest Pacific: RP1-RP2, abundant to rare (WO, WH, CH, FX, MD); RP3, very rare (FX, MD). A specimen from RP4 at Woodside Creek (see Pl. 2, Fig. 4) is uncertainly referred to this species but may be a very small specimen of *A. kina*. *A. aotea* is known only from Marlborough.

RANGE: RP1 to RP3, eDt, Early Paleocene.

Amphisphaera kina Hollis
(Plate 2, figures 5-9)

Amphisphaera kina Hollis 1991, p. 68, pl. 3, fig. 6-10; 1993a, p. 318, pl. 1, fig. 2, 3. Strong *et al.* 1995, p. 208, fig. 8F.

DESCRIPTION: Medium-sized spherical to slightly ellipsoidal test with clusters of 3-6 spines near each pole. Cortical shell has large circular pores set in hexagonal frames. 6-12 short, 3-bladed spines usually of subequal length. Spines may be differentiated into major and minor sets: either a major spine at each pole or two major spines symmetrically placed at each pole, or a combination of both; minor spines irregularly distributed near poles. One pyriform medullary shell with axis not aligned to main axis of cortical shell.

DIMENSIONS: (range of 93 specimens [mean]): cortical shell length = 85-125 µm [105], width = 80-115 µm [100], length/width = 1-1.11 [1.05]; major spine length = 20/30-10/15 µm [15/20]; minor spine length = 5-15 µm [10]; number of spines = 6-12 [10]; distance between pore centres = 15-20 µm [18]; number of pores across half-equator = 6-7 [7]; medullary shell length = 34-42 µm [37], width = 32-37 µm [34].

REMARKS: Medullary shells are not easily distinguished in the Marlborough material, but better preserved specimens from the basal Paleocene at DSDP Site 208 (Plate 2, Figure 8, 9) reveal that the medullary shell has the same pyriform shape as that of *A. goruna* and related forms (*A. coronata sensu* Sanfilippo & Riedel 1973). As in *A. goruna*, the medullary shell often appears circular in outline because its axis is not aligned to the main axis of the test. *A. kina* is distinguished from *A. aotea* by a larger test and more numerous major spines, and from *A. goruna* by more numerous shorter, major spines which are not as regularly placed, and usually by a more inflated cortical shell.

Doubtfully included in this species is a form, apparently laterally compressed by compaction, which is very common within the RP2-3 interval at Woodside Creek, Wharanui, Flaxbourne River, and Mead Stream.

DISTRIBUTION: Southwest Pacific: RP2-3, abundant to few (WO, WH, CH, FX, MD, DSDP 208); RP4-6, rare (WO, CH, MD, DSDP 208). May not have been separated from *A. goruna* in studies from other areas.

RANGE: RP2 to RP6, eDt to lDt, Early to Late Paleocene.

Amphisphaera goruna (Sanfilippo & Riedel)
(Plate 2, Figures 10, 11)

Stylosphaera goruna Sanfilippo & Riedel 1973, p. 521, pl. 1, fig. 20-22; pl. 25, fig. 9, 10 (? fig. 11). Westberg *et al.* 1980, p. 432, pl. 1, fig. 1. Nishimura 1986, pl. 1, fig. 1; 1987, p. 729, pl. 1, fig. 3.
Druppatractus cf. *coronatus* (Squinabol). Dumitrica 1973, p. 787, pl. 6, fig. 4, 6; pl. 12, fig. 11 (*non* Squinabol 1904).
Stylosphaera cf. *goruna* Sanfilippo & Riedel. Iwata & Tajika 1986, pl. 8, fig. 9-11.
Amphisphaera spinulosa (Ehrenberg). Hollis 1991, p. 69, pl. 3, fig. 11-15; 1993a, p. 318, pl. 1, fig. 5 (*non* Ehrenberg 1873, 1875).
Amphisphaera goruna (Sanfilippo & Riedel). Strong *et al.*, 1995, p. 208, fig. 8G, 9A.

DESCRIPTION: Medium-sized spheroidal test with two polar spines, and accessory spines clustered near the poles. Cortical shell has large circular pores set in hexagonal frames. Five or more 3-bladed spines. Major spines usually comprise a long polar spine and a pair of slightly shorter spines symmetrically placed at each pole. When present, minor spines are irregularly distributed. One pyriform medullary shell with axis not aligned to long axis of cortical shell.

DIMENSIONS: (range of 17 specimens [mean]): cortical shell length = 80-110 µm [100], width = 70-100 µm [90], length/width = 1.05-1.2 [1.12]; major spine length = 20/25-45/70 m [30/50]; minor spine length = 10-20 µm; number of spines = 5-9 [6]; distance between pore centres = 12-20 µm [16]; number of pores across half-equator = 6-8 [7]; medullary shell length = 34-39 µm, width = 29-37 µm.

REMARKS: Comparison of Paleocene and Eocene material from Mead Stream indicates that inclusion of this species within Eocene *A. spinulosa* (Petrushevskaya 1975; Hollis 1991, 1993a) is mistaken. The two species are very similar, but *A. spinulosa* is distinguished by longer polar spines and a greater number of minor spines. The two species appear to be separated in time by a stratigraphic gap of at least 3 m.y. (Strong *et al.* 1995). *Lithomespilus coronatus* Squinabol is distinguished from *A. goruna* by shorter spines, smaller pores within weakly developed frames, and absence of well-differentiated medullary shells (see *L. coronatus* below).

DISTRIBUTION: Southwest Pacific: RP2-3, very rare (WO, FX, MD, DSDP 208); RP4-8, common to few (WO, CH, MD, TK, DSDP 208). Hokkaido, Early Paleocene. Widely distributed from Late Paleocene to Eocene.

SOUTHWEST PACIFIC RANGE: RP2 to RP8, eDt to Dw, Early Paleocene to Early Eocene.

Amphisphaera macrosphaera (Nishimura)
(Plate 2, Figures 12, 13)

Druppatractus sp., Dumitrica 1973, p. 787, pl. 12, fig. 3.
Stylosphaera coronata (Ehrenberg). Nishimura 1987, p. 729, pl. 1, fig. 1, 2.
Amphisphaera radiosa (Ehrenberg). Hollis 1991, p. 71, pl. 3, fig. 16-19; 1993a, p. 319, pl. 1, fig. 6. Strong *et al.* 1995, p. 208. (*non* Ehrenberg 1854a)

Stylosphaera coronata macrosphaera Nishimura 1992, p. 325, pl. 1, fig. 3, 4; pl. 11, fig. 1.

Description: Medium-sized spherical test with two short polar spines of unequal length. Cortical shell has large circular pores set in hexagonal frames. Polar spines 3-bladed, of unequal length; longer spine rarely more than half the length of main axis and usually twice as long as shorter spine. No additional spines. One pyriform medullary shell with axis aligned to long axis of cortical shell.

Remarks: This form is given full species status here because a phylogenetic relationship with *A. coronata* has not been established.

Dimensions: (range of nine specimens [mean]): cortical shell length = 85-135 µm [113], width = 75-127 µm [105]; spine length = 10/5-45/25 µm [26-12]; distance between pore centres = 17-20 µm; number of pores across half-equator = 6-7.

Distribution: Southwest Pacific: RP2-4, rare (WO, FX, MD, KW, DSDP 208); RP5, few (MD, TK, DSDP 208); RP6-13, rare to very rare (MD). North Atlantic, Late Paleocene.

Southwest Pacific range: RP3 to RP13, eDt to Ab, Early Paleocene to Middle Eocene.

***Amphisphaera coronata* s.l.** (Ehrenberg)
(Plate 2, Figures 14-17)

Stylosphaera coronata coronata (Ehrenberg). Sanfilippo & Riedel 1973 (*part.*), p. 520, pl. 1, fig. 14.
Stylosphaera sp., Iwata & Tajika 1986, pl. 8, fig. 6.
Amphisphaera spp. gp D, Hollis 1991, p. 71, pl. 3, fig. 20; 1993a, p. 319.

Description: Medium-sized spheroidal to ellipsoidal test with polar spines of unequal length. Cortical shell has large circular pores in polygonal frames. Polar spines 3-bladed; shorter spine at least quarter of length of main axis. Medullary shell pyriform with long axis aligned to long axis of cortical shell.

Remarks: This complex is distinguished from *A. macrosphaera* by its longer polar spines and usually less inflated cortical shell. *A. coronata s.s.* is distinguished by a shorter arrow-shaped spine, i.e. cylindrical proximally, sharply tapering distally (as in Plate 2, Figure 17).

Distribution: Southwest Pacific: RP4, very rare (WO, MD); RP5-13, few to common (WO, CH, MD, TK, DSDP 208).

Southwest Pacific range: uRP4 to RP13, eDt to Ab, Early Paleocene to Middle Eocene.

Genus *CONOCARYOMMA* Lipman

Conosphaera? Haeckel. Kling 1971, p. 1106. Renz 1974, p. 789.
Conocaryomma Lipman 1969, p. 184. Empson-Morin 1981, p. 260.
Praeconocaryomma Pessagno 1976, p. 40; 1977b, p. 33.

Type species: *Conocaryomma aralensis* Lipman 1969, p. 186, pl. 1, fig. 1-4; pl. 2, fig. 1 (OD). Russia, Eocene.

Diagnosis: Large, relatively thick-walled, spherical cortical shell. Up to five medullary shells. Surface ornamented by tubercles ("mammae" of Pessagno, 1976) at the nodes of pore frames. Tubercles connected to outer medullary shell by radial beams. Radial spines may protrude from centre of tubercles.

Remarks: *Conocaryomma* was identified as senior synonym of *Praeconocaryomma* by Empson-Morin (1981). P. Dumitrica (pers. comm.), however, notes that although both genera have similar cortical shells, *Praeconocaryomma* may be distinguished by a double medullary shell with a wide space between it and the cortical shell. Under this scheme, the species described below is closer to *Conocaryomma*.

Range: Late Jurassic to Eocene.

Conocaryomma* aff. *universa (Pessagno)
(Plate 3, Figures 1, 2)

Praeconocaryomma? aff. *universa* Pessagno. Nakaseko & Nishimura 1981, p. 158, pl. 1, fig. 13, 14; pl. 14, fig. 1.
Conocaryomma aff. *universa* (Pessagno). Hollis 1991, p. 58, pl. 1, fig. 2-4.
aff. *Praeconocaryomma universa* Pessagno 1976, p. 42, pl. 6, fig. 14-46.
aff. *Conocaryomma universa* (Pessagno). Empson-Morin 1981, p. 260, pl. 3, fig. 5.

Description: Large spherical cortical shell with dome-shaped papillate tubercles surrounded by 6-8 subspherical to ellipsoidal pores. Rare specimens bear a single 3-bladed spine. Three spherical medullary shells.

Dimensions: (range of four specimens [mean]): diameter of cortical shell = 230-290 µm [250], of outer medullary shell = 123-135 µm [125], of middle medullary shell = 58-62 µm [60].

Remarks: This species is distinguished from *C. universa* by its larger test and the absence of conical tubercles. The species described by Nakaseko & Nishimura (1981) also has dome-shaped tubercles. *C. aralensis* has 4-5 internal shells, but otherwise appears similar to the described form.

DISTRIBUTION: Southwest Pacific: RK9, very rare (WO); RP2-RP5, very rare to rare (WO); isolated occurrence, uRP5 (TK). Specimens in RP5 bear a closer resemblance to *C. universa* by possessing more conical tubercles which more commonly bear radial spines.

RANGE: RK9 to lRP5, lMh to eDt, Maastrichtian to Late Paleocene; occurrence in uRP5 may be due to reworking.

Genus *HALIOMMA* Ehrenberg.

Haliomma Ehrenberg 1838, p. 128. Haeckel 1887, p. 230. Emend. Petrushevskaya 1975, p. 568.

TYPE SPECIES: *Haliomma aequorea* Ehrenberg 1844, pl. 22, fig. 35. (*fide* Campbell 1954, p. D62). Barbados, prob. Eocene.

DIAGNOSIS: Test usually of three concentric spherical shells with few or no radial spines.

REMARKS: Broadly applied in the sense of Petrushevskaya (1975).

RANGE: Paleozoic?, Mesozoic to Recent.

***Haliomma teuria* n.sp.**
(Plate 3, Figures 3-6)

Actinommidae gen. *et* spp. indet., Hollis 1991 (*part.*), p. 75.

DESCRIPTION: Large ellipsoidal to spherical test usually without radial spines, commonly with pyramidal tubercles. Cortical shell thick-walled. Subcircular pores numerous, irregular in size, with or without pore frames. If frames are present, short thorn-like pyramidal tubercles occur at some nodes. Two medullary shells. Outer medullary shell ellipsoidal to spherical, thin-walled with an open lattice of rounded polygonal pores, connected to cortical shell by numerous radial beams. Inner medullary shell spherical, thin-walled with numerous circular pores, connected to outer medullary shell by relatively few radial beams.

DIMENSIONS: (range of 15 specimens [mean]): cortical shell length = 250-378 μm [304], width = 240-315 μm [274]; cortical shell thickness = 20-30 μm [26]; outer medullary shell length = 125-158 μm [138], width = 118-138 μm [128]; inner medullary shell diameter = 50-63 μm [58].

REMARKS: Distinguished from other members of the genus by large, thick-walled cortical shell and tendency to be ellipsoidal. Distinguished from *Lithelius marshalli* n.sp. by absence of radial spines or regularly distributed pyramidal tubercles and by concentric internal structure.

HOLOTYPE AND TYPE LOCALITY: R734 (Pl. 3, Fig. 5); P30/f369 (WO60), RP2, Mead Hill Formation, Woodside Creek.

ETYMOLOGY: Reference to the Teurian age range of the species.

DISTRIBUTION: Southwest Pacific: RP2-3, rare to very rare (WO). Uncertainly identified in RP4-5 at Woodside Creek and in RK9 at Mara.

RANGE: RP2 to RP3, eDt, Early Paleocene.

***Haliomma* spp. gr. B, new group**
(Plate 3, Figures 7-9)

Actinomminae gen. gr. B., Hollis 1991, p. 75, pl. 4, fig. 1, 2.

DESCRIPTION: large spherical test with few or no radial spines. Cortical shell relatively thin-walled, numerous small subcircular pores set in weak polygonal frames. 1-2 medullary shells.

REMARKS: This complex includes a variety of forms which have not been confidently allocated to species.

DISTRIBUTION: Southwest Pacific: RP2, very rare (WO); RP3, rare (WO, FX, MD); RP4-13, few to common (WO, CH, MD, KW, TK, DSDP 208).

RANGE: RP2 to RP13, eDt to Ab, Early Paleocene to Middle Eocene.

Genus *HEXADORIDIUM* Haeckel

Hexadoridium Haeckel 1881, p. 455; 1887, p. 206; Campbell, p. D60.

TYPE SPECIES: *Hexadoridium streptacanthum* Haeckel 1887, p. 206, pl. 25, fig. 1, 1a (by subsequent monotypy). Central Pacific, Recent.

DIAGNOSIS: Spherical spongy cortical shell encloses two latticed medullary shells. Six very long-bladed radial spines in opposing pairs perpendicular to each other.

REMARKS: This genus may prove to be a junior synonym of *Hexadoras* Haeckel (1881) which differs only by the presence of a single medullary shell (see discussion of *Heliodiscus* on facing page).

RANGE: Late Cretaceous to Recent.

***Hexadoridium* cf. *magnificum* Campbell & Clark**
(Plate 3, Figures 12-13)

Heliodiscus? spp., Hollis 1991, p. 78, pl. 4, fig. 10, 11.
cf. *Hexadoridium magnificum* Campbell & Clark 1944a, p. 10, pl. 4, fig. 4-6, 11.

DESCRIPTION: Large spheroidal test with six very long radial spines which are at least twice as long as diameter of shell, 3-bladed, with blades bearing evenly spaced, short triangular thorns. Cortical shell consists of loose spongy meshwork with numerous short spines arising form junctions of pore frames. Two spherical latticed medullary shells.

Dimensions: (range of five specimens): diameter of outer latticed (outer medullary) shell = 100-135 µm, of inner latticed shell ~35 µm; length of longest intact spine = 245 µm.

Remarks: Differs from *Hexadoridium magnificum* by lacking large pores at the base of the six radial spines and a less developed outer spongy meshwork which is often altogether absent, although this latter feature may be due to poor preservation. All specimens are incomplete and most are laterally compressed.

Distribution: Southwest Pacific: RP2-3, few to rare (WO). Uncertainly identified in RK9 at Woodside Creek and Mara. *H. magnificum* was described from the late Campanian of California.

Range: RP2 to RP3, eDt, Early Paleocene.

Genus *LITHOMESPILUS* Haeckel, emend. herein

Lithomespilus Haeckel 1881, p. 450.

Type species: *Lithomespilus phloginus* Haeckel 1887, p. 302, pl. 14, fig. 16 (SD Campbell 1954, p. D69). Indian Ocean, Recent.

Diagnosis: Ellipsoidal test with cluster of small spines at one pole and one or more spines at the other. A single medullary shell may be present.

Remarks: The original definition excludes several species with multiple spines at both poles which were subsequently assigned to the genus, i.e. *L. phlogoides*, *L. flammeus*, ?*L. flammabundus* (all of Haeckel 1887), *L. coronatus* Squinabol and *L. mendosa* (Krasheninnikov). The definition is here emended to permit inclusion of these species, and to include forms with a medullary shell. Haeckel (1887) restricted the genus to single-shelled forms, but a large irregularly shaped medullary shell was noted by Sanfilippo & Riedel (1973) in specimens they ascribed to *L. mendosa* (= *L. coronatus* herein).

Range: Late Cretaceous to Recent.

Lithomespilus coronatus Squinabol, emend. herein
(Plate 4, Figures 1-3)

Lithomespilus coronatus Squinabol 1904, p. 198, pl. 4, fig. 7. Hollis 1991, p. 60, pl. 1, fig. 5-9; 1993a, p. 324. Strong *et al.* 1995, p. 205.

Lithomespilus ovoideus Squinabol 1904, p. 198, pl. 4, fig. 8.

Lithomespilus? sp. Campbell & Clark 1944a, p. 13, pl. 4, fig. 2.

Lithomespilus mendosa (Krasheninnikov). Sanfilippo & Riedel 1973, p. 517, pl. 4, fig. 6, 7; pl. 24, fig. 10, 11 (? pl. 25, fig. 12).

Lithomespilus cf. *mendosa* (Krasheninnikov), Nishimura 1986, pl. 1, fig. 2. Iwata & Tajika 1986, pl. 7, fig. 7, 8.

? *Ellipsidium*? *mendosum* Krasheninnikov 1960, p. 281, pl. 1, fig. 14.

Description: Ellipsoidal test with clusters of short spines at each pole, usually fewer at one pole. Cortical shell with numerous small subcircular pores. Spines 3-bladed, very rarely smoothly conical. An irregular medullary shell may be present.

Dimensions (range of 23 specimens [mean]): Cortical shell length = 105-170 µm [130], width = 100-150 µm [115]; length/width = 1.05-1.25 [1.15]; spine length = 5-30 µm [13]; number of spines = 3-18 [11]; distance between pore centres = 8-12 µm [10]; number of pores across half-equator = 10-16 [13].

Remarks: This definition permits more variation than the original which was based on a single specimen and only 8-spined forms. Number of spines varies from 3-10 in the material examined, and is not restricted in the emended definition. Forms with only three spines, as in *L. ovoideus*, are included. Both *L. coronatus s.s.* and the species described by Campbell & Clark (1944a) have longer spines (45-72 µm) than specimens in the material examined. It is not known whether this is a real distinction, or a peculiarity of the two specimens examined by these earlier workers. Campbell & Clark's description was also based on a single specimen. The emended definition permits inclusion of forms ascribed to *L. mendosa* by Sanfilippo & Riedel (1973) (although an inner shell was not observed), and those forms figured by Nishimura (1986) and Iwata & Tajika (1986).

L. mendosa s.s. is only doubtfully included. It is significantly larger (main axis = 221-265 µm) than *L. coronatus*, and is described as being compressed laterally. *Ellipsidium cultum* Borisenko (1960), which Sanfilippo & Riedel (1973) include in *L. mendosa*, has spines that are irregularly distributed, rather than clustered at the poles, and therefore is not considered to be a species of *Lithomespilus*. In contrast, *Ellipsoxiphus bipolaris* Haeckel (1887) is quite similar to *L. coronatus*, differing only in the clear distinction between the two main polar spines and much smaller accessory spines.

Distribution: Southwest Pacific: RK9, few to rare (WO, WH, FX, MD, MR, DSDP 275); RP1-3, common to few (WO, WH, CH, FX) or rare (MD); RP4-7, very rare (WO, CH, MD, TK, DSDP 208). Northern Italy and California, late? Campanian; Hokkaido, Early Paleocene; Mid to North Atlantic, Late Paleocene to Early Eocene.

Southwest Pacific range: RK9 to RP7, Mh to eDw, late Campanian-Maastrichtian to earliest Eocene.

Genus *PROTOXIPHOTRACTUS* Pessagno

Protoxiphotractus Pessagno 1973, p. 81.

Type species: *Protoxiphotractus perplexus* Pessagno 1973, p. 83, pl. 15, fig. 1-3 (OD). California, Cretaceous.

Diagnosis: Narrowly ellipsoidal test with two polar spines. Pores of cortical shell typically arranged in rosettes of 3-7 within large polygonal frames; 5-7 rosettes across the half-equator. Polar spines smoothly conical, with basal buttresses.

Range: Early Campanian to Early Paleocene, possibly Coniacian to Campanian in Hokkaido (Taketani 1982).

Protoxiphotractus perplexus Pessagno

(Plate 1, Figure 13)

Protoxiphotractus perplexus Pessagno 1973, p. 83, pl. 15, fig. 1-3; 1976, p. 40, pl. 12, fig. 3,4. Iwata & Tajika 1986, pl. 9, fig. 4. Hollis 1991, p. 62, pl. 2, fig. 16, 17.
?*Protoxiphotractus* cf. *perplexus* Pessagno. Taketani 1982, p. 48, pl. 1, fig. 5a,b.

Description: Medium-sized narrowly ellipsoidal test with short sturdy polar spines. Pores of cortical shell arranged in rosettes of 3-4 within large hexagonal to pentagonal frames; 5-7 rosettes across half-equator. Polar spines smoothly conical, with basal buttresses; one spine basally wider and usually shorter.

Remarks: Distinguished from *P. kirbyi* Pessagno by its cylindrical cortical shell, thicker buttresses at the base of each spine, more massive pore frames, and fewer pores within each rosette (5-7 in *P. kirbyi*). Taketani's species is only questionably included because, apart from its small size (cortical shell ~90 x 60 µm), the absence of SEM micrographs precludes confident identification.

Distribution: Southwest Pacific: RP2 and RP4, isolated occurrences (WO). California, Early Campanian. Hokkaido, Early Paleocene and possibly Coniacian to Campanian.

Southwest Pacific range: RP2 to RP4, eDt, Early Paleocene.

Pessagno (1976) considered *P. perplexus* to be restricted to the earliest Campanian *P. perplexus* Subzone within his *Crucella espartoensis* Zone (*Amphipyndax pseudoconulus* Zone). Occurrences in Marlborough and Hokkaido indicate that the species survived into the Early Paleocene. *P. perplexus* may be more widely distributed in both the Late Cretaceous and Paleocene, but is not recognised because it is only easily distinguished from similar species by SEM examination.

Protoxiphotractus wilsoni **n.sp.**

(Plate 1, Figures 8-12)

Ellipsoxiphus sp. B, Foreman 1977, p. 313, pl. 1, fig. 4.
Ellipsoxiphus privus Foreman 1978 (*part.*), p. 743, pl. 2, fig. 16.
Protoxiphotractus perplexus Pessagno. Ling & Lazarus 1990, p. 356, pl. 1, fig. 1; pl. 4, fig. 11.
Protoxiphotractus sp. A, Hollis 1991, p. 63, pl. 2, fig. 1-6.

Description: Medium-sized, narrowly ellipsoidal test with slender polar spines. Large polygonal pore-frames raised at junctions, giving surface roughened appearance, and typically enclosing rosettes of 3-5 pores. Polar spines of unequal length, the longer usually as long as main axis of cortical shell. Spines are smoothly conical with strong basal buttresses. Two medullary shells, outer one ellipsoidal, inner one spherical to ellipsoidal.

Dimensions: (range of 20 specimens [mean]): cortical shell length = 85-130 µm [110], width = 60-100 µm [84], length/width = 1.25-1.4 [1.3]; spine length = 30/50-90/100 µm [68/81]; distance between pore rosettes = 12-15 µm; number of pores across half-equator = 5-6; outer medullary shell length = 50-65 µm, width = 42-50 µm; inner medullary shell length = 27-34 µm, width = 25-30 µm.

Remarks: Like the form figured by Ling & Lazarus (1990), this species is distinguished from *P. perplexus* by a more rounded test, a roughened outline, and more slender, usually longer, polar spines. Length/width ratio of the cortical shell in *P. perplexus* is seldom less than 1.4:1, pore frames are not raised at junctions, and length of spines rarely exceeds 70 m. Distinguished from *Amphisphaera priva* by a smaller less rounded test with fewer pores or rosettes across the half-equator. A similar form, *Ellipsoxiphus* sp. B (Foreman 1977), was subsequently included in *A. priva* (Foreman 1978, pl. 2, fig. 16). In the present study, these two morphotypes appear sufficiently distinct to retain Foreman's earlier separation.

Holotype and type locality: R714 (Pl. 1, Fig. 9); P30/f374 (WO74), RP4, Mead Hill Formation, Woodside Creek.

Etymology: Named after dinoflagellate specialist Dr Graeme J. Wilson, Institute of Geological & Nuclear Sciences, in recognition of his substantial contribution to Late Cretaceous and early Tertiary biostratigraphy in New Zealand.

Distribution: Southwest Pacific: RK9, rare to few (WO, WH, FX, MR, DSDP 275); RP1-5, rare to very rare (WH, CH, FX) or few to rare (WO); absent from Mead Stream and DSDP 208. Tropical Atlantic and Weddell Sea, late Campanian to Maastrichtian.

Southwest Pacific range: RK9 to RP5, Mh to eDt, late Campanian to Late Paleocene.

Genus *PRUNOCARPUS* Haeckel

Prunocarpus Haeckel 1887, p. 315.

Type species: *Prunocarpus datura* Haeckel 1887, p. 316, not figured (SD Campbell 1954, p. D72). North Atlantic, Quaternary.

Diagnosis: Ellipsoidal cortical shell, numerous radial spines, two medullary shells.

Range: Late Cretaceous to Quaternary.

***Prunocarpus* sp. A**
(Plate 4, Figures 4-9)

Actinommidae gen. *et* spp. indet., Hollis 1991 (*part.*), p. 75.

Description: Medium-sized ellipsoidal test with numerous pyramidal spines distributed regularly around the test. Pores of cortical shell circular and set in rounded frames which are raised at nodes to form sturdy thorn-like pyramidal spines which are usually regularly distributed, Larger spines may be concentrated in the polar area. 2-3 medullary shells, outer one ellipsoidal, inner shell(s) spheroidal.

Dimensions (range of 9 specimens [mean]): cortical shell length = 104-150 µm [133], width = 98-122 µm [110]; outer medullary shell length =70 µm, width = 64 µm (three specimens); inner medullary shell diameter = 30-37 µm (three specimens); spine length = 8-17 µm.

Remarks: This species is not formally described because the number of specimens that have internal details preserved is insufficient to be confident that a single species is represented. Generic assignment follows the geometric scheme of Haeckel for convenience. Distinguished from *Lithomespilus coronatus* (and synonyms listed under the latter species) by the presence of medullary shells and a cortical shell with more numerous thorns which usually are regularly distributed over the test rather than clustered at each pole.

Distribution: Southwest Pacific: RK9, few to rare (WO, DSDP 275); RP1-5, very rare (WO).

Range: RK9 to RP5, Mh to eDt, late Campanian-Maastrichtian to Late Paleocene.

Genus *STYLOSPHAERA* Ehrenberg

Stylosphaera Ehrenberg 1847, p. 54.
Amphisphaera Ehrenberg. Sanfilippo & Riedel 1973, p. 486.

Type species: *Stylosphaera hispida* Ehrenberg 1854a, p. 246; 1854b, pl. 36, fig. 26 (SD Frizzell & Middour 1951, p. 14). Barbados, Eocene.

Diagnosis: Spherical to ellipsoidal cortical shell with 10-20 pores across the half-equator. Two slender polar spines, at least one being longer than main axis of cortical shell.

Remarks: See *Amphisphaera* Haeckel above.

Range: Paleozoic?, Late Mesozoic to Recent.

Stylosphaera* aff. *hastata (Campbell & Clark)
(Plate 1, Figures 14-16)

aff. *Sphaerostylus (Sphaerostylantha) hastatus* Campbell & Clark 1944a, p. 5, pl. 1, fig. 1, 6.
aff. *Ellipsoxiphus hastatus* (Campbell & Clark). Foreman 1978, p. 742, pl. 2, fig. 13.
aff. *Praestylosphaera hastata* (Campbell). Empson-Morin 1981, p. 262 (*part.*), pl. 4, fig. 4.
Stylosphaera sp. A., Hollis 1991, p. 74, pl. 1, fig. 16-18.

Description: Medium-sized spherical to prolately ellipsoidal test with long polar spines. Cortical shell has small, regularly distributed circular pores set in hexagonal frames. Spines are smoothly conical with 3-4 basal buttresses, unequal in length, both longer than axis of cortical shell, longer spine almost twice length of axis. One spherical medullary shell.

Dimensions: (range of six specimens): cortical shell length = 85-110 µm, width = 80-100 µm; longer spine length = 115-145 µm; shorter spine length = 75-110 µm.

Remarks: Resembles *S. hastata* in size and general shape of cortical shell and length of spines, but differs by having conical rather than 3-bladed spines and tendency for cortical shell to be prolately, rather than oblately, ellipsoidal (see Foreman 1978, p. 742). Distinguished from *S. pusilla* also primarily by polar spines which are conical, longer and never diverge from the polar axis. Cortical shell is smaller, thicker, and less smooth than in *S. minor*; has smaller, more regularly arranged pores than in *S. megaxyphus* or *S. hexaxyphophora* (all of Clark & Campbell 1942; latter species now considered to be a litheliid: see *Lithelius* cf. *hexaxyphophora* below), and does not have the shallow surface depressions noted for *S. angelina* Campbell (Campbell & Clark 1944b) by Petrushevskaya (1975).

Distribution: Southwest Pacific: RK9-RP4, very rare to rare (WO, WH, CH, FX).

Range: RK9 to RP4, lMh to eDt, Maastrichtian to Early Paleocene.

Stylosphaera pusilla **Campbell & Clark**
(Plate 1, Figures 5-6, ?7)

Stylosphaera (Stylosphaerella) pusilla Campbell & Clark 1944a, p. 5, pl. 1, fig. 2, 4, 5. ? Renz 1974, p. 798, pl. 9, fig. 20 (*non* pl. 2, fig. 17, 18). Hollis 1991, p. 73, pl. 1, fig. 10-15; 1993a, p. 324. Strong *et al.* 1995, p. 205.
Druppatractona sp. A, Foreman 1977, p. 315, pl. 1, fig. 3.
Ellipsoxiphus pusilla (Campbell & Clark), Foreman 1978, p. 743, pl. 2, fig. 9, 10, 17.
Praestylosphaera hastata (Campbell & Clark). Empson-Morin 1981, p. 262 (*part.*), pl. 4, fig. 5a-c).
Praestylosphaera aff. *pusilla* (Campbell & Clark). Empson-Morin 1981, p. 262, pl. 4, fig. 6.
Lithatractus pusillus (Campbell & Clark). Taketani 1982, p. 48, pl. 1, fig. 8a, b; pl. 9, fig. 5, 6.

Description: Small spherical to prolately ellipsoidal test with slender polar spines of unequal length. Cortical shell has small regularly distributed circular pores set in hexagonal frames. Polar spines three-bladed, short, slender, may be coaxial but usually diverge at an angle of 5-10° from polar axis. One spherical medullary shell.

Dimensions: (range of 10 specimens [mean]): cortical shell length = 70-110 µm [90], width = 65-105 µm [82], length/width = 1.05-1.15 [1.1]; spine length = 40/50-60/80 µm [50/62]; distance between pore centres = 8-12 µm [10]; number of pores across half-equator = 9-12 [10].

Remarks: This description follows Foreman (1978) in admitting ellipsoidal forms, but differs by excluding forms with smoothly conical spines. A specimen with conical spines (Pl. 1, Fig. 7) in the upper limit of the species range is only doubtfully included.

The species is retained in *Stylosphaera* for reasons outlined under *Amphisphaera* above. Of the alternative generic names proposed by previous workers, *Ellipsoxiphus* Dunikowski is restricted to species which lack medullary shells. *Lithatractus* Haeckel and *Druppatractona* Haeckel are considered junior synonyms of *Amphisphaera* (Petrushevskaya 1975) and until a thorough review of related genera is made it is premature to use *Praestylosphaera* Empson-Morin for this species.

S. hastata Campbell is distinguished by its larger size and by being oblately ellipsoidal. In this respect, one of the specimens ascribed to *S. hastata* by Empson-Morin (1981) is more properly referred to *S. pusilla*. The other specimen Empson-Morin (1981, pl. 4, fig. 6) doubtfully referred to *S. pusilla* also appears to conform with the species. A similar species, *Amphisphaera gracilis* Campbell, is distinguished by two medullary shells, a more thorny cortical shell, and longer spines. Of two morphotypes ascribed to *S. pusilla* by Renz (1974), one is excluded from the species because it has a narrowly ellipsoidal cortical shell, ellipsoidal medullary shells, and long polar spines. The other is only doubtfully included because its polar spines are longer than the main axis of the cortical shell.

Southwest Pacific distribution: RK9-RP3, few to rare (WO, WH, FX, CH, MR, DSDP 275 & 208); RP4, very rare (WO). California, tropical Atlantic and tropical Pacific, late Campanian to Maastrichtian. Hokkaido, possibly Coniacian to Campanian in Hokkaido.

Southwest Pacific Range: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Stylosphaera minor **Clark & Campbell**
(Plate 1, Figures 17, 18)

Stylosphaera minor Clark & Campbell 1942, p. 16, pl. 1, fig. 13, 14. Petrushevskaya & Kozlova 1972, p. 520, pl. 10, fig. 4. Petrushevskaya 1975, p. 569. Strong *et al.* 1995, p. 209.
Amphisphaera minor (Clark & Campbell). Sanfilippo & Riedel 1973, p. 486, pl. 1, fig. 1-5, pl. 22, fig. 4.
Stylosphaera spp. gp B., Hollis 1991 (*part.*), p. 75, pl. 1, fig. 19, 20.

Description: Large spherical test with long slender polar spines. Cortical shell has small circular pores set in polygonal frames. Surface may be smooth or slightly roughened by raised areas at junctions between pore-frames. Polar spines smoothly conical with weakly developed basal buttresses. One to two spherical medullary shells.

Distribution: Southwest Pacific: RP3-RP5, rare to few (WO, CH, MD, TK, DSDP 208); RP6-13, rare to very rare (MD). California, mid Atlantic and South Pacific, Late Paleocene to Middle Eocene.

Range: RP3 to RP13, eDt to Ab, Early Paleocene to Middle Eocene. May range into the Miocene (Petrushevskaya & Kozlova, 1972).

Family PHACODISCIDAE Haeckel 1881

Diagnosis: Lenticular cortical shell encloses 1-2 spherical medullary shells. Cortical shell lacks spongy or chambered arms or rings, and may have marginal spines or a solid girdle.

Genus *HELIODISCUS* Haeckel

Heliodiscus Haeckel 1862, p. 436; 1887, p. 444.
Astrophacus Haeckel 1881, p. 457; 1887, p. 452.

Type species: *Haliomma phacodiscus* Haeckel 1860, p. 815; *Heliodiscus phacodiscus* (Haeckel) in Haeckel 1862, pl. 17, fig. 5-7 (SD Strelkov & Lipman in Khabakov *et al.* 1959, p. 444). Mediterranean, Recent [not *Heliodiscus inchoatus* Rüst (1885, p. 293, pl. 29, fig. 13) as was indicated by Campbell (1954, p. D82); *nomen dubium*].

Diagnosis: Lenticular cortical shell with relatively large pores and rough surface. 1-2 medullary shells.

Remarks: O'Connor's emendation allows for inclusion of species with two medullary shells which were previously ascribed to *Astrophacus*. The presence or absence of a second medullary shell is not considered a reliable taxonomic character as delicate inner shells are very prone to dissolution (Caulet 1972). This appears to be the case with six of seven species of *Astrophacus* described by Haeckel (1887), all of which have equivalent forms, apart from the absence of an inner medullary shell, described under *Heliodiscus*: *Astrophacus asteriscus*, *A. trochiscus*, *A. solaris*, *A. phacodiscus*, *A. cingillum*, and *A. apollinis*. As the first of these, *A. asteriscus*, is the type species, *Astrophacus* is considered the junior synonymn of *Heliodiscus*.

The definition was further emended, in accordance with usage of *Astrophacus* recommended by Sanfilippo & Riedel (1973), to restrict the generic name to species with a rough cortical surface. Species with a smooth surface are placed in *Periphaena* Ehrenberg.

Range: Jurassic to Recent.

***Heliodiscus* spp.**
(Plate 5, Figure 4)

Heliodiscus? spp. Hollis 1991 (*part.*), p. 78.

Remarks: Included here are several forms with lenticular to discoidal tests, some indication of an internal latticed shell, and lack of well-developed radial spines. They vary in degree of inflation, thickness of test wall, pore arrangement, and pore-frame development. Similar forms ascribed to *Astrophacus* were recorded from the Russian Eocene by Kozlova & Gorbovetz (1966).

Distribution: Southwest Pacific: RK9-RP1, very rare (WO, WH); RP2-RP3, rare to few (WO, FX, MD).

Range: RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Genus *HELIOSESTRUM* Haeckel, emend. herein

Heliosestrum Haeckel 1881, p. 457; 1887, p. 438.
Astrosestrum Haeckel 1881, p. 457; 1887, p. 441.

Type species: *Heliodiscus medusinus* Haeckel 1887, p. 438, pl. 34, fig. 6 (*fide* Campbell 1954, p. D78). North Pacific, Recent.

Diagnosis: Lenticular cortical shell with 6-10 well-developed radial spines. 1-2 medullary shells.

Remarks: Although originally restricted to species with eight radial spines, Haeckel (1887) noted that the number of spines may range from 6 to 10 within a single species. The same relationship exists between this genus and *Astrosestrum* as for *Heliodiscus* and *Astrophacus* (see *Heliodiscus* above).

Range: Late Cretaceous to Recent.

***Heliosestrum*? spp.**
(Plate 5, Figures 1, 2)

Heliodiscus? spp., Hollis 1991 (*part.*), p. 78, pl. 4, fig. 9, 12, 16.

Remarks: Included here are several forms with lenticular to discoidal tests, some indication of an internal latticed shell, and well-developed radial spines. They vary in degree of inflation, thickness of test wall, pore-frame development, and arrangement of pores and radial spines.

Distribution: Southwest Pacific: RK9-RP1, very rare (WO, WH, CH); RP2-3, rare to few (WO, WH, CH, FX, MD).

Range: RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Genus *PERIPHAENA* Ehrenberg

Periphaena Ehrenberg 1873, p. 246. Sanfilippo & Riedel 1973, p. 522.

Type species: *Periphaena decora* Ehrenberg 1873, p. 246; 1875, pl. 28, fig. 6 (fide Campbell 1954, p. D78).

Diagnosis: Lenticular cortical shell with smooth surface and numerous small pores. 1-2 medullary shells.

Range: Paleocene to Recent.

***Periphaena* sp.**
(Plate 5, Figure 3)

Description: Lenticular test with numerous short marginal thorns. No girdle.

Remarks: Distinguished from *P. decora* by absence of a girdle, and from *P. heliasteriscus* (Clark & Campbell) by absence of well-developed marginal spines.

Southwest pacific distribution & range: WO, very rare, RP4, eDt, Early Paleocene.

Family SATURNALIDAE Deflandre 1953, *sensu* Dumitrica 1985

Diagnosis: Skeleton consists of a heteropolar microsphere (initial central chamber) surrounded by spongy or latticed concentric shells, and connected by two polar bars to a circular or elliptical ring which may bear spines.

Remarks: Usage follows Dumitrica (1985).

Genus *ACANTHOCIRCUS* Squinabol

Acanthocircus Squinabol 1903, p. 124. Pessagno 1977b, p. 31. Sanflippo & Riedel 1985, p. 591. O'Dogherty 1994, p. 251.
Spongosaturninus Campbell & Clark 1944a, p. 7.
Spongosaturnalis Campbell & Clark 1944a, p. 7.

TYPE SPECIES: *Acanthocircus irregularis* Squinabol 1903, p. 125, pl. 9, fig. 6 (SD Campbell 1954, p. D106). Italy, Cretaceous.

DIAGNOSIS: Spheroidal microsphere surrounded by a spongy shell with close concentric layering. Shell of variable shape from lenticular to narrowly ellipsoidal. Polar bars connect microsphere to bladed or unbladed ring, usually bilaterally symmetrical, and subcircular, elliptical or rectangular in outline. Ring bears two opposite spines (perpendicular to connecting bars), or multiple spines radiating from the periphery.

REMARKS: Synonymies follow Pessagno (1977) and O'Dogherty (1994). The latter illustrated the type species from the type region.

Undifferentiated saturnalids listed in the distribution charts are mainly incomplete specimens of *Acanthocircus* spp.

RANGE: Early Cretaceous (Valanginian) to Paleocene.

Acanthocircus campbelli (Foreman)
(Plate 4, Figure 12)

Spongosaturnalis campbelli Foreman 1968, p. 9, pl. 1, fig. 5a, b.

DESCRIPTION: Spheroidal microsphere surrounded by a lenticular spongy shell with indistinct concentric layering, and connected by smooth short polar bars to an elliptical ring which bears 3-5 smooth spines on each half ring, the central opposite spines being longest. Elliptical ring with a ridge on inner edge, slightly indented at junction with polar bars.

DISTRIBUTION: Southwest Pacific: isolated occurrences in RK9 (WH) and RP3 (WO). California, Maastrichtian.

RANGE: RK9, lMh, Maastrichtian. An isolated Paleocene occurrence may be due to reworking.

Acanthocircus ellipticus (Campbell & Clark)
(Plate 4, Figures 10, 11)

Spongosaturninus ellipticus Campbell & Clark 1944a, p. 8, pl. 1, fig. 8, 9, 12, 14, 16. Moore 1973, p. 824, pl. 13, fig. 14. Pessagno 1976, p. 39, pl. 11, fig. 15-16.
? *Spongosaturninus latuformis* Campbell & Clark 1944a, p. 8, pl. 3, fig. 2, 4, 7, 8, 11, 12.
Spongosaturnalis aff. *latuformis* Campbell & Clark. Petrushevskaya & Kozlova 1972, p. 521, pl. 4, fig. 5.
Acanthocircus ellipticus (Campbell & Clark). Hollis 1991, p. 76, pl. 4, fig. 4, 5.
non Acanthocircus ellipticus (Squinabol). O'Dogherty 1994, p. 261, pl. 46, fig. 10-12.

DESCRIPTION: Spheroidal microsphere surrounded by a lenticular spongy shell with indistinct concentric layering, and connected by short smooth polar bars to a narrowly elliptical ring which bears a long smooth spine at each pole of the ring. Ring smooth, and slightly indented at junction with connecting bars.

REMARKS: This species name is provisionally retained, while noting that O'Dogherty's (1994) study indicates that it is a junior homonym for a different species—*Saturnalis ellipticus*—described by Squinabol (1903) from the mid Cretaceous of Italy. *A. ellipticus* is distinguished from *A. latuformis* primarily by having longer spines. The value of this feature for species diagnosis is questionable. However, if it proves useful, the specimen figured by Petrushevskaya & Kozlova (1972) is more properly allocated to *A. ellipticus*.

DISTRIBUTION: Southwest Pacific: RK9-RP4, very rare (WO, WH, FX). California, late Campanian. Central Atlantic, Maastrichtian. Central Pacific, Coniacian-Santonian.
SOUTHWEST PACIFIC RANGE: RK9 to RP4, lMh to eDt, Maastrichtian to Early Paleocene.

Genus *SATURNALIS* Haeckel

Saturnalis Haeckel 1881, p. 450. Emend. Nigrini 1967, p. 24.

TYPE SPECIES: *Saturnalis circularis* Haeckel 1887, p. 131, unfigured (SD Nigrini 1967, p. 25). South Atlantic, Recent.

DIAGNOSIS: Spheroidal microsphere surrounded by a single latticed shell and connected by polar bars to an circular or elliptical ring.

RANGE: Late Cretaceous to Recent.

Saturnalis kennetti Dumitrica
(Plate 4, Figure 14)

Saturnulus cf. *planetes* Haeckel. Dumitrica 1973, p. 787, pl. 1, fig. 7, 8; pl. 5, fig. 7.
Saturnalis kennetti Dumitrica 1985, p. 189, pl. 2, fig. 1-2, pl. 3, fig. 15. Hollis 1993a, p. 319. Strong *et al.* 1995, p. 209.
Saturnalis cf. *circularis* Haeckel. Hollis 1991, p. 77, pl. 4, fig. 6, 7.

DESCRIPTION: Microsphere surrounded by a spherical latticed shell, and connected by smooth polar spines to an elliptical ring indented at the poles and relatively straight-edged parallel to the polar axis.

REMARKS: Distinguished externally from *S. circularis* by the bilobed and rectilinear shape of the saturnalin ring. Internal differences are discussed by Dumitrica (1985).

DISTRIBUTION: Southwest Pacific: RP1-RP6, very rare (WO, CH, FX, MD, DSDP 208). A similar saturnalin occurs in the Mara fauna (RK9).

RANGE: RP1 to RP6, eDt to lDt, Early to Late Paleocene.

Family PYLONIIDAE Haeckel 1881, emend Dumitrica 1989

DIAGNOSIS: Whole test or at least early ontogenetic stages fenestrated and formed of successively larger girdles (latticed bands) in inverted or perpendicular planes built around a complex microsphere (initial central chamber) incorporating one or more pairs of gates (openings between girdles).

REMARKS: The broad definition of the family conforms with earlier workers usage (Riedel, 1967b) while accommodating Dumitrica's (1989) emendation of the superfamily. Originally thought to be restricted to the Neogene, the family is now considered to range from Middle Triassic to Recent (Dumitrica, 1989).

Genus *PERITIVIATOR* Pessagno

Peritiviator Pessagno 1976, p. 45.

TYPE SPECIES: *Peritiviator labyrinthi* Pessagno 1976, p. 45, pl. 13, fig. 2-4 (OD). California, Late Cretaceous.

DIAGNOSIS: Crudely ellipsoidal test composed of labyrinthine meshwork arranged in a coarse outer part and a finer inner part.

REMARKS: Similarities between forms encountered in this study and the genus *Tetrapyle* support provisional inclusion of this genus within the Pyloniidae (i.e. Pylonacea *sensu* Dumitrica, 1989).

RANGE: Late Cretaceous to Late Paleocene (Nishimura 1992).

Peritiviator* cf. *labyrinthi Pessagno
(Plate 4, Figure 16)

cf. *Peritiviator labyrinthi* Pessagno 1976, p. 45, pl. 13, fig. 2-4.

DESCRIPTION: As for genus with rhomboid test with blunt conical spines arising from outer meshwork at corners.

REMARKS: Similar to one specimen of *P. labyrinthi* figured by Pessagno (1976, pl. 13, fig. 4), but otherwise distinguished by rhomboid shape and relatively regular arrangement of spines. Distinguished from the Late Paleocene species *Peritiviator*? *dumitricai* Nishimura (1992, p. 328, pl. 1, fig. 13-16, pl. 11, fig. 11-12) by a more narrowly ellipsoidal test and the absence of well-defined outer shell.

DISTRIBUTION: Southwest Pacific: RK9-RP3, very rare (WO, WH, FX, DSDP 275). *P. labyrinthi* occurs in the late Campanian and Maastrichtian of California.

RANGE: RK9 to RP3, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Genus *PALAEOTETRAPYLE* Dumitrica

Palaetetrapyle Dumitrica 1988, p. 186.

TYPE SPECIES: *Palaeotetrapyle muelleri* Dumitrica 1988, p. 186, pl. 2, fig. 1-9; pl. 5, fig. 1-17 (OD). Southwest Pacific (DSDP-21-208-30CC), Early Paleocene.

DIAGNOSIS: Test consist of 2-3 girdles, each with four wide gates.

REMARKS: Distinguished from Neogene genus *Tetrapyle* Müller by structure of the central chamber (microsphere) as discussed by Dumitrica (1988, 1989).

RANGE: Early to Late Paleocene, insofar as known.

Palaeotetrapyle muelleri Dumitrica
(Plate 5, Figure 6)

Palaeotetrapyle muelleri Dumitrica 1988, p. 186, pl. 2, fig. 1-9; pl. 5, fig. 1-17.
? *Tetrapyle* sp., Nishimura 1992, p. 326, pl. 2, fig. 16, 18 (not fig. 17 or pl. 12, fig. 14).

DESCRIPTION: Small ellipsoidal to rhomboidal test consists of two complete girdles and one incomplete outer girdle with one pair of open gates. Eight diagonal bars prolonged as short conical spines at each corner. Surface of girdles smooth, with circular pores of irregular size and arrangement.

REMARKS: Dumitrica (1988, p. 186) notes a close resemblance between this species and the Quaternary type species of *Tetrapyle, T. octacantha* Müller. The species are distinguished by distinctive features of the microsphere in *Paleotetrapyle,* the chief one being the absence of a "dorsal sagittal beam" traversing the long axis of the test. Such an equatorial beam is evident in otherwise similar Late Paleocene species ascribed to *Tetrapyle* by Nishimura (1992, p. 326, pl. 2, fig. 17; pl. 12, fig. 14). These latter co-occur with a form which is possibly *P. muelleri,* based on the absence of a distinct equatorial beam (ibid. pl. 2, fig. 16, 18).

Distribution: Southwest Pacific: RP4, very rare (WO, DSDP 208). Possibly in North Atlantic, Late Paleocene. A single specimen of a similar but larger and more robust species occurs in RP3 (Pl. 5, Fig. 5).

Range: RP4, eDt, Early Paleocene.

Family LITHELIIDAE Haeckel 1862, emend. Petrushevskaya 1975

Diagnosis: Spherical to ellipsoidal test comprising numerous (usually five or more) closely spaced shells arranged in a spiral, or concentrically.

Genus *LITHELIUS* Haeckel

Lithelius Haeckel 1860, p. 843; 1862, p. 519; 1881, p. 464.

Type species: *Lithelius spiralis* Haeckel 1860, p. 843; 1862, p. 519, pl. 27, fig. 6, 7 (by monotypy). Mediterranean, Recent.

Diagnosis: Subspherical to ellipsoidal test with up to ten shells arranged in a simple spiral. Radial spines.

Range: Paleocene to Recent (revised herein).

Lithelius* aff. *foremanae Sanfilippo & Riedel
(Plate 5, Figures 7-9)

aff. *Lithelius foremanae* Sanfilippo & Riedel 1973, p. 522, pl. 7, fig. 1-6; pl. 26, fig. 4-5.
Lithelius sp. A., Hollis 1991, p. 80. pl. 4, fig. 13-15; 1993, p. 320, pl. 1, fig. 7.

Description: Small spheroidal test comprising a single spiral of 3-5 whorls. Cortical shell moderately thick, with a smooth surface and closely spaced, evenly distributed circular pores. Inner whorls thin-walled with closely-spaced circular pores. Four to ten regularly distributed conical radial spines originating from initial or second whorl.

Dimensions: (range of six specimens [mean]): maximum diameter = 93-118 μm [106].

Remarks: Distinguished from Late Paleocene-Eocene *L. foremanae* by absence of thorns, fewer radial spines, and a less defined separation between the cortical shell and the internal spiral. Similar to *L. nautiloides* Popofsky (see below), but differs by having fewer whorls and fewer radial spines.

Distribution: Southwest Pacific: RP1-3, very rare (WO, WH, FX, MD, DSDP 208); RP4-5, rare to very rare (WO, CH, DSDP 208).

Range: RP1 to RP5, eDt, Early to Late Paleocene.

Lithelius* cf. *hexaxyphophorus (Clark & Campbell)
(Plate 5, Figure 10)

cf. *Stylosphaera hexaxyphophora* Clark & Campbell 1942, p. 28, pl. 6, fig. 4, 5, 7, 11, 12.
cf. *Lithelius hexaxyphoporus* (Clark & Campbell). Sanfilippo & Riedel 1973, p. 522, pl. 7, fig. 7-9; pl. 26, fig. 6-7.
Litheliidae gen *et* spp. indet., Hollis 1991 (*part.*), p. 80.

Description: Medium-sized spheroidal test comprising a single spiral of 3-4 whorls. Surface roughened by small spines arising from junctions between pore frames. Pores circular and evenly distributed. Eight to ten strong, conical, radial spines.

Dimensions: (range of two specimens): maximum diameter = 150-160 μm.

Remarks: Resembles Eocene *L. hexaxyphophorus* (*sensu* Sanfilippo & Riedel) in size, surface details, and number of whorls and radial spines, but differs by lacking a clear separation between outer shell and internal whorl. Distinguished from *L. nautiloides* Popofsky by its fewer whorls and thicker radial spines; from *L. kaikoura* by its larger size and thicker and more numerous radial spines.

Distribution and range: WO, very rare, RP4 to RP5, eDt, Early Paleocene.

Lithelius marshalli **n.sp.**
(Plate 6, Figures 1-5)

Spongotrochus sp., Hollis 1991, p. 89 (*part.*), pl. 7, fig. 11, 12.
? *Lithelius*? *nautiloides* Popofsky. Petrushevskaya 1975, p. 572, pl. 33, fig. 3, 4.

Description: Large spheroidal to inflated lenticular test with thick cortical shell. Numerous short, regularly placed, pyramidal spines extend from internal radial beams which support an inner spiral structure of 2-3 whorls.

Dimensions: (range of 12 specimens [mean]): cortical shell length = 214-325 μm [270], width = 200-255 μm [240], thickness = 175-237 μm [205]; spine length = 8-43 μm (median = 15 μm).

Remarks: Distinguished from *L. nautiloides* Popofsky by its larger size and fewer whorls. Possibly conspecific with a large form (diameter = 200 μm) ascribed to *L. nautiloides* by Petrushevskaya. Distinguished from *L. hexaxyphphora* and the related species described above by its larger size and lack of conical spines. If internal structure is not seen,

Holotype and type locality: R773 (Pl. 6, Fig. 1); P30/f372 (WO69), RP3, Mead Hill Formation, Woodside Creek.

Etymology: Named after eminent New Zealand geologist Dr Patrick Marshall (1869-1950) who was first to argue

(1916) that the silica in Muzzle Group rocks of Marlborough was largely derived from radiolarians and diatoms, and is not of inorganic origin.

DISTRIBUTION AND RANGE: WO, rare to few, RP2 to RP3, eDt, Early Paleocene.

Lithelius*? *minor Jörgensen gr., new group
(Plate 6, Figures 6-15)

Lithelius minor Jörgensen 1900, p. 65, pl. 5, fig. 24; Nigrini & Moore 1979, p. S135, pl. 17, fig. 3, 4a, b; Nigrini & Lombari 1984, p. S95, pl. 14, fig. 1a, b.
Cromyodruppa concentrica Lipman 1952, p. 29, pl. 1, fig. 8, 9. Kozlova & Gorbovetz 1966, p. 62, pl. 1, fig. 1-4. Foreman 1978, p. 742, pl. 2, fig. 18. Ling & Lazarus 1990, p. 355, pl. 1, fig. 11-13.
Litheliid gen. A sp. indet., Petrushevskaya & Kozlova 1972, p. 529, pl. 5, fig. 14, 15.
Spongurus? spp., Nigrini & Lombari 1984, p. S33-36, pl. 5, fig. 1a-2d.
Litheliidae gen. gr. A, Hollis 1991 (*part.*), p. 80, pl. 5, fig. 1-7.

DESCRIPTION: Small spherical to ellipsoidal test composed of three or more closely spaced concentric or spiral shells; both single or double spirals occur. Surface smooth or roughened by raised points at junctions between pore frames. A pylom may be present.

REMARKS: Variation ranges from spherical forms identical to Miocene-to-Recent *Lithelius? minor s.s.* to narrowly ellipsoidal forms found in Cretaceous rocks and ascribed to *Cromyodruppa concentrica* by previous workers. Similar forms have been doubtfully ascribed to *Spongurus* (see Nigrini & Lombari 1984 and references therein), but lack the dense spongy meshwork of that genus. Incomplete outer shells in the middle of the test cause these ellipsoidal forms to resemble *Amphymenium* spp., but the latter are distinguished by more clearly defined arms.

This group and the related form described below are only doubtfully referred to *Lithelius,* as neither have shells arranged in a simple loose spiral. Most of the forms examined here have closely spaced concentric shells, although forms with closely spaced single and double spirals are relatively common (e.g. single spiral: Pl. 6, Fig. 10; double spiral: Pl. 6, Fig. 11).

DISTRIBUTION: Southwest Pacific: RK9, rare to few (WO, WH, FX, MD, MR) or common (DSDP 275 & 208); RP1-6, few to common (WO, WH, CH, FX, MD, KW, TK, DSDP 208); RP7-13, few (MD). The group has a worldwide distribution from Late Cretaceous to Recent.

SOUTHWEST PACIFIC RANGE: RK9 to RP13, Mh to Ab, late Campanian-Maastrichtian to Middle Eocene.

Lithelius*? aff. *minor Jörgensen
(Plate 7, Figures 1-3)

Litheliidae gen. gr. A, Hollis 1991 (*part.*), p. 80.

DESCRIPTION: Small ellipsoidal test composed of five or more closely spaced concentric shells. Short pyramidal spines clustered near poles, each cluster usually consisting of a polar spine and 1-3 accessory spines; polar spines of unequal length.

DIMENSIONS (range of 5 specimens [mean]): cortical shell length = 133-150 µm [140], width = 90-102 [95]; length of spines: long polar = 8-22 µm [16]; short polar = 5-14 µm [8]; accessory 8-18 µm (14).

REMARKS: Apart from the presence of polar spines this form closely resembles ellipsoidal forms of *Lithelius minor* gp.

SOUTHWEST PACIFIC DISTRIBUTION & RANGE: RP1 to RP4, rare to few (WO, FX); eDt, Early Paleocene.

Genus *PRUNOPYLE* Dreyer

Prunopyle Dreyer 1889, p. 18.
Lithocarpium Stöhr. Petrushevskaya 1975, p. 572.

TYPE SPECIES: *Prunopyle pyriformis* Dreyer, 1889, p. 18, pl. 2, fig. 19 (SD Campbell 1954, p. D72). North Pacific, Recent.

DIAGNOSIS: Ellipsoidal test of one or more concentric shells with a well-developed pylom at one pole.

REMARKS: *Prunopyle* is preferred over its possible senior synonym *Lithocarpium* because, although a cephalis is not evident in Stöhr's illustration (1880, pl. 3, fig. 10), the type species of *Lithocarpium, L. pyriforme* was described as a nassellarian.

RANGE: Paleocene to Recent.

***Prunopyle* spp.**
(Plate 7, Figures 12, 13)

REMARKS: Included here are several ellipsoidal forms, either with a dense spongy meshwork or three or more indistinct concentric shells, distinguished from other litheliids by a well-developed posterior pylom.

SOUTHWEST PACIFIC DISTRIBUTION & RANGE: WO, very rare, RP3-RP5, eDt, Early to Late Paleocene.

Family SPONGURIDAE Haeckel 1862, emend. Petrushevskaya 1975

Diagnosis: Spongy ellipsoidal to cylindrical test consisting of a central area and two opposite arms. Concentric layering of meshwork usually confined to central area. Meshwork of arms not linearly aligned as in Patulibracchiidae. One arm usually bears a pylome, both arms may bear terminal spines.

Remarks: Petrushevskaya's definition is modified slightly to clarify the distinction between this family and Patulibracchiidae (emend. Baumgartner 1980) which has superficially similar elements.

The Prunobrachiidae is here included in the family. Pessagno (1975) established the Prunobrachiidae because four features were considered significantly distinctive to separate the genus *Prunobrachium* Lipman from Sponguridae: (1) well-developed concentric meshwork confined to central area; (2) presence of bracchiopyles (spongy tubes) at poles; (3) presence of a pseudopatagium which differs from a true patagium by having "crudely concentric" meshwork, and (4) absence of terminal spines. None of these features conflicts with Petrushevskaya's (1975) emended definition of Sponguridae. Several spongurids figured by Petrushevskaya and other workers (e.g. Dumitrica 1973, pl. 5, fig. 1-3) lack terminal spines and have both a concentrically layered central area and crudely concentric patagium. In addition, *Spongurus spongiosa* appears to have rudimentary bracchiopyles (see Pl. 7, Fig. 14).

Phaseliformidae, which Petrushevskaya (1975) included in Sponguridae, is provisionally excluded. Although the type species of *Phaseliforma* is similar to some spongurids, members of the genus described here differ from spongurids by being bilaterally compressed.

Genus *AMPHYMENIUM* Haeckel

Amphymenium Haeckel 1881, p. 460; 1887, p. 519.

Type species: *Amphymenium zygartus* Haeckel 1887, p. 520, pl. 44, fig. 7 (SD Campbell 1954, p. D86). Central Pacific, Recent.

Diagnosis: Elongate test with two opposite chambered arms extending from central area. Meshwork of central area arranged in concentric layers. Patagium and weak terminal spines may be present.

Remarks: Distinguished from *Amphibracchium* (*sensu* Baumgartner 1980; see below) by absence of linear alignment in meshwork of arms.

Range: Late Cretaceous to Recent.

Amphymenium concentricum (Lipman)
(Plate 7, Figure 7)

Amphibrachium concentricum Lipman 1960, p. 125, pl. 28, fig. 6, 7. Kozlova & Gorbovetz 1966, p. 82, pl. 3, fig. 3.
Sponguridae gen. et spp. indet., Hollis 1991 (*part.*), p. 82.

Description: Large dumbbell-shaped test with well-developed concentric layering in central area and arms. Arms expand distally, and lack terminal spines or brachiopyles. Patagium may be present. Maximum length ~350 m.

Distribution: Southwest Pacific: RK9, very rare (WO) or rare to few (DSDP 275 and 208). Russia, Late Cretaceous.
Southwest Pacific range: RK9, Mh, late Campanian-Maastrichtian.

Amphymenium* cf. *splendiarmatum Clark & Campbell
(Plate 7, Figures 8-10)

cf. *Amphymenium splendiarmatum* Clark & Campbell 1942, p. 46, pl. 1, fig. 12, 14. Sanfilippo & Riedel 1973, p. 524, pl. 11, fig. 6-8, pl. 28, fig. 6-8.
Sponguridae gen. *et* spp. indet., Hollis 1991 (*part.*), p. 82.

Description: Narrowly cylindrical test. Central area of 2-3 concentric layers. Slender arms consists of 4-15 cupola-shaped chambers. 1-2 short terminal spines may be present at each pole. Patagium not observed.

Remarks: Differs from *A. splendiarmatum* by absence of a patagium. Sanfilippo & Riedel (1973) included similar forms in *A. splendiarmatum*, but the lack of co-occurring forms with a patagium suggests that this Paleocene form is a distinct species.

Distribution: Southwest Pacific: RP1, very rare (WH, FX); RP2-5, rare to few (WO, WH, FX). *A. splendiarmatum* is widely distributed in Middle Eocene.

Range: RP1 to RP5, eDt, Early to Late Paleocene.

Genus *PRUNOBRACHIUM* Kozlova & Gorbovetz

Prunobrachium Kozlova & Gorbovetz 1966, p. 65.

Type species: *Amphymenium crassum* Lipman 1960 (*fide* Pessagno 1975, p. 1014). Russia, Late Cretaceous.

Diagnosis: Spongy trilobate test with two opposite arms extending from central area. Concentric layering confined to central area. Terminal lobes bear bracchiopyles, but never terminal spines.

Remarks: The type species was referred to but not described by Lipman (1960). It appears to have been described in an earlier paper by Lipman which was not specified by either Lipman (1960) or Kozlova & Gorbovetz (1966), and not located by me.

Range: Late Cretaceous, possibly Early Paleocene.

Prunobrachium kennetti Pessagno.
(Plate 7, Figure 11)

Prunobrachium kennetti Pessagno 1975, p. 1015, pl. 1, fig. 9-12; pl. 2, fig. 1-2.
Prunobrachium spp., Hollis 1991, p. 82, pl. 11-13; 1993a, p. 324. Strong *et al.* 1995, p. 205, fig. 8A.

Description: Large spongy trilobate test with elongate ellipsoidal central lobe flanked by oblately ellipsoidal distal lobes, each with a polar bracchiopyle. Central lobe equates with area covered by pseudopatagium. Concentric meshwork restricted to central area and inner pseudopatagium.

Remarks: Although Pessagno (1975) described this species as having cylindrical distal lobes, his figures show the lobes to be oblately ellipsoidal, becoming subconical distally. This distinction clarifies the difference between *P. kennetti* and *P. sibericum* (Lipman) in which the terminal lobes are truly cylindrical proximally. *P. kennetti* is distinguished from *P. longum* Pessagno by having a more inflated central lobe.

Distribution: Southwest Pacific: RK9, very rare (WO, FX, MD, MR, DSDP 275); RP3-4, isolated occurrences (WO); uRP5, isolated occurrence (TK); common in probable Paleocene, Garden Cove Formation, Campbell Island (CA/f31 = F6406 in Oliver *et al.* 1950; pers. obs. 1995).

Range: RK9, Mh, late Campanian-Maastrichtian to Late Paleocene. All Paleocene occurrences may be due to reworking.

Genus *SPONGOPRUNUM* Haeckel

Spongoprunum Haeckel 1887, p. 347.

Type species: *Spongoprunum amphilonche* Haeckel 1887, p. 347, pl. 48, fig. 7 (SD Campbell 1954, p. D74). Central Pacific, Quaternary, and Barbados, Eocene?

Diagnosis: Dense, spongy, narrowly ellipsoidal to cylindrical test with two polar spines.

Spongoprunum* cf. *markleyense Clark & Campbell
(Plate 7, Figures 5-6)

cf. *Spongoprunum markleyense* Clark & Campbell 1942, p. 37, pl. 4, fig. 1.
Sponguridae gen. *et* spp. indet., Hollis 1991 (*part.*), p. 82.

Description: Small cylindrical spongy test with 2 slender conical polar spines of unequal length and usually offset from main axis.

Dimensions (range of 3 specimens): cortical shell length = 95-143 µm, width = 52-65 µm; spine length: long polar = 27-31 µm, short polar = 15-25 µm.

Remarks: Distinguished from Eocene *Spongoprunum markleyense* by its smaller size, cylindrical shape, and more slender polar spines.

Distribution & range: RP2-3, rare (WO, FX); eDt, Early Paleocene.

Genus *SPONGURUS* Haeckel

Spongurus Haeckel 1860, p. 844; 1862, p. 465. Campbell 1954, p. D74.

Type species: *Spongurus cylindricus* Haeckel 1860, p. 845; 1862, p. 465, pl. 27, fig. 1 (by monotypy). Cosmopolitan, Quaternary.

Diagnosis: Ellipsoidal to cylindrical test comprising a central area and two opposing arms. Meshwork may be weakly concentric in central area, otherwise densely spongy. May bear radial or terminal spines.

Range: Mesozoic to Recent.

Spongurus spongiosus **(Lipman)**
(Plate 7, Figure 14)

Amphibrachium spongiosum Lipman 1960, p. 127, pl. 28, fig. 1-5. Kozlova & Gorbovetz 1966, p. 81, pl. 3, fig. 1, 2.
Sponguridae gen. et. spp. indet., Hollis 1991 (*part.*), p. 82.

Description: Large densely spongy test. Two flaring arms with bulbous tips, no terminal spines or brachiopyles. Patagium may be present.

Distribution: Southwest Pacific: RK9, rare (WO, DSDP 275); RP3, isolated occurrences (WO, FX). Russia, Late Cretaceous.

Southwest Pacific range: RK9, Mh, late Campanian-Maastrichtian. Paleocene occurrences may be due to reworking.

Spongurus* cf. *bilobatus Clark & Campbell
(Plate 7, Figures 15-18)

cf. *Spongurus bilobatus* Clark & Campbell 1942, p. 36, pl. 1, fig. 7, 9. Blueford 1988, p. 252, pl. 6, fig. 9, pl. 7, fig. 1.
Sponguridae gen. *et* spp. indet. Hollis 1991 (*part.*), p. 82, pl. 5, fig. 9, 10, 15.

DESCRIPTION: Small test consisting of small central area, variably developed patagium, and two moderately flared arms with sharp to moderately rounded terminations. Meshwork uniformly spongy in arms, arranged in indistinct concentric layers in central area. Patagium often not preserved or incomplete, but when fully developed it covers >0.7 length of the test and test outline is rectangular. No terminal spines.

REMARKS: Distinguished from *S. bilobatus* by conical arms with less rounded terminations, and less inflated central area; from *S. spatulaeformis* Clark & Campbell by lacking spatulate terminal lobes.

DISTRIBUTION: Southwest Pacific: RP1-4, very rare to rare (WO, WH, FX). *S. bilobatus* and *S. spatulaeformis* are known from the Middle Eocene of California.

RANGE: RP1 to RP4, eDt, Early Paleocene.

Spongurus* aff. *prolixum (Sanfilippo & Riedel)
(Plate 7, Figures 19-21)

aff. *Amphicraspedum prolixum* Sanfilippo & Riedel 1973, p. 524, pl. 10, fig. 7-11, pl. 28, fig. 3, 4. Strong *et al.* 1995, p. 208.
cf. *Amphicraspedum prolixum* gr. Sanfilippo & Riedel 1973, p. 524, pl. 11, fig. 1-5, pl. 28, fig. 5., Strong *et al.* 1995, p. 205.
Sponguridae gen. *et* spp. indet., Hollis 1991 (*part.*), p. 82.

DESCRIPTION: Small elongate test consisting of an uninflated central area and 2 cylindrical arms, each with a rounded tip bearing 1-3 short, sturdy, conical spines. Meshwork uniformly spongy. Patagium covers 0.75 length of test but rarely preserved. Arm tips usually slightly spatulate with two divergent spines at opposing corners.

REMARKS: Bears a superficial resemblance to members of *A. prolixum* gr. but is distinguished by lack of any longitudinal structure to meshwork, although this may be due to relatively poor preservation of all specimens encountered.

OCCURRENCE AND RANGE: Southwest Pacific: RP2, rare (WO); eDt, Early Paleocene. Not differentiated from other poorly preserved spongurids in the Paleocene at other Marlborough sections. Similar forms first appear in earliest Eocene (RP7) at Mead Stream.

Family PHASELIFORMIDAE Pessagno 1972

DIAGNOSIS: Test subellipsoidal, thicker at anterior end. Internal meshwork weakly concentric.

Genus *PHASELIFORMA* Pessagno

Phaseliforma Pessagno 1972, p. 274.

TYPE SPECIES: *Phaseliforma carinata* Pessagno 1972, p. 274, pl. 22, fig. 1-3,8; pl. 23, fig. 1 (OD). California, Late Cretaceous.

DIAGNOSIS: Ellipsoidal to discoidal spongy test with elliptical outline, thicker at one end (designated anterior end by Pessagno). Internal meshwork weakly concentric.

RANGE: Late Cretaceous to Early Paleocene (revised herein).

Phaseliforma laxa Pessagno
(Plate 8, Figure 1)

Phaseliforma laxa Pessagno 1972, p. 276, pl. 23, fig. 7-9; 1975, p. 1013, pl. 1, fig. 2.
Phaseliforma spp., Iwata & Tajika 1986, pl. 4, fig. 5-7; pl. 9, fig. 5. Hollis 1991, p. 83, pl. 6, fig. 5-8. Strong *et al.* 1995, p. 205.
? *Phaseliforma* sp., Foreman 1978, p. 744, pl. 3, fig. 3.

DESCRIPTION: Flattened test, elliptical in outline. In side view, periphery rounded, one end thickened (anterior), other end compressed. Meshwork relatively coarse in central area, finer close to periphery. Surface smooth, with circular to elliptical pores regularly distributed over surface, tending to be smaller near periphery.

REMARKS: The surface of the central area is not preserved in the figured specimen, thus revealing the coarse meshwork below. As this coarse meshwork was not mentioned by Pessagno, it is possible that the New Zealand specimens represent a different species. However, examination of material from DSDP Site 275 indicates that this is the same species as ascribed to *P. laxa* by Pessagno (1975). *P. laxa* is distinguished from *P. subcarinata* and *P.. carinata* by the absence of an indentation in the middle of one side, and by the absence of a peripheral keel. The form recorded by Foreman (1978) is similar in outline to *P. laxa*, but the pore arrangement is not clearly shown.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, WH, FX, MD, MR, DSDP 275); RP1-3, very rare (WO, WH, CH, FX, DSDP 208); RP4-5, rare (WO). California, late Campanian.

SOUTHWEST PACIFIC RANGE: RK9 to lRP5, Mh to eDt, late Campanian-Maastrichtian to Late Paleocene.

Phaseliforma subcarinata Pessagno
(Plate 8, Figure 2-5)

Phaseliforma subcarinata Pessagno 1975, p. 1013, pl. 1, fig. 1. Hollis 1991, p. 83, pl. 6, fig. 1-4; 1993a, p. 324.

DESCRIPTION: Flattened test, elliptical to reniform in outline, with a V-shaped indentation in the middle of one side. In side view, one end thickened and rounded (anterior), other end compressed and acute. A blunt keel commonly extends from posterior edge of marginal indentation and around the posterior margin. Meshwork arranged in three broad zones: a relatively dense central zone beneath the surface of the test, a surrounding zone of coarser meshwork extending to the surface, and a peripheral zone of fine meshwork. Surface smooth, with circular to elliptical pores regularly distributed over the surface, tending to be smaller near the periphery.

REMARKS: As with *P. laxa* the structure of the internal meshwork is only evident when the surface of the test is partly removed (Pl. 8, Fig. 2, 4; surface is preserved in Pl. 8, Fig. 5). This structure is also evident in specimens of *P. subcarinata* examined from the type locality (DSDP Site 275). *P. subcarinata* is distinguished from *P. carinata* by its wider test. Both species differ from other members of the genus by their keeled reniform test.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, WH, FX, MR, DSDP 275); RP1-3, very rare (WO, CH, FX, DSDP 208); RP4-5, rare (WO, KW); uRP5, isolated occurrence (TK). California, late Campanian.

SOUTHWEST PACIFIC RANGE: RK9 to lRP5, Mh to eDt, late Campanian-Maastrichtian to Late Paleocene. Isolated occurrence in uRP5 may be due to reworking.

Family PATULIBRACCHIIDAE Pessagno 1971, emend. Baumgartner 1980

DIAGNOSIS: Flat spongy test with 2-5 arms. Internal meshwork is uniformly spongy rather than differentiated into concentric shells and longitudinal canals as it is in the Hagiastridae (Riedel 1971, emend. Baumgartner 1980). Outer meshwork of arms is linearly aligned.

Genus *AMPHIBRACHIUM* Haeckel

Amphibrachium Haeckel 1881, p. 460. Emend. Pessagno 1971, p. 20.
non Amphibrachium Hertwig 1879.

TYPE SPECIES: *Amphibrachium diminutum* Rüst 1885, p. 296, pl. 7, fig. 5 (*fide* Campbell 1954, p. D86); Europe, Jurassic.

DIAGNOSIS: Test consists of two straight opposing arms extending from a small central area. Meshwork of arms linearly aligned. Arms with expanded tips, sometimes possessing small spines. With or without patagium.

REMARKS: For expediency Haeckel's generic name is used in the conventional sense here, despite knowledge that the name is a junior homonym for both *Amphibrachium* Hertwig (1879) and *Amphibrachium* Schultze (1880). The genus is transferred to Patulibrachiidae following Baumgartner's (1980) revision of the family.

Amphibrachium* aff. *sansalvadorensis Pessagno
(Plate 8, Fig. 10, 11)

aff. *Amphibrachium sansalvadorensis* Pessagno 1971, p. 21, pl. 19, fig. 9, 10.
Patulibracchium sp., Hollis 1991, p. 84 (*part.*), pl. 6, fig. 14.

DESCRIPTION: Test as for genus. Two slender arms extend from small bulbous central area, increasing in width distally and terminating in an expanded or bulbous tip. Arms subequal in length, elliptical in cross-section, with pores arranged in 3-4 linear rows across the equator; 4-5 short thorns distributed along opposite sides in slightly offset pairs. Tips bear a sturdy central primary spine and, rarely, additional minor spines.

DIMENSIONS: Total length (one specimen) = 720 µm; maximum length of solitary arms (three specimens) = 340-350 µm; maximum width (three specimens) = 65-90 µm.

REMARKS: Superficial resemblance with Late Jurassic *A. sansalvadorensis* which is distinguished by its smooth arms and the presence of a cluster of spines at each tip. Distinguished from Eocene *Amphicraspedum prolixum* (see *Spongurus* aff. *prolixum* above) by its arms which increase in width gradually, bear short thorns, and have a less bulbous tip. The arms of *A. prolixum* may bear side spines (Sanfilippo & Riedel 1973, pl. 28, fig. 4), but do not increase in width towards the tip.

DISTRIBUTION: RK9, very rare (WO, WH); RP1-3, very rare (WO).

RANGE: RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Genus *PATULIBRACCHIUM* Pessagno

Patulibracchium Pessagno 1971, p. 26.

TYPE SPECIES: *Patulibracchium davisi* Pessagno 1971, p. 30, pl. 1, fig. 1-4 (OD). California, Late Cretaceous.

DIAGNOSIS: Test has three arms, one of which terminates in a bracchiopyle. Patagium may be developed between arms to such an extent as to give the test a triangular outline.

RANGE: Jurassic?, Cretaceous to Early Paleocene (revised herein).

***Patulibracchium* spp.**
(Plate 8, Fig. 6-8, 13, ?9, ?12)

Patulibracchium spp., Iwata & Tajika 1986, pl. 5, fig. 2, 3. Hollis 1991, p. 84 (*part.*), pl. 6, fig. 12, 13. Strong *et al.* 1995, fig. 8C.

Remarks: At least four distinctive morphotypes are present, but are not differentiated here because preservation is usually poor and consistent identification of each morphotype has not been possible. All morphotypes appear to be new species, but one may prove to be more properly referred to *Spongotripus* (Pl. 8, Fig. 9, 12; see below).

Distribution: RK9, rare (WO, WH, MD, MR, DSDP 275, DSDP 208); RP1-4, very rare (WO, WH, FX).

Southwest pacific range: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Family SPONGODISCIDAE Haeckel 1862, emend. Riedel 1967b, emend. herein

Diagnosis: Discoidal spongy test with or without marginal spines and porous gown (sieve plate of Riedel 1967b). Meshwork may be irregular or arranged in closely spaced concentric bands.

Remarks: Riedel's (1967b) broad definition is emended to exclude cylindrical, ellipsodial or radiate taxa with two, three, or more arms (e.g., Sponguridae, Patulibracchiidae).

Genus *ORBICULIFORMA* Pessagno

Orbiculiforma Pessagno 1973, p. 71; emend. Pessagno 1976, p. 34.

Type species: *Orbiculiforma quadrata* Pessagno 1973, p. 73, pl. 16, fig. 1-4; pl. 18, fig. 3 (OD). California, Late Cretaceous.

Diagnosis: Spongy discoidal test with a central depression which may be obscured by secondary meshwork. Peripheral outline may have a marginal notch (defining the posterior end of the test *sensu* Pessagno).

Remarks: Pessagno's broad definition does not adequately distinguish the genus from *Spongodiscus*. The generic name is applied here only to forms with a marginal notch, such as *O. renillaeformis*, and Orbiculiformidae (Pessagno 1973) is subsumed within Spongodiscidae. It has been suggested (B. O'Connor pers. comm., 1996) that this notch is homologous with the pylom in other genera such as *Spongopyle* (see below).

Range: Early Cretaceous to Late Paleocene (revised herein).

***Orbiculiforma renillaeformis* s.s.** (Campbell & Clark), (Plate 9, Figures 4-7)

Spongodiscus renillaeformis Campbell & Clark (*part.*), 1944a, p. 18, pl. 6, fig. 5, 6 (*non* fig. 8, 10).
Orbiculiforma renillaeformis (Campbell & Clark). Pessagno 1975, p. 1014, pl. 1, fig. 7. Pessagno 1976, p. 36, pl. 11, fig. 11. Hollis 1991, p. 86, pl. 7, fig. 1-3; 1993a, p. 324, pl. 1, fig. 17. Strong *et al.* 1995, p. 205, fig. 8B.

Diagnosis: Test circular in outline except for a V-shaped marginal notch. Meshwork relatively coarse throughout. Wide, depressed central area may be obscured by secondary meshwork. 3-bladed marginal spines usually restricted to either side of notch.

Remarks: Applied in the restricted sense of Pessagno (1975) to distinguish this Late Cretaceous zonal marker from several slightly different forms which are grouped together below.

Distribution: Southwest Pacific: RK9, few to rare (WO, WH, MD, MR, DSDP 275); RP1-RP4, very rare (WO, WH, CH); uRP5, isolated occurrence (TK). California, late Campanian to Maastrichtian.

Range: RK9 to RP4, Mh to eDt, late Campanian to Early Paleocene. Isolated occurrence in RP5 may be due to reworking.

***Orbiculiforma renillaeformis* s.l.** (Campbell & Clark) (Plate 9, Figures 1-3)

Spongodiscus renillaeformis Campbell & Clark (*part.*), 1944a, p. 18, pl. 6, fig. 8, 10 (*non* fig. 5, 6).
Spongodiscus cf. *renillaeformis* Campbell & Clark. Dumitrica 1973, p. 788, pl. 9, fig. 7.
Orbiculiforma australis Pessagno 1975, p. 1014, pl. 1, fig. 3,4.
Orbiculiforma campbellensis Pessagno 1975, p. 1014, pl. 1, fig. 5,6.
Orbiculiforma spp. aff. *O. renillaeformis* (Campbell & Clark). Hollis 1991, p. 86, pl. 7, fig. 4-10.

Description: Test circular to subtrapezoidal in outline, with a V- or U-shaped marginal notch. Central depression usually weakly developed, may be covered by secondary meshwork. Pores may be evenly fine across the test (e.g., *O. australis*) or coarser in the central area (e.g., *O. campbellensis*). Internally, meshwork may show concentric banding (e.g., Dumitrica 1973, pl. 9, fig. 7). When present, marginal spines are 3-bladed and variably arranged.

Remarks: This group accommodates a range of forms previously ascribed to *O. renillaeformis*, but excluded under the revised definition of Pessagno (1975). These forms may represent distinct species, or variation within a single species.

DISTRIBUTION: Southwest Pacific: RK9, few to rare (WO, WH, FX, MD, MR, DSDP 275); RP1-RP4, very rare (WO, DSDP 208); RP5, isolated occurrences (TK, DSDP 208). California, late Campanian to Maastrichtian.

SOUTHWEST PACIFIC RANGE: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene. Isolated occurrences in RP5 may be due to reworking.

Genus *SPONGODISCUS* Ehrenberg, emend. herein

Spongodiscus Ehrenberg 1854a, p. 237.

TYPE SPECIES: *Spongodiscus resurgens* Ehrenberg 1854a, p. 246; 1854b, pl. 35b, fig. 16 (SD Frizzell & Middour 1951, p. 26). Barbados, Eocene.

DIAGNOSIS: Spongy discoidal test with radial spines, if present, restricted to the marginal plane. Meshwork may be either in closely spaced concentric rings or irregular.

REMARKS: Excludes species with a marginal notch which are assigned here to *Orbiculiforma*. Forms ascribed to *S. communis* Clark & Campbell elsewhere (Hollis 1991, 1993a) are now thought to belong to more than one species, none of which appear a good match with either *S. communis* or the similar Eocene species *S. americanus* Kozlova.

RANGE: Mesozoic to Recent.

Spongodiscus alveatus (Sanfilippo & Riedel)
(Plate 10, Figures 4, 5)

Stylotrochus alveatus Sanfilippo & Riedel 1973, p. 525, pl. 13, fig. 4, 5; pl. 30, fig. 3, 4. Nishimura 1992, p. 329.
Spongodiscus spp. gp D., Hollis 1991 (*part.*), p. 88, p. 8, fig. 4, 5.

DESCRIPTION: Large discoidal test with four orthogonal slender cylindrical radial beams extending beyond the margin of the test as short conical spines. Internal meshwork arranged in distinct concentric layers. Peripheral meshwork dense with numerous marginal thorns. Loose outer meshwork of central area rarely preserved.

REMARKS: This species is transferred to *Spongodiscus* because it lacks the numerous spines requisite for inclusion in *Spongotrochus*, which is treated here as the senior synonym of *Stylotrochus* (i.e. *sens.* emend. Petrushevskaya 1975). See *Spongotrochus* below.

DISTRIBUTION AND RANGE: Southwest Pacific: RP4 to RP5, rare (WO); eDt, Early Paleocene. Tropical and North Atlantic, Late Paleocene.

Spongodiscus rhabdostylus (Ehrenberg)
(Plate 10, Figures 6-8)

Spongosphaera rhabdostylus Ehrenberg 1873, p. 256; 1875, pl. 26, fig. 1.
Spongodiscus rhabdostylus (Ehrenberg). Sanfilippo & Riedel 1973, p. 525, pl. 13, fig. 1-3; pl. 30, fig. 1, 2. Nishimura 1987, p. 728.
Spongodiscus spp. gp D., Hollis 1991 (*part.*), p. 88, pl. 8, fig. 2, 3.
Spongotripus spp., Hollis 1991 (*part.*), p. 89.

DESCRIPTION: Spongy lenticular test with circular outline; four sturdy conical radial spines, rarely three or five spines. Meshwork relatively coarse, lacks concentric layering.

REMARKS: Three-spined variants distinguished from *Spongotripus* spp. by circular outline.

DISTRIBUTION: Southwest Pacific: RK9, very rare (WO, MR); RP1-RP5, very rare (WO). Tropical Atlantic, Middle Eocene; North Atlantic, Late Paleocene.

SOUTHWEST PACIFIC RANGE: RK9 to lower RP5, Mh to eDt, late Campanian-Maastrichtian to Late Paleocene.

Genus *SPONGOPYLE* Dreyer

Spongopyle Dreyer 1889

TYPE SPECIES: *Spongopyle setosa* Dreyer 1889, p. 43, pl. 6, fig. 97, 98 (SD Campbell 1954, p. D94). South Indian Ocean, Recent.

DIAGNOSIS: Spongy discoidal to biconvex test with well-developed pylom.

RANGE: Late Cretaceous to Recent.

Spongopyle* cf. *insolita Kozlova
(Plate 10, Figure 9)

cf. *Spongopyle insolita* Kozlova & Gorbovetz 1966, p. 91, pl. 4, fig. 11a, b. Nishimura 1992, p. 329.

DESCRIPTION: Small inflated disk with broad conical pylom which comprises at least half the test. Spongy meshwork of disc arranged in 5-7 concentric layers. Close-spaced circular pores cover surface of disk and walls of pylom.

REMARKS: Distinction from similar Cretaceous and later Paleocene morphotypes recorded elsewhere uncertain.

DISTRIBUTION AND RANGE: Southwest Pacific: upper RP4, very rare (WO), eDt, Early Paleocene. *S. insolita* was described from the Late Cretaceous of Russia, and has subsequently been reported from the Late Paleocene of the North Atlantic.

Genus *SPONGOTRIPUS* Haeckel

Spongotripus Haeckel 1881, p. 461; 1887, p. 580.

Type species: *Spongotripus regularis* Haeckel 1887, p. 580, not figured (*fide* Campbell 1954, p. D94). Central Pacific, Recent.

Diagnosis: Spongy discoidal test with triangular or trilobate outline and three radial spines in marginal plane. Surface lacks interlocking triangular pore-frames of the Pseudoaulophacidae (Riedel 1967b).

Range: Late Cretaceous to Recent.

***Spongotripus* spp.**
(Plate 9, Figure 8-10)

Spongotripus spp. Hollis 1991 (*part.*), p. 89, pl. 6, fig. 9-11.

Remarks: Included here are at least 3 forms which vary in outline (straight-edged, rounded, or trilobate) and shape of spines (bladed or conical). Preservation is usually too poor to allow consistent identification.

Distribution: Southwest Pacific: RK9, very rare (WO, WH); RP1-4, very rare, sporadic (WO, FX).

Range: RK9 to RP4, lMh to eDt, Maastrichtian to Early Paleocene.

Genus *SPONGOTROCHUS* Haeckel

Spongotrochus Haeckel 1860, p. 844; 1887, p. 585. Emend. Petrushevskaya 1975, p. 574.
Stylotrochus Haeckel 1862, p. 464; 1887, p. 583. Sanfilippo & Riedel 1973, p. 525 (*non* Campbell 1954, p. 94).

Type species: *Spongotrochus brevispinus* Haeckel 1860, p. 844; 1862, p. 462, pl. 27, fig. 4, 5 (*fide* Campbell 1954, p. D94). Cosmopolitan, Recent.

Diagnosis: Spongy discoidal test with numerous radial spines concentrated in, but not restricted to, the marginal plane. Meshwork irregular, never arranged in concentric rings, and usually with a central thickened mass. Test may be covered by a porous gown or sieve plate.

Remarks: Species in which all spines are located in the marginal plane (as in *Stylotrochus*) are included in the genus under Petrushevskaya's (1975) emendation. Petrushevskaya also noted that Campbell (1954) was mistaken in treating *Stylotrochus* as a junior synonym of *Stylospongia*. *Stylospongia* Haeckel (1862, p. 473) was erected as subgenus of *Stylotrochus*. Both *Stylospongia* and a subgenus of *Spongotrochus*, *Stylospongidium* Haeckel (1881, p. 460) are characterised by concentric or spiral inner layering and are not at this stage included within *Spongotrochus*. Species with a circular outline, few radial spines and closely-spaced or no internal layering are treated under *Spongodiscus* here (i.e. *Spongodiscus alveatus* and *S. rhabdostylus*).

Range: Late Mesozoic to Recent.

Spongotrochus antiquus (Campbell)
(Plate 9, Figures 11-14)

Stylotrochus antiquus Campbell & Clark 1944a, p. 19, pl. 4, fig. 8, 12.
Spongotrochus spp., Hollis 1991 (*part.*), p. 89, pl. 7, 13-16.

Description: Medium-sized, flattened to biconvex discoidal test with circular outline and numerous radial spines more-or-less symmetrically placed around margin. Occasional spines outside marginal plane. Diameter = 150-205 μm.

Distribution: Southwest Pacific: RK9, rare to few (WO, WH, FX); RP1-RP3, few to common (WO, WH, FX). Californian, late Campanian.

Southwest Pacific range: RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Spongotrochus* cf. *polygonatus (Campbell)
(Plate 9, Figures 15-17)

cf. *Stylotrochus polygonatus* Campbell & Clark 1944a, p. 19, pl. 5, fig. 2, 10, 11.
Spongotrochus spp., Hollis 1991 (*part.*), p. 89.

Description: Large flattened polygonal test with regular hexagonal to octagonal outline. Strong three-bladed radial spines at corners, with triangular spongy bases in some specimens producing a stellate outline.

Remarks: An average of eight spines and a tendency to develop a stellate outline distinguish this form from *S. polygonatus*, which has six spines and a hexagonal outline.

Distribution: RK9, very rare (WO, WH); RP2-3, very rare (WO). *S. polygonatus* was described from the late Campanian of California.

Range: RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Spongotrochus* aff. *glacialis Popofsky
(Plate 9, Figure 18, 19)

aff. *Spongotrochus glacialis* Popofsky 1908, p. 228, pl. 27, fig. 2. Riedel 1958, p. 227, pl. 2, fig. 1, 2. Petrushevskaya 1975, p. 575, pl. 5, fig. 8; pl. 35, fig. 1-6. Nakaseko & Nishimura 1982, p. 105, pl. 29, fig. 1-3; pl. 30, fig. 1, 2; pl. 31, fig. 1, 2; pl. 34, fig. 1-3, pl. 35, fig. 1-3; pl. 60, fig. 5.
Spongotrochus spp., Hollis 1991 (*part.*), p. 89.

DESCRIPTION: Large lenticular test composed of a loose spongy meshwork. Numerous short, sturdy, triangular spines distributed around the margin. Surface roughened by numerous thorns arising from junctions between pore frames (sepaloid points); rarely covered by a gown. Diameter = 200-250 µm.

REMARKS: Differs from *Spongotrochus glacialis* by usually lacking a gown, and having more numerous radial spines.

DISTRIBUTION AND RANGE: RP1 to RP4, few to rare (WO); eDt, Early Paleocene. Grouped with *Spongotrochus* spp. in other Marlborough sections.

Family PORODISCIDAE Haeckel 1881, emend. Kozlova in Petrushevskaya & Kozlova 1972

DIAGNOSIS: Flattened discoidal test composed of one layer of chambers. Small central chamber is surrounded by concentric or spiral latticed bands which may be divided into sectors with radial boundaries (usually four). Radial spines may be present.

REMARKS: Porodiscids with numerous, closely spaced concentric bands are often difficult to distinguish from concentrically banded spongodiscids, and some workers (e.g., Riedel 1967b; Sanfilippo & Riedel 1973) include members of the family within the Spongodiscidae. Petrushevskaya (1975) placed a group of distinctive porodiscid genera in the Stylodictyidae (Haeckel 1881); the remainder being allocated to the Spongodiscidae. This fails to account for taxa which do not have the radial beams of the Stylodictyidae but otherwise have more affinities with that family than they do with spongodiscids. As these taxa occur in small numbers in this study, Porodiscidae (*sensu* Petrushevskaya & Kozlova 1972) is retained here as the senior synonym of Stylodictyidae.

Genus *FLUSTRELLA* Ehrenberg

Flustrella Ehrenberg 1838, p. 132. Campbell 1954, p. D89.
Porodiscus Haeckel 1881, p. 459; 1887, p. 491. Emend Kozlova in Petrushevskaya & Kozlova 1972, p. 525.

TYPE SPECIES: *Flustrella concentrica* Ehrenberg 1838, p. 132; 1854b, pl. 19, fig. 61; pl. 20, fig. 42; 1875, p. 72, pl. 22, fig. 13 (by monotypy). Barbados, Eocene.

DIAGNOSIS: Flattened discoidal test consists of a single layer of chambers arranged in concentric rings or a spiral. Spines absent or indistinct.

употреблено в понимании

REMARKS: Applied in the sense of Kozlova's emendation of *Porodiscus*. In erecting *Porodiscus*, Haeckel (1881) appeared to ignore the seniority of *Flustrella*. Deflandre (1960, p. 218) made a case for conserving *Porodiscus* because *Flustrella* has been used for a bryozoan genus for over a century.

RANGE: Early Cretaceous to Recent.

Flustrella cretacea (Campbell & Clark)
(Plate 10, Figure 10)

Porodiscus (Trematodiscus) cretaceus Campbell & Clark 1944a, p. 15, pl. 6, fig. 7.
Porodiscidae gen. *et* spp. indet., Hollis 1991 (*part.*), p. 92.
? *Trematodiscus orbiculatus* Stöhr 1880, p. 108. Haeckel 1862, p. 492, pl. 29, fig. 1.
? *Porodiscus orbiculatus* (Stöhr). Haeckel 1887, p. 492.

DESCRIPTION: Small flattened discoidal test consisting of one layer of chambers arranged in 8-10 concentric rings of regular breadth. Two (rarely three) rows of subcircular pores on each ring. No radial spines.

REMARKS: As noted by Campbell & Clark, this species is similar to Stöhr's Paleogene-Recent species which apparently differs only by having slightly more rows of pores on each ring (2-2.5 according to Haeckel 1887).

DISTRIBUTION: Southwest Pacific: RK9-RP3, very rare (WO). Grouped with "Porodiscidae indet." in other Marlborough sections and DSDP 208. California, late Campanian; possibly Germany, Late Cretaceous.

SOUTHWEST PACIFIC RANGE: RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Flustrella ruesti (Campbell & Clark)
(Plate 10, Figure 11)

Porodiscus (Discospira) rüsti Campbell & Clark 1944a, p. 16, pl. 5, fig. 5.
Porodiscidae gen. *et* spp. indet., Hollis 1991 (*part.*), p. 92.

DESCRIPTION: Small flattened discoidal test consisting of one layer of chambers arranged in a spiral of 6-8 whorls of regular breadth. 1-1.5 rows of subelliptical pores on each ring. No radial spines.

REMARKS: Tertiary-to-Recent *F. helicoides* (Haeckel) differs only by having more rows of pores (2) on the breadth of each ring.

DISTRIBUTION: Southwest Pacific: RK9-RP3, very rare (WO). Grouped with "Porodiscidae indet." in other Marlborough sections and DSDP 208. California, late Campanian.

SOUTHWEST PACIFIC RANGE.: RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Genus *STYLODICTYA* Ehrenberg

Stylodictya Ehrenberg 1847, p. 54 (*part.*). Haeckel 1887, p. 509 (*part.*). Emend. Kozlova in Petrushevskaya & Kozlova 1972, p. 525;

Staurodictya Haeckel 1881, p. 460 (*part.*); 1887, p. 506 (*part.*).

TYPE SPECIES: *Stylodictya gracilis* Ehrenberg 1854b, pl. 36, fig. 28 (*fide* Campbell 1954, p. D92). Barbados, Eocene.

DIAGNOSIS: Discoidal test with circular outline and four or more radial beams which continue externally as radial spines. Single layer of chambers arranged in annular bands not offset or overlapping across radial beams. Inner bands, at least, usually curve inwards where they cross beams (i.e. are scalloped) which otherwise may be poorly delineated.

RANGE: Paleocene to Recent (revised herein).

Stylodictya* cf. *sexispinata Clark &Campbell
(Plate 11, Figure 11)

cf. *Stylodictya sexispinata* Clark & Campbell 1942, p. 45, pl. 3, fig. 7.
Stylodictya spp. Hollis 1991 (*part.*), p. 92.

DESCRIPTION: Biconvex lenticular test with circular to polygonal outline. 6-8 beams extend as 3-bladed radial spines. Single layer of chambers arranged in 4-6 concentric bands which increase in breadth towards periphery; outer bands twice breadth of inner ones. Pores subcircular, even-sized, and regularly distributed over central 2-3 bands, becoming irregular in shape and size over outer bands.

REMARKS: Eocene *S. sexispinata* is distinguished by a constant number of six radial spines, a strongly hexagonal outline, and even-sized circular pores over the entire surface.

DISTRIBUTION AND RANGE: uRP3 to lRP5, very rare (WO); eDt, Early to Late Paleocene.

Genus *THOLODISCUS* Kozlova

Tholodiscus Kozlova in Petrushevskaya & Kozlova 1972, p. 525.
Staurodictya Haeckel 1881, p. 460 (*part.*). Emend. Kozlova & Gorbovetz 1966, p. 79. Foreman 1968, p. 14.
Xiphospira Haeckel. Petrushevskaya 1975, p. 576.

TYPE SPECIES: *Stylodictya ocellata* Ehrenberg 1875, p. 84, pl. 23, fig. 7 (OD). Barbados, Eocene.

DIAGNOSIS: Discoidal test with rounded polygonal, usually quadrangular, outline. Bands are either offset at quadrant boundaries to form a loosely polygonal spiral or overlap to form a zig-zag boundary line. Four radial spines extend from quadrant boundaries.

REMARKS: This definition follows Kozlova by excluding species with strictly annular concentric bands which are assigned to *Stylodictya*. *Tholodiscus* is preferred to *Staurodictya* because the type species of the latter, *S. beneckei* Rüst (1885, pl. 32, fig. 1), does not appear to have the diagnostic chamber arrangement observed in *Tholodiscus ocellatus*. Petrushevskaya's (1975) usage of *Xiphospira* for this four-spined taxon is not accepted. Although it also possesses overlapping bands, *Xiphospira* Haeckel is, by definition, restricted to two-spined species.

RANGE: Late Cretaceous to Recent.

Tholodiscus densus (Kozlova)
(Plate 11, Figures 1-3)

Staurodictya? *densa* Kozlova & Gorbovetz 1966, p. 79, pl. 13, fig. 1, 2.
Staurodictya? sp., Kozlova & Gorbovetz 1966, pl. 4, fig. 2.
Spongodiscus spp. gp D, Hollis 1991 (*part.*), p. 88, pl. 8, fig. 1(?), 6.

DESCRIPTION: Inflated lenticular test with rhomboid outline and four slender bladed spines at apices. Spines extend from internal radial beams. Internal chambers arranged in a rhomboidal spiral of 6-8 whorls; offsets at junctions with radial beams indistinct. Surface roughened by raised nodes at junctions between pore frames; pores circular, closely spaced.

REMARKS: A similar Late Cretaceous species *T. fresnoensis* (Foreman) (= ? *Staurodictya bipolaris* Campbell & Clark 1944a, p. 44, pl. 2, fig. 7) is distinguished by a more compressed, delicate test. The Late Cretaceous specimen illustrated by Kozlova & Gorbovetz (1966, pl. 4, fig. 2) is within the range accepted for *T. densus* here.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, MR, DSDP 275); RP1-RP5, very rare (WO, WH, FX). Russia, Late Cretaceous and Eocene.
SOUTHWEST PACIFIC RANGE: RK9 to RP5, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Tholodiscus* cf. *ocellatus (Ehrenberg)
(Plate 11, Figures 4-8)

Tholodiscus splendens (Ehrenberg). Petrushevskaya & Kozlova 1972, pl., 18, fig. 5.
Tholodiscus spp., Hollis 1991, p. 91 (*part.*), pl. 8, fig. 7-9.
cf. *Stylodictya ocellata* Ehrenberg 1875, pl. 23, fig. 7.
cf. *Staurodictya ocellata* (Ehrenberg). Haeckel 1887, p. 508.
cf. *Tholodiscus ocellatus* (Ehrenberg). Petrushevskaya & Kozlova 1972, p. 525, pl. 18, fig. 1, 2.
? *Staurodictya rotulata* Campbell & Clark 1944a, p. 16, pl. 6, fig. 9.

DESCRIPTION: Flattened discoidal test with circular to subquadrangular outline and four radial spines. First chamber diamond-shaped to circular, with four radial beams projecting from apices to divide test into four sectors. Subsequent chambers arranged in cupola-shaped bands, indented and slightly offset at sector boundaries to form a lobulate spiral of up to seven whorls which increase in breadth towards periphery; fifth whorl approximately twice breadth of first. Pores circular, two rows on each ring. Beams project from margin of test as thin, cylindrical spines.

REMARKS: *T. ocellatus* is distinguished by fewer whorls (4-5) and somewhat smaller size (diameter of four whorls = 100 µm). A similar form referred to *T. splendens* by Petrushevskaya & Kozlova differs from that species by having whorls that increase in breadth towards the periphery. Late Cretaceous *Staurodictya rotulata* as described by Campbell & Clark (1944a) is distinguished by the presence of 8-10 radial beams within each quadrant, and strictly annular chambers. However pore arrangement in the illustrated specimen indicates that bands are offset where they cross the primary radial beams, suggesting a close relationship to the species described here.

DISTRIBUTION: Southwest Pacific: RK9-RP5, very rare to rare (WO, WH, CH, FX, MD, DSDP 275 & 208). *T. ocellatus* was described from the Oligocene of Barbados.

RANGE: RK9 to RP6, Mh to lDt, late Campanian-Maastrichtian to Late Paleocene.

Tholodiscus* cf. *targaeformis (Clark & Campbell)
(Plate 11, Figures 9-10)

Stylodictya spp., Hollis 1991, p. 92 (*part.*), pl. 8, fig. 10, 11.
cf. *Staurodictya targaeformis* Clark & Campbell 1942, p. 43, pl. 3, fig. 6.

beams as spines

DESCRIPTION: Discoidal test with circular outline. Four cylindrical beams extending from margin as slender conical radial spines. Single layer of chambers arranged in 8-15 concentric rings slightly offset across radial beams. Rings increase in width towards periphery. Pores circular, 2-3 on breadth of a ring, and increasing in size towards periphery. Margin of disc thickened, bearing numerous short thorns.

REMARKS: This species resembles *T.* cf. *ocellata*, being distinguished by the greater number of bands, and a circular outline. Eocene *Stylodictya targaeformis* is distinguished by having only seven bands with no observed offset across radial beams.

DISTRIBUTION: Southwest Pacific: RP4-RP5, very rare to rare (WO, MD, DSDP 208). *S. targaeformis* was described from the Eocene of California.

RANGE: RP4 to uRP5, eDt to lDt, Early to Late Paleocene.

Order NASSELLARIA Ehrenberg 1875

Family PLAGIACANTHIDAE Hertwig

Plagiacanthiden Hertwig 1879, p. 72.
Plagoniidae Haeckel, emend. Riedel 1967b, p. 295.
Plagiacanthidae Hertwig, emend. Petrushevskaya 1971a, p. 988; 1971b, p. 57.

DIAGNOSIS: Test of two segments. Large cephalis and usually reduced thorax. Cephalis has eucephalic and antecephalic lobes separated by arches between apical and primary lateral bars; arches may have external expression as ribs or furrows; apical spine may form a central columella.

Subfamily LOPHOPHAENINAE Haeckel.

Lophophaenida Haeckel 1881, p. 430.
Lophophaeninae Haeckel, emend. Petrushevskaya 1971a, p. 989.

DIAGNOSIS: Test of two segments. Large cephalis has a large eucephalic lobe and smaller antecephalic lobe; apical bar forms a central columella; apical, dorsal and primary lateral bars form horns or spines.

Genus *LITHOMELISSA* Ehrenberg

Lithomelissa Ehrenberg 1847, p. 54.

TYPE SPECIES: *Lithomelissa microptera* Ehrenberg 1854, pl. 36, fig. 2. (by subsequent monotypy). Barbados, Miocene (Eocene?).

DIAGNOSIS: Test of two segments. Large cephalis with well-developed eucephalic lobe and small antecephalic lobe; apical bar forms spine or horns; dorsal and primary lateral bars project obliquely down through thorax to form three lateral spines or wings.

RANGE: Late Cretaceous to Recent.

Lithomelissa* cf. *heros Campbell & Clark
(Plate 12, Figures 9-11)

Lithomelissa? sp., Dumitrica 1973, p. 788, pl. 2, fig. 2; pl. 4, fig. 6.
cf. *Lithomelissa heros* Campbell & Clark 1944a, p. 25, pl. 7, fig. 23;
cf. *Lithomelissa*? *heros* Campbell & Clark. Foreman 1968, p. 25, pl. 3, fig. 5 a-b; text-fig. 1, fig. 7; 1978, p. 749, pl. 15, fig. 14.
cf. *Bisphaerocephalina*? *heros* (Campbell & Clark). Pessagno 1976, p. 54, pl. 13, fig. 11; Yamasaki 1987, pl. 2, fig. 2.
Lithomelissa? cf. *heros* Campbell & Clark. Hollis 1991, p. 93, pl. 9, fig. 1-4. Strong *et al.* 1995, p. 205.

DESCRIPTION: Small fusiform test of two segments. Large hemispherical cephalis with large eucephalic lobe and slightly smaller antecephalic lobe; apical bar forms a central columella that extends upward as a strong apical horn; dorsal and primary lateral bars project into thorax but do not usually form external spines; weak lateral spines are rarely observed. Wall of cephalis imperforate. Externally collar stricture marked by a slight change in contour. Thorax inflated in proximal or medial part, narrows distally; wall sparsely perforate.

REMARKS: Very similar in general form and cephalic structure to *L. heros*, differing only by lack of well-developed lateral spines. Previous uncertainty over generic allocation of *L. heros* relates to inadequacies of the type species that Campbell (1954) indicated for *Lithomelissa,—L. tartari* Ehrenberg (1854, p. 245). Although having page priority, this unfigured and poorly described species was only doubtfully ascribed to *Lithomelissa* by Ehrenberg.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, FX, MD, DSDP 275 & 208); RP1-4, rare to very rare (WO, WH, CH, FX, MD, DSDP 208); RP5, isolated occurrences (MD, DSDP 208). *L. heros* is widely distributed from Santonian to Maastrichtian elsewhere, and ranges into possible Paleocene in California.

SOUTHWEST PACIFIC RANGE: RK9 to RP4, lMh to eDt, late Campanian-Maastrichtian to Early Paleocene. Isolated occurrences in RP5 may be due to reworking.

Lithomelissa* cf. *gelasinus O'Connor
(Plate 12, Figures 13-14)

cf. *Lithomelissa* aff. *sphaerocephalis* Chen. O'Connor 1993, p. 60, pl. 6, fig. 1.
cf. *Lithomelissa gelasinus* O'Connor in press, p. 24, pl. 2, fig. 3-6, pl. 6, fig. 6-9.

DESCRIPTION: Small bullet-shaped test. Cephalis spheroidal with weak apical horn; dorsal and primary lateral bars project obliquely downward to form three weak spines in the proximal part of the thorax. Wall of cephalis perforate with regularly arranged pores. Distinct collar stricture. Thorax subcylindrical, slightly inflated medially, with closely spaced, irregularly arranged, circular pores.

DIMENSIONS: (three specimens): total length (without horn) = 98-110 µm, maximum width = 66-71 µm; cephalis width = 54-56 µm.

REMARKS: Distinguished from Oligocene *L. gelasinus* by a perforate cephalis and very weak apical horn; from Eocene *L. sphaerocephalis* Chen by the same features and its subcylindrical thorax which lacks a spongy covering.

SOUTHWEST PACIFIC DISTRIBUTION AND RANGE: RP4, very rare (WO); eDt, Early Paleocene.

***Lithomelissa? aitai* n.sp.**
(Plate 12, Figures 5-8)

aff. *Lophophaena? polycyrtis* (Campbell & Clark). Foreman 1968, p. 23, pl. 3, fig. 3a-c.
Ceratocyrtis? volubilis Petrushevskaya 1977 (*part.*), p. 11, pl. 1, fig. b (not fig. a,v).
Plagiacanthidae? gen. *et* spp. indet., Hollis 1991 *(part.)*, p. 95, pl. 9-12.

DESCRIPTION: Conical test of two segments. Cephalis hemispherical, moderately large, with closely-spaced circular pores; large eucephalic lobe and smaller antecephalic lobe; apical bar projects outside as a sturdy conical apical horn, rarely surrounded by cluster of much smaller spines; dorsal and primary lateral spines project into thorax, rarely extend outside proximal thorax as weak downward-directed spines. Thorax conical proximally, subcylindrical to slightly flared distally. Pores of cephalis circular, regularly arranged. Pores of thorax circular to irregularly lobate, loosely quincuncially or irregularly arranged in low frames.

DIMENSIONS: (range of 12 specimens [mean]): total length (without horn) = 123-285 µm [183]; maximum width = 74-160 µm [104]; apical horn length = 12-40 µm [20]; cephalis length = 16-35 µm [21], width = 29-50 µm [38].

REMARKS: *L.? polycyrtis* is similar in general form and structure of cephalis, but differs by having a cluster of spines of similar size in the apical area rather than a primary central apical horn, and a less regular, more spinose thorax. Both species are more properly referred to *Lithomelissa* than *Lophophaena* (*sens.* emend. Petrushevskaya 1971b, p. 105) because they have an apical bar which is a free central column rather than being embedded in the cephalic wall, as well as a moderately large antecephalic lobe. The holotype of *Ceratocyrtis? volubilis*, which was described from DSDP Site 275 (275-1, CC), and a second specimen figured by Petrushevskaya (1977, pl. 1, fig. v, a) closely resemble *L.? polycyrtis* with a cluster of apical spines and a relatively short thorax. However a third specimen (*ibid.* pl. 1, fig. b) conforms with *L.? aitai*. Similar forms which lack the single prominent apical spine of *L? aitai* are doubtfully referred to *L? polycyrtis* (Pl. 12, Fig. 4, 12).

HOLOTYPE AND TYPE LOCALITY: R98 (Pl. 12, Fig. 5); P30/f368 (WO56), RP1, Mead Hill Formation, Woodside Creek.

ETYMOLOGY: Named after radiolarian researcher Dr Yoshiaki Aita who first recognised the significance of abundant radiolarians in the K-T boundary sections of Marlborough.

DISTRIBUTION: Southwest Pacific: RK9-RP3, few to rare (WO, WH, CH, FX, MD, Mara, DSDP 275 & 208); RP4, very rare (WO, DSDP 208); uncertain record in uRP5 (TK). Beyond NE Marlborough *L? polycyrtis* occurs in RK9 (Mara, DSDP 275 & 208), RP1-3 (MD), while similar forms occur in RP1-3 at Woodside Creek (Pl. 12, Fig. 4, 12) and in uRP5 at Tioriori, Chatham Islands.

RANGE: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Lithomelissa? hoplites Foreman
(Plate 12, Figures 1-3)

Lithomelissa? hoplites Foreman 1968, p. 26, pl. 3, fig. 2a-c; 1977, pl. 1, fig. 7; 1978, p. 749, pl. 5, fig. 9. Hollis 1991, p. 94, pl. 9, fig. 5-8; 1993a, p. 324, pl. 1, fig. 14. Strong *et al.* 1995, p. 205, fig. 8D.
Tripodiscium? sp. aff. *Lithomelissa hoplites* Foreman. Petrushevskaya & Kozlova 1972, p. 534, pl. 7, fig. 2.
Lithomelissa sp., Pessagno 1975, p. 1017, pl. 5, fig. 8.
Bisphaerocephalina? sp. A, Iwata & Tajika 1986, pl. 4, figs 1, 2.

DESCRIPTION: Large fusiform test of two segments. Relatively small hemispherical cephalis with large eucephalic lobe and reduced antecephalic lobe; apical bar extends vertically to form a sturdy apical horn; small upward-directed tube extends from vertical bar; connection between dorsal and lateral bars and thoracic wings uncertain. Indistinct collar stricture. Thorax proximally pyramidal, triangular in transverse section, with three sturdy wings extending from apices; distally subcylindrical, somewhat irregular, narrowing basally. Cephalis imperforate, surface covered with small papillae. Thoracic pores circular, within loosely quincuncially or irregularly arranged frames; surface of thorax may be smooth or roughened.

REMARKS: Only provisionally retained in *Lithomelissa*. Distinguished from other members of the genus by presence of a vertical tube, lack of a clear connection between cephalic elements and thoracic wings, and a distinctive irregularly tapering thorax.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, WH, FX, MD, DSDP 275 & 208); RP1-3, rare to very rare (WO, WH, CH, FX). California and tropical Atlantic, late Campanian to Maastrichtian; Hokkaido, Early Paleocene.

SOUTHWEST PACIFIC RANGE: RK9 to RP3, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Family ARTOSTROBIIDAE Riedel

Artostrobiidae Riedel 1967a, p. 149. Emend Foreman 1973a, p. 431.

DIAGNOSIS: Cephalis with well-developed vertical tube. Pores of at least one major segment arranged in transverse rows. The term "vertical tube" refers to a tubular structure extending from the "vertical bar" (Foreman 1973a), but neither tube nor bar are usually oriented vertically.

REMARKS: With the exception of *Theocampe* (discussed below), the revised generic definitions of Nigrini (1977) are followed here. In her review of mainly Tertiary members of the family, Nigrini did not address the close relationships between several Cretaceous and Tertiary species. Possible relationships are discussed below.

Genus *ARTOSTROBUS* Haeckel

Artostrobus Haeckel 1887, p. 1481. Campbell 1954, p. D140. Petrushevskaya 1971b, p. 212; 1975, p. 578.

TYPE SPECIES: *Cornutella annulata* Bailey 1856, p. 3, pl. 1. fig. 5a-b (SD Campbell 1954). Pacific, Quaternary.

DIAGNOSIS: Slender, subcylindrical test of two segments. Small spheroidal cephalis, sparsely perforate. Thorax narrowly subcylindrical to fusiform, with pores arranged in widely spaced transverse rows.

REMARKS: Although lacking a distinct vertical tube, this genus is provisionally retained in Artostrobiidae because of other similarities with *Theocampe* and *Siphocampe* (see Petrushevskaya 1975, p. 578).

RANGE: Late Cretaceous to Recent.

Artostrobus pusillus (Ehrenberg)
(Plate 13, Figures 6, 7)

Eucyrtidium pusillum Ehrenberg 1873, p. 232; 1873, pl. 11, fig. 6.
Artostrobus pusillum (Ehrenberg). Petrushevskaya 1975, p. 578, pl. 26, fig. 1, 2.
cf. *Artostrobus* sp. Cr., Petrushevskaya 1975, p. 578, pl. 10, fig. 1.
cf. *Cyrtocalpis* aff. *operosa* Tan Sin Hok. Foreman 1978, p. 746, pl. 5, fig. 6. Ling 1991, p. 318, pl. 1, fig. 10.
Artostrobus sp. Ling & Lazarus 1990, p. 355, pl. 3, fig. 14.
Archicorys sp. Ling 1991, p. 318, pl. 1, fig. 11.
Artostrobiidae gen. *et* spp. indet. Hollis 1991, p. 102.

DESCRIPTION: Small slender test of two segments. Small spheroidal imperforate cephalis with weak apical spine; internal features indistinct, but in some specimens an axial spine projects into thorax from junction of median and vertical bars (Pl. 13, Fig. 6a; see also Petrushevskaya 1975, pl. 26, fig. 1). Thorax elongate with regularly spaced constrictions in the inner wall. Proximal constriction forms a ovate cavity resembling a thorax, but there is no true segmentation. Pores of thorax small, circular arranged in 5-10 somewhat irregular widely spaced transverse rows.

Dimensions: (two specimens): total length = 110-118 µm; maximum width = 49-51 µm; cephalis length = 12-17 µm, width = 20-25 µm.

Remarks: Distinguished from a purported Cretaceous ancestor (*Artostrobus* sp. Cr. of Petrushevskaya; = *Cyrtocalpis* aff. *operosa* of others) by having fewer, more widely distributed pores. Resembles type species and purported Neogene descendent *A. annulus* (Petrushevskaya 1975) in pore arrangement but differs by lacking a "pedestal" between cephalis and thorax. A possibly conspecific Eocene form ascribed by Petrushevskaya (1975, pl. 26, fig. 3) to *Theocampe* aff. *minuta* Clark and Campbell appears to have a well-developed axial spine, and the only superficial difference from *A. pusilla* is the lack of an apical spine.

Distribution: Southwest Pacific: RK9-RP1, rare to very rare (WO, WH, CH, FX, MD, DSDP 275 & 208); RP2-3, rare to few (WO, WH, CH, FX, DSDP 208); RP4-RP5, very rare (WO, DSDP 208). South Pacific, Oligocene. Tropical Atlantic, Paleocene to Oligocene. South Atlantic, Late Campanian-Maastrichtian. *Artostrobus* sp. Cr. occurs in the Maastrichtian at DSDP Site 208.

Southwest Pacific range: RK9 to *Dorcadospyris ateuchus* Zone, lMh to Lwh-Ld, late Campanian-Maastrichtian to Oligocene.

Genus *BOTRYOSTROBUS* Haeckel

Botryostrobus Haeckel 1887, p. 1475. Emend. Nigrini 1977, p. 243.

Artostrobus (Artostrobium) Haeckel 1887, p. 1482. Type species = *Lithocampe aurita* Ehrenberg 1844, p. 44; 1854, pl. 22, fig. 25 (SD Campbell 1954, p. 140).

Artostrobium Haeckel, emend. Foreman 1966, p. 355.

Type species: *Lithostrobus botryocyrtis* Haeckel 1887, p. 1475, pl. 79, fig. 18, 19 (SD Campbell 1954, p. D141). Pacific, Quaternary.

Diagnosis: Slender fusiform to conical test of at least four segments. Cephalis bears apical spine and cylindrical vertical tube. Post-thoracic segments separated by rounded constrictions, with 2-8 transverse rows of pores.

Remarks: Under Nigrini's emended definition of the genus, *Botryostrobus* becomes the senior synonym of *Artostrobium*, and consequently the type genus of the Artostrobiidae.

Range: Late Cretaceous to Recent. Late Cretaceous species from Cuba were noted by Foreman (1966).

***Botryostrobus*? *parsonsae* n.sp.**

(Plate 13, Figures 13-15, 16?)

Botryostrobus? sp. A, Hollis 1991, p. 102, pl. 10, fig. 11-15.

Description: Narrowly conical test of five medially-inflated segments, very rarely six segments. Ovate cephalis with very small apical horn and lateral-directed vertical tube; external expression of vertical tube is usually a large pore on the side of the cephalis, but in well-preserved specimens a tubular structure extends down from the area of the pore to the third or fourth segment, following the contour of the test. Surface of cephalis otherwise imperforate and dimpled. Thorax, hemispherical, imperforate or sparsely perforate; surface simply dimpled or with four rows of occluded pores, quincuncially arranged in regular hexagonal frames. Single row of open pores at collar and lumbar strictures. Abdomen and subsequent segments medially inflated, separated by rounded constrictions, and increase regularly in size. Pores on these segments usually occluded, occasional patches of small, circular open pores; quincuncially arranged in 4-8 rows, set in regular hexagonal frames; 7-10 rows on final segment. Constrictions between post-thoracic segments have 2-3 transverse rows of open, unframed pores. Final segment terminates with 1-2 rows of open pores, framed or unframed, above slightly constricted, thickened peristome.

Dimensions: (range of 10 specimens [mean]): length of five segments = 213-262 µm [237]; cephalis length = 20-25 µm [21], width = 23-27 µm [24]; thorax length = 23-33 µm [27], width = 39-50 µm [43]; abdomen length = 36-44 µm [41], width = 54-65 µm [59]; fourth segment length = 53-65 µm [55], width = 73-87 µm [79]; fifth segment length = 78-95 µm [87], width = 91-105 µm [97]; sixth segment length, width = 86, 96 µm (one specimen); number of pore rows on thorax = 4, on abdomen = 4-6 [5], on fourth segment = 5-8 [6], on fifth segment = 7-10 [8].

Remarks: This species is doubtfully included in *Botryostrobus* because it differs from all other members of the genus by having a relatively small cephalis, several rows of pores in constrictions between segments, and no segment in which all pores, occluded and open, are in well-defined transverse-rows. A possible rare variant of this species (Pl. 13, Fig. 16) has a similar overall shape but lacks pore-frames on thorax and subsequent segments. P. Dumitrica (pers. comm. 1996) suggests that this form may be a species of *Solenotryma* Foreman.

Holotype and type locality: R97 (Pl. 13, Fig. 13); P30/f368 (WO56), RP4, Lower Paleocene, Mead Hill Formation, Woodside Creek.

Etymology: Named after Margaret Parsons who, with husband David, is past owner of Ben More Station which includes the Woodside Creek type locality, in appreciation of her many years of hospitality to visiting geologists.

DISTRIBUTION: RK9-RP3, rare to very rare (WO, WH, CH, FX); RP4-5 very rare (WO).

RANGE: uRK9 to lRP5, lMh to eDt, Maastrichtian to Late Paleocene.

Genus *PHORMOSTICHOARTUS* Campbell

Acanthocyrtis Haeckel 1887, p. 1461 (*non Acanthocyrtis* Haeckel 1881)
Phormostichoartus Campbell 1951, p. 530. Emend Nigrini 1977, p. 252.

TYPE SPECIES: *Cyrtophormis cylindrica* Haeckel 1887, p. 1461, pl. 77, fig. 17 (OD). Tropical Pacific, Quaternary.

DIAGNOSIS: Subcylindrical to fusiform test of four segments. Cephalis lacks apical horn, cylindrical vertical tube well developed, projects laterally from base of cephalis. Basal margin constricted with well-developed imperforate collar (peristome).

RANGE: Late Cretaceous to Recent.

Phormostichoartus? strongi n.sp.
(Plate 13, Figures 1-5)

Artostrobiidae gen. *et* spp. indet. Hollis 1991, p. 102.

DESCRIPTION: Small subcylindrical to fusiform thick-walled test of four segments. Spheroidal cephalis with indistinct vertical tube; surface dimpled, imperforate or sparsely perforate with small subcircular pores. Thorax hemispherical, closely-spaced subcircular pores, quincuncial in 4-5 rows with hexagonal frames. Collar and lumbar strictures externally well-defined, subsequent stricture less distinct. Abdomen moderately inflated, with subcircular pores quincuncially arranged in 5-7 rows. Fourth segment subcylindrical, narrows distally with well-developed basal peristome; pores subcircular to irregular, quincuncial in 4-9 rows.

DIMENSIONS: (range of 8 specimens [mean]): length of 4 segments = 115-151 μm [131]; cephalis length = 10-12 μm [12], width = 22-27 μm [24]; thorax length = 23-32 μm [26], width = 44-57 μm [49]; abdomen length = 25-54 μm [41], width = 64-76 μm [67]; fourth segment length = 29-68 μm [52], width = 56-74 μm [66]; number of pore rows on thorax = 4-5 [4], on abdomen = 5-7 [6], on fourth segment = 4-9 [7].

REMARKS: Doubtfully ascribed to the genus because the vertical tube is not well-developed, and pores of post-cephalic segments are quincuncially arranged rather than in well-defined transverse rows. In this latter respect the species resembles Eocene-Oligocene *P. fistula* Nigrini which also has closely-spaced quincuncial pores on thorax and abdomen; a quincuncial pattern is also evident in the transversely-aligned pores of the fourth segment due to an offset between rows. In addition to the absence of a well-developed vertical tube, *P? strongi* differs from *P. fistula* having smaller, more numerous pores on post-cephalic segments.

HOLOTYPE AND TYPE LOCALITY: R867 (Pl. 13, Fig. 1); P30/f363 (WO28), RK9, Mead Hill Formation, Woodside Creek.

ETYMOLOGY: Named after foraminifera specialist Dr C. Percy Strong in acknowledgment of his considerable contribution to K-T boundary studies in Marlborough.

DISTRIBUTION: Southwest Pacific: RK9, very rare (WO, WH, Mara, DSDP 275); RP1-RP4, very rare (WO, WH, FX); RP5, isolated occurrence and may be reworked (CH).

SOUTHWEST PACIFIC RANGE: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Genus *SIPHOCAMPE* Haeckel

Siphocampe Haeckel 1881, p. 438. Emend. Nigrini 1977, p. 254.

TYPE SPECIES: *Siphocampe annulosa* Haeckel 1887, p. 1500, pl. 79, fig. 10 (SD Stelkov & Lipman in Khabakov *et al.* 1959); Pacific, Recent.

DIAGNOSIS: Subcylindrical test of three segments. Cephalis as for family. No apical horn. Abdomen relatively long, subcylindrical, with or without regular constrictions.

REMARKS: The taxa described below are transferred to *Siphocampe* following Nigrini's (1977) emended definition of the genus. Relationships between these and other members of the genus remain uncertain. Several species are superficially similar, but only the Tertiary *S. lineata* (Ehrenberg) group (*sensu* Nigrini 1977) possesses a similar cephalis with a laterally- to downward-directed vertical tube. It is not clear whether the orientation of the vertical tube has value only at the level of species discrimination, as implied by Nigrini (1977), or at a higher level, such as in the recognition of lineages.

RANGE: Late Cretaceous to Recent.

Siphocampe altamontensis (Campbell & Clark)
(Plate 14, Figure 1-3)

Tricolocampe (Tricolocamptra) altamontensis Campbell & Clark 1944a, p. 33, pl. 7, fig. 24, 26.
Theocampe altamontensis (Campbell & Clark). Foreman 1968, p. 53, pl. 6, fig. 14a,b; 1978, p. 745, pl. 5, fig. 27. Taketani 1982, p. 53, pl. 3, fig. 1a,b; pl. 11, fig. 1. Empson-Morin 1984, pl. 2, fig. 6. Yamasaki 1987, pl. 2, fig. 3. Ling & Lazarus 1990, p. 357, pl. 3, fig. 18.

Theocampe aff. *altamontensis* (Campbell & Clark). Pessagno 1975, p. 1016, pl. 4, fig. 10.

Siphocampe altamontensis (Campbell & Clark). Ling 1991, p. 320, p. 1, fig. 12).

Siphocampe cf. *altamontensis* (Campbell & Clark). Hollis 1991, p. 96, pl. 10, fig. 1-4. Strong *et al.* 1995, p. 205.

non Theocampe altamontensis (Campbell & Clark). Empson-Morin 1981, p. 262, pl. 6, fig. 1a-d (= *Siphocampe* aff. *altamontensis*, below).

DESCRIPTION: Slender, subcylindrical to fusiform test of three segments. Spheroidal cephalis with large downward-directed vertical tube. Thorax short, truncate-conical. No collar stricture; lumbar stricture indistinct. Abdomen subcylindrical to moderately inflated medially or distally. Thoracic pores small, circular, quincuncial, and set in downward-directed frames in 2-3 rows. Abdominal pores in 7-17 transverse rows, offset between rows; proximally small and subcircular, becoming large and polygonal distally. Ragged basal margin.

DIMENSIONS: (range of seven specimens): maximum length (probably all incomplete) = 140-200 µm; maximum width = 65-90 µm.

REMARKS: New Zealand specimens, including that recorded by Pessagno (1975) from DSDP Site 275, tend to have a more inflated abdomen than typical *S. altamontensis*. The Paleogene species *S. quadrata* (Petrushevskaya & Kozlova = *Lithomitra docilus* Foreman, *sens.* emend. Nigrini 1977) is distinguished by an upward-directed vertical tube.

A single Paleocene specimen (Pl. 14, Fig. 4), at first thought to be a good example of typical *S. altamontensis* because of its subcylindrical abdomen, on further examination appears most similar to the Maastrichtian species *S. argyris* (Foreman) which has a distinct lumbar stricture and smaller abdominal pores.

DISTRIBUTION: Southwest Pacific: RK9-RP3, rare to very rare (WO, WH, CH, FX, MD, DSDP 275); RP4, very rare (WO). California: late Campanian to late Maastrichtian. Hokkaido: Coniacian-Campanian. Tropical and South Atlantic: Santonian to Maastrichtian.

SOUTHWEST PACIFIC RANGE: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Siphocampe* cf. *altamontensis (Campbell & Clark)
(Plate 14, Figures 5, 6)

Theocampe altamontensis (Campbell & Clark). Empson-Morin 1981, p. 262, pl. 6, fig. 1a-d (*non* Campbell & Clark).

? *Theocampe yaoi* Taketani 1982, p. 53, pl. 3, fig. 2a-c, 3a,b; pl. 11, fig. 2.

Theocampe sp. A, Empson-Morin 1984, pl. 2, fig. 7.

Lithomitra sp., Iwata & Tajika 1986, pl. 8, fig. 4.

Siphocampe sp. A., Hollis 1991, p. 97, pl. 10, fig. 6-10.

DESCRIPTION: As for *S. altamontenis* in all respects except for abdominal pore arrangement and related surface ornament. Abdominal pores small, subcircular, arranged in 6-8 widely spaced transverse; set in downward-directed frames which form longitudinal ridges and furrows; weak transverse ridges between pore rows rarely may be more strongly developed.

REMARKS: This species equates with *Theocampe* sp. A of Empson-Morin (1984). Cretaceous species *S. yaoi* differs by having a more inflated abdomen. When transverse ridges are well-developed, the abdomen has a corrugated outline as in several Paleogene-Recent species. Under Nigrini's (1977) broad definitions, most of these Tertiary taxa may be allocated to *S. arachnea* (Ehrenberg) group or *S. nodosaria* (Haeckel) with the latter, including *Lithomitra eruca* Haeckel. Both taxa differ from *S.* cf. *altamontensis* by having an upward-directed vertical tube.

DIMENSIONS: (range of ten specimens): maximum length (most specimens incomplete) = 150-200 µm; maximum width = 60-75 µm.

DISTRIBUTION: Southwest Pacific: RK9-RP3, very rare to rare (WO, WH, CH, FX, Mara, DSDP 275); RP4, very rare (WO). Tropical Pacific, late Campanian. Hokkaido, Early Paleocene.

SOUTHWEST PACIFIC RANGE: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Genus *THEOCAMPE* Haeckel, emend. herein

Theocampe Haeckel 1887, p. 1422. Campbell & Clark 1944a, p. 34. Campbell 1954, p. 134. Emend. Burma 1959, p. 328 (*part.*). Foreman 1968, p. 48 (*part.*); 1971, p. 1678 (*part.*); 1973a, p. 431. Petrushevskaya & Kozlova 1972, p. 537. Petrushevskaya 1975, p. 578; 1981, p. 202.

Dictyocephalus (Streptodelus) Campbell 1953, p. 296; 1954, p. 128. Burma 1959, p. 328. = *Dictyocephalus (Dictyoprora)* Haeckel 1887, p. 1305; Clark & Campbell 1942, p. 77; Campbell & Clark 1944a, p. 45; 1944a, p. 28 (hom. pro *Sethamphora (Dictyoprora)* Haeckel 1887). = *Dictyoprora* Haeckel sensu Nigrini 1977, p. 249 (*non* Haeckel 1881). Type species: *Dictyocephalus amphora* Haeckel 1887, p. 1305, pl. 62, fig. 4.

non Dictyoprora Haeckel 1881, p. 430. = *Sethamphora (Dictyoprora)* Haeckel 1887; Campbell 1953, p. 296; Burma 1959, p. 326. = *Cryptocephalus (Dictyoprora)* Haeckel sensu Campbell 1954, p. 127. Type species: *Sethamphora hexapleura* Haeckel 1887, p. 1250, not figured (SD Burma 1959).

TYPE SPECIES: *Dictyomitra ehrenbergi* Zittel 1876, p. 82, pl. 2, fig. 15 (SD Campbell 1954). Germany, Cretaceous.

DIAGNOSIS: Fusiform test of three segments. Typical artostrobiid cephalis. Abdomen inflated with constricted aperture.

REMARKS: Synonymies listed above summarise the main developments in the emended concept of the genus applied here. For more detailed discussion and treatment of subgeneric synonymies see Burma (1959); for a different interpretation of these see Petrushevskaya & Kozlova (1972; also Petrushevskaya 1975, 1981).

The definition applied here differs from that of Haeckel (1887), Campbell (1954), and Burma (1959), and follows the sense of Foreman (1968, 1971, 1973a) in specifying the presence of a vertical tube as a diagnostic feature, despite one not having been identified in the poorly preserved type material. Its presence was presumed by Foreman (1968) because of other morphologic similarities between her Cretaceous species and the species ascribed to *Theocampe* by Haeckel (1887). This strategy finds support in the second species Haeckel (1887) placed in the genus, *T. pirum* (Ehrenberg), which has a vertical tube. The definition differs from that of Burma (1959) and Foreman (1968, 1971) by excluding species with subcylindrical abdomens which are transferred to *Siphocampe* (*sens.* emend. Nigrini 1977).

With these two emendations, the definition of *Theocampe* becomes equivalent to Nigrini's emended definition of *Dictyoprora* Haeckel. Nigrini herself found no morphological basis for separation, and suggested that with further study both may be united. However, since her study the norm has been to maintain a purely stratigraphic separation, with Mesozoic species being referred to *Theocampe* (e.g., Sanfilippo & Riedel 1985), and Cenozoic species to *Dictyoprora* (e.g., Sanfilippo *et al.* 1985). As these taxa are a conspicuous element in the Cretaceo-Tertiary faunas described in the present study, it is appropriate to attempt to rectify this unsatisfactory situation. *Dictyoprora* was erected without type species by Haeckel (1881). He subsequently (1887) used the name for two distinct subgenera: *Sethamphora (Dictyoprora)* and *Dictyocephalus (Dictyoprora)*. To rectify this homonymy, Campbell (1953) observed that the first subgenus corresponded with the original genus, and erected *Streptodelus* (with *Dictyocephalus amphora* Haeckel as type species) to accommodate the second subgenus. This treatment was followed in Campbell (1954), supported and somewhat expanded upon by Burma (1959), but misrepresented by Nigrini (1977) when she indicated that Campbell (1954) had designated *D. amphora* as type species of *Dictyoprora* Haeckel (1881). Therefore, the genus Nigrini describes under *Dictyoprora* is in fact *Streptodelus* Campbell, and it is this genus that must be compared with *Theocampe*.

Campbell (1953, 1954) and Burma (1959) accepted Haeckel's original description of *D. amphora* as two-segmented which meant, under Haeckel's system of classification, that *Streptodelus* and *Theocampe* were widely separated. Subsequent study of *D. amphora* (Foreman 1973a; Nigrini 1977) showed that it has three segments. Had Campbell or Burma realised this it is almost certain that Burma, at least, would have treated *Streptodelus* as a junior synonym of *Theocampe*. In his major revision of *Theocampe*, Burma transferred many species of *Dictyocephalus (Dictyoprora)* (of Clark & Campbell 1942; Campbell & Clark 1944a, b) to *Theocampe* because they had three, rather than two segments. Therefore, as *D. amphora* fulfils the definition of *Theocampe* as emended here, *Streptodelus* is considered a subjective synonym of *Theocampe*. The only possible argument for accepting *Streptodelus* is that a vertical tube is clearly evident in the type species. However such a strategy is not recommended as it not only violates the priority of *Theocampe*, but also would inevitably lead to a trichotomy amongst future workers. *Dictyoprora s.s.* has an unfigured type species (SD Burma 1959) and remains of uncertain affinity.

RANGE: Late Cretaceous to Miocene.

Theocampe* cf. *vanderhoofi Campbell & Clark
(Plate 13, Figure 9-12)

cf. *Theocampe vanderhoofi* Campbell & Clark 1944a, p. 34, pl. 7, fig. 19. Emend Foreman 1968, p. 51, pl. 6, fig. 12.
Theocampe pirum (Ehrenberg). Dumitrica 1973, p. 788, pl. 4, fig. 5.
Theocampe vanderhoofi Campbell & Clark. Johnson 1974, pl. 1, fig. 9. Hollis 1991, p. 100, pl. 11, fig. 1-6; 1993a, p. 324. Strong *et al.* 1995, p. 205.

DESCRIPTION: Inflated fusiform test of three segments. Spheroidal cephalis sparsely perforate, with a cylindrical, downward-directed vertical tube and a weak apical horn. Collar stricture with no external expression, so that cephalothorax has a triangular outline. Thorax relatively large, subconical, and sparsely perforate with a distinct row of larger downward-directed pores directly above the lumbar stricture. Longitudinal ridges extending from this row of pores to the lower abdomen are present in some specimens. Medially inflated abdomen with a convex outline proximally; a concave outline distally with abdomen tapering and wall becoming thinner, terminating with a smooth to slightly ragged basal margin. Abdominal pores small, circular, set in 4-6 widely spaced transverse rows, and may be separated by longitudinal ridges; no pores on distal part of abdomen. Thorax and abdomen compressed, with widest diameter in sagittal plane.

REMARKS: Distinguished from *T. vanderhoofi* by its abdomen which has fewer pore rows and, often, longitudinal ridges (Foreman records 6-12 pore rows and makes no mention of ridges). *T.* cf. *vanderhoofi* may also have a larger cephalothorax and a less well-defined internal band at the lumbar stricture (A. Sanfilippo, pers. comm., 1996). Three similar species, with a compressed thorax and abdomen and downward-directed vertical tube, can be distinguished as follows: *T. lispa* Foreman has a cephalothorax which is not triangular in outline and a less inflated abdomen with evenly convex outline; *T. apicata* Foreman has a relatively small cephalothorax, an inflated abdomen with a triangular outline, and both thorax and abdomen widest in the lateral plane; and *T. pirum* (Ehrenberg) has a relatively small cephalothorax, an inflated abdomen with evenly convex outline. The specimen ascribed to *T. pirum* by Dumitrica (1973) is here referred to *T.* cf. *vanderhoofi* because of its large triangular cephalothorax. The relationship between these four species and the type species *T. ehrenbergi* remains uncertain because the orientation of the vertical tube and the degree of test compression has not been detailed for that species.

DIMENSIONS: (range of 15 specimens [mean]): total length = 130-170 μm [142]; maximum width = 70-100 μm [82]; length of abdomen = 80-120 μm [93].

DISTRIBUTION: Southwest Pacific: RK9, common (FX, MD) or few to rare (WO, WH, Mara, DSDP 275 & 208); RP1-3, few to rare (WO, WH, CH, FX, MD); RP4, very rare (WO, DSDP 208). Indian Ocean, Maastrichtian. *T. vanderhoofi* is known from late Campanian to possible Paleocene in California, and from Campanian-Maastrichtian in the South Atlantic.

SOUTHWEST PACIFIC RANGE: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Family CARPOCANIIDAE Haeckel

Carpocanida Haeckel 1881, p. 427.

Carpocaniidae Haeckel, emend. Riedel 1967b, p. 296. Petrushevskaya 1971a, p. 988. Petrushevskaya & Kozlova 1972, p. 535.

DIAGNOSIS: Test of 2-3 segments. Cephalis consists of a eucephalic chamber embedded completely or partly in the top of the thorax.

REMARKS: Usage follows Petrushevskaya & Kozlova (1972) who included the Cretaceous-Paleogene genera *Myllocercion, Theocapsomma*, and *Diacanthocapsa,* as well as *Cryptocarpium ornatum* (as *Theocapsomma ornatum*; see below), in the family based mainly on common features of the cephalis, namely that it is a simple eucephalic chamber either completely or partly embedded in the thorax. True carpocaniids, however, are thought to have evolved from a pterocorythid ancestor no earlier than the Middle Eocene (Sanfilippo & Reidel (1973, 1992; Sanfilippo *et al.* 1985) and because of this undifferentiated members of the family are recorded as "Carpocaniidae" in Appendix 2.

Genus *MYLLOCERCION* Foreman

Myllocercion Foreman 1968, p. 37. Sanfilippo & Riedel 1985, p. 620.

Schadelfusslerus Empson-Morin 1981, p. 276.

TYPE SPECIES: *Myllocercion acineton* Foreman 1968, p. 37, pl. 5, fig. 11a-b (OD). California, Late Cretaceous.

DIAGNOSIS: Fusiform test of 2-3 segments. Cephalis partially submerged in thorax, without apical spine. Three feet project from base of thorax to form ribs within abdominal wall, and may extend beyond it, or represent all that remains of it. Pores on thorax usually occluded and set between well-developed frames and/or longitudinal ridges; on abdomen sparse with frames absent.

REMARKS: Sanfilippo & Riedel (1985) broadened the definition of the genus by admitting 2-segmented species. This accommodates the species that Empson-Morin placed in her new genus *Schadelfusslerus,* which was erected to accommodate 2- to 3-segmented species differing from *Myllocercion* by having a free cephalis (i.e., not partially submerged in the thorax) and three feet projecting down from the basal chamber. However Foreman's original definition did not exclude species with a free cephalis, and clearly included the species *M. rhodanon* Foreman which has feet projecting below the abdomen. The degree to which the cephalis is enclosed in the thorax varies considerably within Marlborough specimens of *M. acineton* (compare Pl. 14. Figures 8, 10 and 11).

Although *Schadelfusslerus* may prove to be a legitimate genus, based on the distinctive features of the 2-segmented type species *S. echtus*, the genus is not used here because it is often difficult to distinguish between 2- and 3-segmented *Myllocercion*-like forms. The thin-walled abdomen is often lost in *M. acineton* and related forms, leaving ribs that closely resemble the basal feet of 2-segmented species.

Myllocercion acineton Foreman
(Plate 14, Figures 7-11)

Myllocercion acineton Foreman 1968, p. 37, pl. 5, fig. 11a-c. Sanfilippo & Riedel 1985, p. 620, fig. 14.1a, c, d (not fig. 14.1b, = *Schadelfusslerus echtus* Empson-Morin). Hollis 1991, p. 103, pl. 11, fig. 9-13 (also fig. 8); 1993a, p. 324. Strong *et al.* 1995, p. 205.

Myllocercion sp., Dumitrica 1973, p. 789, pl. 2, fig. 5; pl. 5, fig. 8,9; Foreman 1978, p. 747, pl. 5, fig. 3; Empson-Morin 1981, p. 278, pl. 11, fig. 2a-c.

Schadelfusslerus echtus Empson-Morin. Taketani 1982 (*part.*), p. 71, pl. 8, fig. 10a,b (*non* Empson-Morin 1981).

DESCRIPTION: Inflated fusiform test of three segments. Cephalis spheroidal, partially submerged in thorax, without an apical spine. Thorax inflated conical to globose with three broad lamellar feet projecting from base to form ribs within abdominal wall. Abdomen inverted conical, trilobate in transverse section. Collar stricture usually indistinct but marked by 1-3 rows of open pores, elsewhere on thorax pores occluded. Lumbar stricture usually distinct, marked by row of open pores. Surface of cephalis dimpled, imperforate. Wall of thorax thick, pores occluded with low hexagonal frames, aligned vertically between longitudinal ridges which may extend onto cephalis. Wall of abdomen thin with small circular pores irregularly distributed over a smooth surface; bluntly tapered termination with either a single narrow circular aperture or a cluster of basal pores.

Dimensions (range of 10 specimens [median]): total length = 135-200 μm [170]; length of cephalothorax = 70-120 μm [90], width = 70-100 μm [80]; length of abdomen = 50-90 μm [80], width = 60-105 [80].

Remarks: Marlborough specimens tend to be larger than the type material, where total length and maximum width does not exceed 133 μm. In accordance with Sanfilippo & Riedel (1985) a relatively broad definition is adopted, admitting forms with sparsely perforate abdomens (Dumitrica 1973, pl. 2, fig. 5; pl. 5, fig. 8, 9; Empson-Morin 1981, pl. 11, fig. 2a-d); reduced abdomens (Dumitrica 1973, pl. 8, fig. 1) and quincuncial thoracic pores (*ibid*, pl. 5, fig. 8, 9). However, Sanfilippo & Riedel's (1985) inclusion of *Schadelfusslerus echtus* and a related form (*ibid*, fig. 14.1b) within *M. acineton* does not appear justified. *S. echtus* and *Myllocercion* aff. *echtus* below are distinguished by a prominent raised cephalis, a hemispherical thorax with pores consistently quincuncially arranged in hexagonal frames, and usually free feet with no abdomen. The specimens ascribed to *S. echtus* by Taketani (1982, pl. 8, fig. 9a, b, 10a, b; pl. 13, fig. 22) appear to have longitudinal ridges on the thorax, and in one case a clearly trilobate abdomen (pl. 8, fig. 10a, b), features diagnostic of *M. acineton*.

Distribution: Southwest Pacific: RK9-RP2, common to few (WO, WH, CH, FX, DSDP 208) or rare (MD, Mara, DSDP 275); RP3-RP4, very rare (WO, CH, FX, DSDP 208). Known from Campanian to Maastrichtian of California, tropical Pacific, Japan, tropical Atlantic and Europe.

Southwest Pacific range: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Myllocercion* aff. *echtus (Empson-Morin)
(Plate 14, Figures 12, 13)

aff. *Schadelfusslerus echtus* Empson-Morin 1981, p. 276, pl. 10, fig. 5-6c.
Myllocercion sp. aff. *Schadelfusslerus echtus* Empson-Morin. Hollis 1991, p. 104, pl. 11, fig. 14-17.
Myllocercion sp. Strong *et al.* 1995, p. 205.

Description: Campanulate test of two segments, with three feet projecting from base of the thorax. Cephalis spheroidal, partly enclosed in thorax. Thorax inflated hemispherical, moderately constricted basally, with 3 triradiate feet projecting down from base. Surface of cephalis dimpled, imperforate, and pores of thorax in regular quincuncial arrangement set within hexagonal frames.

Dimensions: (range of ten specimens [median]): length of cephalothorax = 70-105 μm [85], width = 70-90 μm [75]; distance between thoracic pore centres = 5-8 μm.

Remarks: This species differs from *S. echtus* by having more numerous pores on thorax; the distance between pore centres is half that of Empson-Morin's species.

Distribution: Southwest Pacific: RK9-RP1, common to few (WO, WH, FX) or very rare (CH, MD); RP2-3, very rare (WO, WH, CH, FX, MD, DSDP 208); RP4, very rare (WO).

Southwest Pacific range: uRK9 to RP4, lMh to eDt, Maastrichtian to Early Paleocene.

Genus *THEOCAPSOMMA* Haeckel

Theocapsomma Haeckel 1887, p. 1428. Campbell 1954, p. D136. Emend. Foreman 1968, p. 29.
Diacanthocapsa Squinabol 1903, p. 133. Campbell 1954, p. D129; emend. Dumitrica 1970, p. 61. p. 536. Type species = *Diacanthocapsa euganea* Squinabol 1903, p. 133, pl. 8, fig. 26 (by monotypy).
Novodiacanthocapsa Empson-Morin 1981, p. 268. Type species = *Diacanthocapsa ovoidea* Dumitrica 1970, p. 63, pl. 5, fig. 25a,b, pl. 6, fig. 26-29b (OD).
? *Eastonerius* Empson-Morin 1981, p. 266. = *Theocapsomma* Haeckel, *sensu* Petrushevskaya & Kozlova 1972, p. 535 (*non* Haeckel). Type species = *Diacanthocapsa acuminata* Dumitrica 1970, p. 65, pl. 7, fig. 38, 39a,b, 43 (OD).

Type species: *Theocapsa linnaei* Haeckel 1887, p. 1429, pl. 66, fig. 13 (SD Campbell 1954, p. D136). No type locality specified: many stations in Atlantic, Indian, and Pacific oceans, Quaternary.

Diagnosis: Ovate test of three (sometimes more) segments. Cephalis partially or completely encased in thorax; surface imperforate; may bear an apical spine. Thorax hemispherical to subconical. Lumbar stricture may or may not be expressed externally. Final segment inverted conical, subcylindrical, or globose, narrowing basally. Aperture, when present, constricted and with or without a peristome. Pores of thorax and subsequent chambers irregularly or quincuncially arranged and set in polygonal frames which may be thickened to form diagonal or rarely longitudinal ridges.

REMARKS: Despite disagreement among subsequent workers, the broad definition of Foreman (1968) is retained because most Cretaceous species she described accord well with the type species in critical diagnostic features: degree of differentiation of cephalis and pore arrangement.

Dumitrica (1970) advocated the transfer of Foreman's species to *Diacanthocapsa* Squinabol because the latter has a Cretaceous type species, and the use of *Theocapsomma* would imply that this Cretaceo-Paleogene group ranges to Recent. This argument cannot be accepted as legitimate because Dumitrica's emended definition of *Diacanthocapsa* provided no morphological basis for separating the two genera. There is also a wealth of evidence to cast doubt on the Recent ages of much of Haeckel's Challenger material, from which *T. linnaei* was described (Sanfilippo *et al.* 1985). However, *Diacanthocapsa* Squinabol is considered to be a subjective synonym of *Theocapsomma* because the type species *D. euganea* conforms with *Theocapsomma* in general form and pore arrangement, although details of cephalic structure remain undetailed.

Other workers (Petrushevsaya & Kozlova 1972; Empson-Morin 1981) have separated this genus into two groups. The first is characterised by a relatively well-differentiated cephalis and irregular to quincuncial pores, e.g., *Theocapsomma amphora* (Campbell & Clark). The other group has a less differentiated cephalis, with elements extending into the thoracic cavity, and with pores aligned longitudinally and typically set between longitudinal ridges, e.g., *Theocapsomma comys* Foreman. Petrushevskaya & Kozlova's (1972) strategy of using the names *Diacanthocapsa* and *Theocapsomma* respectively for these two groups must be rejected as the cephalic structure of both type species has not been described, and both have irregular to quincuncial pores.

Empson-Morin (1981) chose to reject both names and erected two new genera, *Novodiacanthocapsa* and *Eastonerius*, which essentially are equivalent respectively to *Diacanthocapsa* and *Theocapsomma* in the sense of Petrushevskaya & Kozlova. While I agree with her arguments for disposing of *Diacanthocapsa*, I find no reason to reject *Theocapsomma*. As *T. linnaei* conforms with *Novodiacanthocapsa* in pore arrangement, the latter is considered a subjective synonym of *Theocapsomma*. Although not confidently identified in the Marlborough material, *Eastonerius* appears to be a valid genus similar to the pterocorythid genus *Cryptocarpium* Sanfilippo & Riedel (1992), but distinguished by a tapering final chamber and indistinct strictures.

RANGE: Late Cretaceous to Recent?.

Theocapsomma amphora (Campbell & Clark)
(Plate 15, Figures 1, 2)

Theocapsa amphora Campbell & Clark 1944a, p. 35, pl. 7, fig. 30,31.
Tricolocapsa granti Campbell & Clark 1944a, p. 35, pl. 7, fig. 37,38.
Theocapsomma amphora (Campbell & Clark). Emend. Foreman 1968, p. 31, pl. 4, fig. 9a-c. Hollis 1991, p. 107, pl. 12, fig. 1-3; 1993a, p. 324. Strong *et al.* 1995, p. 205.
? *Diacanthocapsa* sp. A gr., Petrushevskaya & Kozlova 1972, p. 536, pl. 7, fig. 11; pl. 22, fig. 4, 6.
? *Diacanthocapsa* sp. B, Petrushevskaya & Kozlova 1972, p. 536, pl. 7, fig. 4, 5.
Theocapsomma sp., Dumitrica 1973, p. 789, pl. 2, fig. 6,7.
non Diacanthocapsa amphora (Campbell & Clark). Pessagno 1975, p. 1017, pl. 5, fig. 5-7. = *Theocapsomma erdnussa* (Empson-Morin).

DESCRIPTION: Ovate to flask-shaped test of three segments. Spheroidal cephalis only partly submerged in thorax; very rarely bearing apical and/or vertical spines. Thorax hemispherical with pores in regular quincuncial arrangement and set in hexagonal frames. Collar and lumbar strictures moderately distinct externally. Abdomen ovate, slightly to moderately inflated, and commonly asymmetric; varies considerably in size and shape; wall thinner than thorax, pore arrangement and frames tending to be less regular; circular basal aperture without a collar.

REMARKS: Synonymies from Campbell and Clark (1944a) follow Foreman (1968) whose emended definition accommodates the form recorded by Dumitrica (1973) and possibly those of Petrushevskaya and Kozlova (1972). Marlborough specimens tend to have a more inflated abdomen than those figured by Foreman (1968). However, in this respect they accord well with Campbell and Clark's original description. A similar species, *T. teren* Foreman, is distinguished by more weakly-defined lumbar stricture and more densely distributed pores. *T. amphora* is distinguished from *T. erdnussa* by the cephalis being only partly submerged in the thoracic wall and by lacking an apertural tube; from the Eocene species *Cryptocarpium ornatum* (Ehrenberg) by lacking a pronounced longitudinal alignment of pores on the thorax.

DISTRIBUTION: Southwest Pacific: RK9-RP3, rare to very rare (WO, WH, CH, FX, MD, Mara, DSDP 275 & 208), RP4, very rare (WO, DSDP 208); RP5, isolated occurrence and identification uncertain (DSDP DSDP 208). California, late Campanian to possible Paleocene; South Atlantic, Campanian-Maastrichtian. Similar forms occur in the Maastrichtian and Eocene of the tropical Atlantic (Petrushevskaya & Kozlova 1972).

SOUTHWEST PACIFIC RANGE: RK9 to RP4, lMh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Theocapsomma erdnussa (Empson-Morin)
(Plate 14, Figures 14-21, ?22-23)

- ? *Theocapsomma* sp. aff. *T. comys* Foreman. Petrushevskaya & Kozlova 1972, p. 535, pl. 7, fig. 6.
- ? *Diacanthocapsa*? sp., Dumitrica 1973, p. 789, pl. 12, fig. 4, 5.
- ? *Theocapsomma comys* Foreman. Riedel & Sanfilippo 1974, p. 781, pl. 10, fig. 8. Foreman 1978, p. 748, pl. 5, fig. 11, 12 (*non* Foreman 1968).
- *Diacanthocapsa amphora* (Campbell & Clark). Pessagno 1975, p. 1017, pl. 5, fig. 5-7 (*non* Campbell & Clark).
- *Novodiacanthocapsa erdnussa* Empson-Morin 1981, p. 270, pl. 10, fig. 1a-c.
- *Diacanthocapsa* sp. 2, Ling & Lazarus 1990, p. 356, pl. 3, fig. 3.
- *Theocapsomma erdnussa* (Empson-Morin). Hollis 1991, p. 108, pl. 12, fig. 4-14 (possibly fig. 15, 18); 1993a, p. 324. Strong *et al.* 1995, p. 205.

DESCRIPTION: Ovate, subcylindrical, or peanut-shaped test of 2-3 segments. Ellipsoidal cephalis completely enclosed in thorax. Thorax hemispherical. Lumbar stricture indistinct to distinct externally, well-defined internally by a wide septal band that constricts the aperture between thorax and abdomen. Abdomen subcylindrical to slightly globose, usually equal to or longer than thorax, with a rounded base and a constricted aperture with a short peristome. Small circular pores in regular quincuncial arrangement and set in hexagonal frames cover entire test. Longitudinal ridges may develop from lower cephalothorax.

REMARKS: Apart from clearly broken specimens, two-segmented variants as reported by Empson-Morin (1981) have not been observed in the Marlborough material. The range of variation accepted here includes variants in which the cephalis protrudes slightly from the thoracic wall (Pl. 14, Fig. 14, 16), and in which the lumbar stricture is indistinct and longitudinal ridges extend to the upper part of the thorax (Pl. 14, Fig. 20). These latter bear a superficial resemblance to the Late Cretaceous index species *Eastonerius comys* (Foreman) which is distinguished by having a rounded-conical thorax and a ragged basal margin.

Variants in which the abdomen is greatly reduced (Pl. 14, Fig. 22, 23) are only doubtfully included because they occur at DSDP Site 208 where typical *T. erdnussa* has not been encountered (see also Johnson 1974, pl. 1, fig. 10).

DISTRIBUTION: Southwest Pacific: RK9-RP3, few to rare (WO, WH, CH, FX, MD, Mara, DSDP 275); rare, RP4-5 (WO). Central Pacific, late Campanian. Weddell Sea, late Campanian-Maastrichtian. The variant noted above occurs in RP4-5 at DSDP 208 and in the late Maastrichtian at DSDP 216, Indian Ocean.

SOUTHWEST PACIFIC RANGE: RK9 to lRP5, Mh to lDt, late Campanian-Maastrichtian to Late Paleocene.

Family PTEROCORYTHIDAE Haeckel

- Pterocorida Haeckel 1881, p. 435.
- Pterocoryidae Haeckel, emend. Riedel 1967b, p. 296.
- Pterocorydinae Haeckel, Petrushevskaya 1971a, p. 986.
- Pterocorythidae Haeckel, Moore 1972, p. 147. Sanfilippo & Riedel 1992, p. 6.

DIAGNOSIS: Test of 2-3 segments. Cephalis divided into three lobes; two lateral lobes separated from central eucephalic lobe by arches between apical and lateral bars; arches usually expressed externally as oblique downward-directed furrows. Cephalis is usually elongate with an apical horn. Pores of thorax and abdomen arranged quincuncially or in longitudinal rows.

Genus *CRYPTOCARPIUM* Sanfilippo & Riedel

- *Cryptoprora* Ehrenberg. Sanfilippo & Riedel 1973, p. 530. Sanfilippo *et al.* 1985, p. 693 (*non* Ehrenberg 1847).
- *Carpocanistrum* Haeckel. Sanfilippo & Riedel 1973, p. 530 (*non* Haeckel 1881, = *Lithocarpium* Stohr 1880).
- *Cryptocarpium* Sanfilippo & Reidel 1992, p. 6.

TYPE SPECIES: *Cryptoprora ornata* Ehrenberg 1873, p. 222; 1875, pl. 5, fig. 8 (OD). Barbados, Eocene.

DIAGNOSIS: Test of 2-3 segments. Cephalis partially enclosed in thorax. Rather rudimentary pterocorythid cephalic structure consists of a low eucephalic lobe and indistinct lateral lobes. Pores of thorax, and abdomen when present, longitudinally aligned but not separated between distinct ridges.

REMARKS: Although not discussed by Sanfilippo & Riedel (1992), the establishment of this genus remedies a long-standing problem with the usage of the generic name *Cryptoprora*. Poor definition of the genus and of the first few species ascribed to it, none of which was illustrated, make its applicability to the only well-known member of the genus, *C. ornata*, difficult to assess. Sanfilippo & Riedel (1992) consider the genus to be intermediate between ancestral theoperids and other pterocorythids, possibly also having given rise to true carpocaniids.

RANGE: Late Cretaceous to Oligocene.

Cryptocarpium*? cf. *ornatum (Ehrenberg)
(Plate 15, Figure 4)

- cf. *Theocapsomma* aff. *ornata* Ehrenberg. Petrushevskaya & Kozlova 1972, p. 535, pl. 22, fig. 2 (also fig. 3).
- *Cryptoprora* cf. *ornata* Ehrenberg. Dumitrica 1973, p. 789, pl. 9, fig. 1.
- cf. *Cryptoprora ornata* Ehrenberg. Sanfilippo *et al.* 1985, p. 693, fig. 27.2b (not 2a);
- *Theocapsomma*? cf. *comys* Foreman. Hollis 1991, p. 109, pl. 12, fig. 16, 17.

DESCRIPTION: Test of three segments. Cephalis oblately ellipsoidal, distinctly asymmetric, only partially enclosed in thorax; indistinct lobate structure. Thorax subconical to campanulate, with smooth outline. Pores of thorax longitudinally, but not transversely, aligned and set in hexagonal frames. Lumbar stricture indistinct externally, internally septum forms constricted aperture between thorax and abdomen; only proximal part of abdomen preserved.

DIMENSIONS: (five specimens): length of cephalothorax = 98-105 µm; length of cephalis = 20 µm; width of cephalis = 22-25 µm; greatest width of thorax = 81-96 µm; width at lumbar stricture = 67-80 µm; number of pore rows on thorax = 11-13.

REMARKS: These specimens are only doubtfully placed in *Cryptocarpium* because the characteristic 3-lobed cephalis has not been clearly distinguished. It is equally doubtful, therefore, that this species is a pterocorythid. The species bears a close superficial resemblance to Paleocene-Eocene specimens of *C. ornatum* and related forms (as listed above). Externally, it is distinguished from *C. ornatum s.s.* by having a more inflated, often campanulate cephalothorax and more numerous rows of pores. The specimen figured by Ehrenberg has only 9 rows of pores visible in side view. The Late Cretaceous species, *Theocapsomma comys* Foreman (1968), is distinguished by a more slender test with fewer rows of pores (7-8 visible in side view) and a simple cephalis without cephalic lobes which is entirely enclosed in the thorax.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, WH, MD, DSDP 275 & 208); RP1-4, very rare (WO, WH, CH, FX, DSDP 208); RP5-6, isolated occurrences and uncertain identification (MD, TK). Similar species are widely distributed from Campanian to earliest Oligocene.
RANGE: uRK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Family AMPHIPYNDACIDAE Riedel

Amphipyndacidae Riedel 1967a, p. 149. Petrushevskaya 1971a, p. 985. Foreman 1973a, p. 430.

DIAGNOSIS: Multisegmented test. Cephalis either divided into an upper spherical chamber and a lower cylindrical chamber by a transverse, ring-like septum, or comprising a single spherical chamber above a transverse septum, from which collar structures extend downward into thoracic cavity.

Genus *AMPHIPYNDAX* Foreman

Amphipyndax Foreman 1966, p. 355.

TYPE SPECIES: *Lithostrobus pseudoconulus* Pessagno 1963, p. 210, pl. 1, fig. 8, pl. 5, fig. 6, 8 (syn. *Amphipyndax enesseffi* Foreman 1966, p. 356, text-fig. 10-11 [OD]. Cuba, Cretaceous). Puerto Rico, Cretaceous.

DIAGNOSIS: Multisegmented narrowly conical to fusiform test. Imperforate cephalis divided into two chambers by a transverse septum. Pores of thorax and subsequent segments arranged quincuncially.

REMARKS: The definition is applied in the original sense of Foreman to forms with or without secondary shell layers. Empson-Morin (1982) argued for transferring the latter into a new genus *Protostichocapsa* with *A. stocki* as type species. More recently O'Dogherty (1994) transferred the latter group to *Stichomitra* Cayeux, the definition of which he revised to admit only species with *Amphipyndax*-like cephalic structure. Given that such a cephalis has not been identified in the species that O'Dogherty recommended as type species of *Stichomitra*, *S. bertrandi*, or the species purported to be its subjective synonym, *S. compsa*, this revision is not followed here.

RANGE: Middle Jurassic (Aita 1987) to Late Paleocene.

Amphipyndax* aff. *conicus Nakaseko & Nishimura
(Plate 15, Figures 12-14)

aff. *Amphipyndax conicus* Nakaseko & Nishimura 1981, p. 143, pl. 12, fig. 1, 2; pl. 17, fig. 8.
Amphipyndax aff. *conicus* Nakaseko & Nishimura. Hollis 1991, p. 110, pl. 13, fig. 1-5.

DESCRIPTION: Moderately large test of 6-8 segments; bluntly conical proximally, cylindrical distally. Cephalis partly enclosed in thorax, collar stricture weak or absent. Thorax and subsequent chambers thick-walled, with quincuncial pores set in hexagonal frames. Lumbar and subsequent strictures lack external expression. Final chamber hemispherical with a small terminal aperture.

DIMENSIONS: (eight specimens): total length = 250-300 µm; maximum width = 110-150 µm.

REMARKS: *A. conicus* is smaller, but with more segments, and lacks well-developed pore frames.

DISTRIBUTION: Southwest Pacific: RK9-RP2, few to rare (WO, WH, CH, FX); RP3, very rare (RP3).

RANGE: Upper 9 - RP3,-lMh to eDt, Maastrichtian to Early Paleocene.

Amphipyndax stocki (Campbell & Clark) **gr., new group**
(Plate 15, Figures 5-11)

? *Dictyomitra polypora* Zittel 1876, p. 80, pl. 2, fig. 1.
Dictyomitra mediocris Tan Sin Hok 1927, p. 55, pl. 10, fig. 82.
Syringium molengraafi Tan Sin Hok 1927, p. 63, pl. 13, fig. 105.
Stichocapsa? *stocki* Campbell & Clark 1944a, p. 44, pl. 8, fig. 31-33.

Stichocapsa megalocephala Campbell & Clark 1944a, p. 44, pl. 8, fig. 26,34.

Dictyomitra uralica Kozlova & Gorbovetz 1966, p. 116, pl. 6 fig. 6,7.

Amphipyndax stocki (Campbell & Clark). Foreman 1968, p. 78, pl. 8, fig. 12a-c; 1971, p. 1677; 1978, p. 745, pl. 4, fig. 4. Petrushevskaya & Kozlova 1972, p. 545, pl. 8, fig. 16, 17. Dumitrica 1973, p. 788, pl. 1, fig. 3; pl. 8, fig. 11,12; pl. 11, fig. 2; pl. 12, fig. 2. Johnson 1974, pl. 1, fig. 1, 2. Riedel & Sanfilippo 1974, p. 775, pl. 11, fig. 1-3; pl. 15, fig. 11. Pessagno 1975, p. 1016, pl. 4, fig. 4-8. Nakaseko & Nishimura 1981, p. 145, pl. 12, fig. 5. Taketani 1982, p. 52, pl. 2, fig. 9a,b; pl. 11, fig. 1-3. Hollis 1991, p. 111, pl. 13, fig. 6-15; 1993a, p. 323. Takemura 1992, p. 743, pl. 6, fig. 10-11. Strong *et al.* 1995, p. 205.

Amphipyndax mediocris (Tan Sin Hok). Renz 1974, p. 788, pl. 5, fig. 1-3; pl. 12, fig. 2. Nakaseko & Nishimura 1981, p. 144, pl. 12, fig. 6.

Eucyrtis? molengraafi (Tan Sin Hok). Renz 1974, p. 792, pl. 7, fig. 1-4; pl. 11, fig. 32.

Amphipyndax ellipticus Nakaseko & Nishimura 1981, p. 144, pl. 12, fig. 7,8a,b.

Amphipyndax sp., Taketani 1982, p. 52, pl. 10, fig. 6.

Protostichocapsa stocki (Campbell & Clark). Empson-Morin 1982, p. 516, pl. 4, fig. 12.

Amphipyndax uralica (Gorbovetz). Kozlova 1984, Tables 1,2.

Stichomitra mediocris (Tan Sin Hok). O'Dogherty 1994, p. 142, pl. 16, fig. 18-24; pl. 17, fig. 1-5.

Stichomitra stocki (Campbell & Clark). O'Dogherty 1994, p. 147, pl. 18, fig. 9-15.

DESCRIPTION: Conical to fusiform test of five more segments. Cephalis imperforate, papillate or smooth; shape ranges from a raised knob with a constricted "neck" at the base ("*A. stocki*" form; Pl. 15, Fi. 5, 6) to a low dome with the lower cephalis enclosed in the thoracic wall ("*A. molengraafi*" form; Pl. 15, Fig. 7-11). Strictures between post-thoracic segments may or may not be well-developed. First four or more segments usually increase regularly in size, so that proximal part of test is conical. Distal segments subequal in size, except for final segment which is usually longest and tapers basally, and may terminate in a perforate apertural tube.

REMARKS: As in previous studies (Campbell & Clark 1944a, Foreman 1968, Empson-Morin 1982), morphotypes allocated to *A. stocki* show much variation. To avoid diminishing the potential value that certain morphotypes may have for biostratigraphy (such as those recognised by Nakaseko and Nishimura (1981) and O'Dogherty 1994), I place all these variants in "*A. stocki* gp". Although no attempt is made to match these morphotypes formally with the species placed in synonymy above, two broad groupings are evident. Individuals with a neck at the base of the cephalis are generally more conical and conform best with Foreman's (1968) emended definition of the species (*A. stocki* form). In the second group the cephalis is partially enclosed in the thoracic wall, and the test is generally fusiform (*A. molengraafi* form). The *Amphipyndax*-type cephalis of Tan's species is clearly shown in Renz (1974, pl. 7, fig. 3). These forms co-occur in the Marlborough material. Because *A. stocki* is firmly entrenched in the literature an argument can be made for establishing it as a name to be conserved. The alternative is to accept the priority of *A. mediocris*, as advocated by Renz (1974), or possibly *A? polypora*.

DISTRIBUTION: Southwest Pacific: RK9, abundant to common (WO, WH, Mara, DSDP 275 & 208) or few to rare (FX, MD); RP1-RP5, common (WO, WH) or few to rare (CH, FX, KW) or very rare (MD, TK, DSDP 208); RP6-7, very rare (MD). *A. stocki* gp is widely distributed from Early Cretaceous to Maastrichtian and has been recorded previously in the Early Paleocene of California, Hokkaido and the Volga region to West Siberia. Takemura (1992) recorded the species in the Early Eocene, southern Indian Ocean.

SOUTHWEST PACIFIC RANGE: RK9 to RP7, lMh to eDw, late Campanian-Maastrichtian to earliest Eocene.

Genus *AMPHIPTERNIS* Foreman

Amphipternis Foreman 1973a, p. 430.

TYPE SPECIES: *Lithocampe? clava* Ehrenberg 1873, p. 238; 1875, p. 76, pl. 4, fig. 2 (OD). Barbados, Eocene.

DIAGNOSIS: Narrowly conical, multi-segmented test. Spherical cephalis with internal elements which extend below transverse septum into thoracic cavity. Pores of thorax and subsequent segments quincuncially arranged.

RANGE: Late Cretaceous to Early Eocene.

Amphipternis alamedaensis (Campbell)
(Plate 15, Figures 15, 16)

Phormocampe alamedaensis Campbell & Clark 1944a, p. 37, pl. 7, fig. 41.

Stichomitra? alamedaensis (Campbell & Clark). Foreman 1968, p. 77, pl. 8, fig. 4.

Amphipternis sp. cf. *Stichomitra? alamedaensis* (Campbell & Clark). Foreman 1973a, p. 430, pl. 7, fig. 18; pl. 9, fig. 1. Westberg *et al.* 1980, p. 431, pl. 1, fig. 5.

Amphipternis clava (Ehrenberg). Dumitrica 1973 (*part.*), p. 788, pl. 8, fig. 2,3.

Stichomitra sp., Iwata & Tajika 1986, pl. 8, fig. 1.

Amphipternis alamedaensis (Campbell & Clark). Hollis 1991, p. 113, pl. 13, fig. 16-20; 1993a, p. 323. Strong *et al.* 1995, p. 205.

non Amphipyndax alamedaensis (Campbell & Clark). Nakaseko & Nishimura 1981, p. 143, pl. 12, fig. 3,4; pl. 17, fig. 11.

Description: Narrowly conical multi-segmented test with well-developed strictures. Prominent spherical cephalis, imperforate. Pores of thorax and subsequent segments quincuncial. Basal aperture not constricted.

Remarks: This species is transferred to *Amphipternis* following Foreman's (1973a) definition of the genus. There is no discernible difference between *A. alamedaensis* and the Paleogene forms recorded in subsequent studies. The species described by Nakaseko & Nishimura (1981) has an *Amphipyndax*-type cephalis and longitudinally elliptical to rectangular pores, and may be more properly assigned to *Amphipyndax strekta* (Empson-Morin 1982).

Distribution: Southwest Pacific: RK9-RP5, rare to very rare (WO, WH, CH, FX, MD, Mara, KW, DSDP 275 & 208); RP6-RP13, very rare (MD). California, late Campanian to Paleocene; Hokkaido, Early Paleocene; tropical Atlantic, Late Paleocene to Early Eocene.

Southwest Pacific range: RK9 to RP13, Mh to Ab, late Campanian-Maastrichtian to Middle Eocene.

Family ARCHAEODICTYOMITRIDAE Pessagno

Archaeodictyomitridae Pessagno 1976, p. 49; emend 1977b, p. 41.

Diagnosis: Multi-segmented test with well-developed costae (longitudinal ribs). Cephalis small, spheroidal, and imperforate to sparsely perforate. Pores of subsequent segments transversely aligned and usually restricted to joints between segments.

Genus *ARCHAEODICTYOMITRA* Pessagno

Archaeodictyomitra Pessagno 1976, p. 49; emend. 1977b, p. 41.

Type species: *Archaeodictyomitra squinaboli* Pessagno 1976, p. 50, pl. 5, fig. 2-8 (OD). California, Late Cretaceous.

Diagnosis: Conical non-lobate test with costae continuous between segments and not indented at joints. A single row of open pores at joints between each post-cephalic segment. Pores occluded (relict) elsewhere, except on last 1-2 segments which may have multiple rows of open pores.

Southwest Pacific range: Jurassic to Early Paleocene.

Archaeodictyomitra* cf. *lamellicostata (Foreman)

(Plate 16, Figures 1-5)

cf. *Dictyomitra lamellicostata* Foreman 1968, p. 65, pl. 7, fig. 8a, b; 1978, p. 747, pl. 4, fig. 13, 14.

cf. *Archaeodictyomitra lamellicostata* (Foreman), Sanfilippo & Riedel 1985, p. 598, fig. 7.5a-d.

Archaeodictyomitra spp. gr. A., Hollis 1991, p. 114, pl. 14, fig. 1-11.

Archaeodictyomitra spp., Hollis 1993a, p. 324.

Description: Large thick-walled test of 6-12 segments; overall shape ranging from conical throughout to bluntly conical proximally, and becoming cylindrical distally; final segments may be inverted conical. Imperforate cephalis lacks an apical horn but is thickened apically. Thorax equal to or shorter than cephalis. Proximal segments inflated, becoming annular distally. On each side 12-16 costae extend from base of cephalis to final segment; additional costae may develop on distal segments. Strictures may develop on distal segments of some specimens, giving this part of test a lobate outline. Open pores restricted to single transverse rows between proximal segments, but form multiple rows on final 1-2 segments.

Remarks: This species is variable in overall shape but consistently has more costae than the otherwise similar *A. lamellicostata* (14-20 costae around the widest segment). Numerous closely spaced costae also distinguish this species from *A. squinaboli* and *Dictyomitra multicostata*; according to Foreman (1968; see pl. 7, fig. 9a) the latter species sometimes develops continuous *Archaeodictyomitra*-type costae.

Dimensions: (range of 16 specimens [median]): length of 12 segments = 430-535 μm; length of first eight segments = 200-275 μm [225]; maximum width = 105-180 μm [130]; width of eighth segment = 100-145 μm [120]; number of costae around widest segment = 22-30.

Distribution: Southwest Pacific: RK9, very rare (WO, WH, FX, Mara, DSDP 275 & 208); RP1-3, rare to few (WO, WH, CH, FX, DSDP 208); RP4-5, rare to few (WO); uRP5, isolated occurrences and may be reworked (TK, DSDP 208). Similar species, some of which may be included in this complex, are widely distributed in the Late Cretaceous.

Southwest Pacific range: RK9 to lRP5, Mh to eDt, late Campanian-Maastrichtian to Late Paleocene.

Genus *DICTYOMITRA* Zittel

Dictyomitra Zittel 1876, p. 80. Emend Pessagno 1976, p. 50.

Type species: *Dictyomitra multicostata* Zittel 1876, p. 81, pl. 2, fig. 2-4 (SD Campbell 1954, p. D140). Germany, Late Cretaceous.

Diagnosis: Conical lobate multi-segmented test with costae indented at joints between segments. A single, sometimes double, row of open pores at strictures; occluded elsewhere, except last 1-2 segments which may have multiple rows.

Range: Late Cretaceous to Early Paleocene.

Dictyomitra andersoni (Campbell & Clark)
(Plate 16, Figures 11-16)

Lithocampe andersoni Campbell & Clark 1944a, p. 42, pl. 8, fig. 25.
Dictyomitra multicostata Zittel. Campbell & Clark 1944a (*part.*), p. 39, pl. 8, fig. 22-24, 29, 35 (not fig. 42). Iwata & Tajika 1986, pl. 2, fig. 1.
Dictyomitra tiara Campbell & Clark 1944a, p. 40, pl. 8, fig. 1-4, 12 (homonym *pro D. tiara* Holmes 1900, p. 701, pl. 38, fig. 4 = *Pseudodictyomitra tiara*). Yamasaki 1987, pl. 1, fig. 8.
Lithomitra regina var. *subconica* Campbell & Clark 1944a, p. 41, pl. 8, fig. 28.
Dictyomitra andersoni (Campbell & Clark). Emend. Foreman 1968, p. 68, pl. 7, fig. 6a-d; 1971, p. 1677, pl. 3, fig. 8; 1978, p. 746, pl. 4, fig. 6. Dumitrica 1973, p. 789, pl. 1, fig. 6; pl. 3, fig. 11; pl. 8, fig. 10. Johnson 1974, pl. 1, fig. 6, 7. Kozlova 1984, Table 1. Hollis 1991, p. 116, pl. 15, fig. 1-5; 1993a, p. 324. Strong *et al.* 1995, p. 205.
Dictyomitra urakawaensis Taketani 1982, p. 59, pl. 4, fig. 8a,b; pl. 11, fig. 16
? *Dictyomitra* spp. Iwata & Tajika 1986, pl. 2, fig. 2-5.
Pseudodictyomitra sp., Iwata & Tajika 1986, pl. 2, fig. 6.
Dictyomitra sp. 2, Ling & Lazarus 1990, p. 356, pl. 2, fig. 7,8.
Dictyomitra spp. cf. *D. andersoni* (Campbell & Clark). Hollis 1991, p. 117, pl. 15, fig. 6-11.

DESCRIPTION: Conical to fusiform test of 7-15 segments. Small imperforate spheroidal cephalis, rarely bearing an apical spine. Thorax, and rarely abdomen, imperforate, smooth. Apart from final segment which may be perforate, pores of subsequent segments restricted to a single row at strictures. Postcephalic segments medially inflated, with well-defined strictures; proximal segments increase more-or-less regularly in width but not in length; distal segments narrow. On each side 14-15 costae extend from thorax or abdomen to base of penultimate segment. Longitudinal rows of circular depressions usually occur between costae, giving costae a wavy appearance. Final segment inverted conical with a circular aperture, often with a peristome; lacks costae; imperforate and hyaline or with irregularly to regularly distributed polygonal pores.

REMARKS: Distinguished from *D. multicostata* by lacking segments which do not increase in length regularly, costae which do not extend on to the cephalis or the distalmost segments, and by having a constricted aperture, usually with a peristome. Usually intercostal depressions are more strongly developed in *D. andersoni* than in *D. multicostata*.

D. urakawaensis Taketani and the specimens figured by Iwata & Tajika (1986) are referred to *D. andersoni* because they have segments which do not increase regularly in size, and well-developed intercostal depressions. Rare specimens with proximally-inflated segments reminiscent of *D.* cf. *crassispina* Squinabol of Foreman (1968) are provisionally included. Similar forms were figured by Iwata & Tajika (1986, pl. 2, fig. 2-5). These differ from Foreman's species by lacking a distinct apical spine and an apertural tube

DISTRIBUTION: Southwest Pacific: RK9, common to few (WO, WH, CH, FX, MD, Mara, DSDP 275 & 208); RP1-6, common to few (WO, WH, CH, FX) or rare to very rare (MD, TX, DSDP 208). Widely distributed in the Late Cretaceous; occurs in possible Paleocene of California and in Early Paleocene of Hokkaido and the Volga region.

SOUTHWEST PACIFIC RANGE: RK9 to RP6, Mh to lDt, late Campanian-Maastrichtian to Late Paleocene.

Dictyomitra* aff. *rhadina Foreman
(Plate 16, Figures 17-20)

aff. *Dictyomitra rhadina* Foreman 1968, p. 66, pl. 7, fig. 5a, b.
Dictyomitra sp. A. Hollis 1991, p. 115, pl. 14, fig. 12-16.

DESCRIPTION: Moderately small, slender test of 6-7 segments. Spheroidal cephalis imperforate; very small apical spine may be present. Post-abdominal segments relatively long in relation to width, medially inflated, with distinct strictures between segments. On each side 10-12 costae extend from base of cephalis to base of final segment.

DIMENSIONS: (range of six specimens [mean]): length of seven segments = 212-228 µm; length of first six segments = 152-168 µm [161]; maximum width = 63-78 µm [72]; width of sixth segment = 63-76 µm [71].

REMARKS: This species differs from *D. rhadina* by its less narrow test, more conical and lobate outline, and fewer segments.

DISTRIBUTION: RK9-RP2, rare to very rare (WO, WH, FX, MD); RP3, very rare (FX).

RANGE: Upper RK9 to RP3, lMh to eDt, Maastrichtian to Early Paleocene.

Dictyomitra multicostata Zittel
(Plate 16, Figures 6-10)

Dictyomitra multicostata Zittel 1876 (*part.*), p. 81, pl. 2, fig. 2, 4 (not fig. 3). Campbell & Clark 1944a (*part.*), p. 39, pl. 8, fig. 42 (not 22-24; 29, 35). Foreman 1968, p. 64, pl. 7, fig. 4a, b. Emend. Pessagno 1976, p. 52, pl. 14, fig. 4-9. Ling & Lazarus 1990, p. 356, pl. 2, fig. 7, 8. Hollis 1991, p. 118, pl. 15, fig. 12-16; 1993a, p. 324. Strong *et al.* 1995, p. 205.
Dictyomitra cf. *multicostata* Zittel. Foreman 1968, p. 64, pl. 7, fig. 9a, b. Johnson 1974, pl. 1, fig. 3, 4.
Dictyomitra pseudoscalaris (Tan Sin Hok). Renz 1974, p. 791, pl. 8, fig. 5,6; pl. 11, fig. 34.

? *Dictyomitra densicostata* Pessagno 1975, p. 1017, pl. 5, fig. 1-3; 1976, p. 51, pl. 14, fig. 10-14, 16.
Archaeodictyomitra sp., Iwata & Tajika 1986, pl. 2, fig. 7.
Dictyomitra sp. A, Yamasaki 1987, pl. 1, fig. 21.

DESCRIPTION: Test conical throughout, or proximally conical and subcylindrical distally; 7-15 segments. Imperforate cephalis with thickened apex; lacks apical spine. Segments generally increase regularly in length, final segment may be considerably larger than preceding one and inverted conical. On each side 10-18 costae extend from base of cephalis to final segment. Intercostal depressions absent or very weak.

REMARKS: This species name is applied in the sense of Pessagno (1976), except that forms with segments that do not increase in length regularly (e.g. Campbell & Clark 1944a, pl. 8, fig. 22-24, 35) are placed in *D. andersoni* in accordance with Foreman's (1968) emended definition of that species. Forms with closely spaced rounded costae reminiscent of *D. densicostata* Pessagno are provisionally included (Pl. 16, Fig. 6).

DISTRIBUTION: Southwest Pacific: RK9, few to rare (WO, WH, FX, Mara, DSDP 275 & 208); RP1-3, few to very rare (WO, WH, CH, FX, DSDP 208); RP4-5, very rare (WO); RP4-5, isolated occurrences and may be reworked (DSDP 208). *D. multicostata* is widely distributed in the Late Cretaceous and recorded in the Paleocene of California and Hokkaido.

SOUTHWEST PACIFIC RANGE: RK9 to lower RP5, Mh to eDt, Maastrichtian to Early Paleocene.

Genus *MITA* Pessagno

Mita Pessagno 1977b, p. 44.

TYPE SPECIES: *Mita magnifica* Pessagno 1977b, p. 44, pl. 6, fig. 2, 5, 11, 13, 17; pl. 7, fig. 24; pl. 12, fig. 11 (OD). California, Cretaceous.

DIAGNOSIS: Conical, fusiform or subcylindrical test with continuous costae, not indented at joints between segments. Multiple rows of open pores on each post-cephalic segment.

RANGE: Early Cretaceous (Albian) to Early Paleocene.

Mita regina (Campbell & Clark)
(Plate 17, Figures 1-4, 10)

Lithomitra (Lithomitrissa) regina Campbell & Clark 1944a, p. 41, pl. 8, fig. 30, 38, 40.
Dictyomitra regina (Campbell & Clark). Emend. Foreman 1968, p. 68, pl. 8, fig. 5a-c. Johnson 1974, pl. 1, fig. 5.
Dictyomitra cf. *regina* (Campbell & Clark). Dumitrica 1973, p. 789, pl. 8, fig. 9. ? Riedel & Sanfilippo 1974, p. 778, pl. 15, fig. 1-3.
Archaeodictyomitra? *regina* (Campbell & Clark). Pessagno 1975, p. 1016, pl. 4, fig. 11, 12. Pessagno 1976, p. 49, pl. 14, fig. 1-3. Ling & Lazarus 1990, p. 355, pl. 2, fig. 1, 2.
Mita regina (Campbell & Clark). Taketani 1982, p. 60, pl. 5, fig. 3a, b; pl. 12, fig. 2. Iwata & Tajika 1986, pl. 2, fig. 9 (also fig. 8, 10). Hollis 1991, p. 119, pl. 16, fig. 1-5; 1993a, p. 324. Strong *et al.* 1995, p. 205.

DESCRIPTION: Slender conical to cylindrical test with a blunt apex and consisting of 6-14 segments. Cephalis small with small circular irregularly distributed pores. Subsequent segments increase gradually in size, except that last few narrow slightly. Strictures indistinct to absent. Costae extend from base of cephalis throughout length of test and separate longitudinal rows of circular pores which are not transversely aligned. Pore frames are circular on proximal segments, but become quadrangular on distal segments. Basal margin ragged.

REMARKS: The form figured by Dumitrica (1973) is considered to be an incomplete specimen of this species. Provisionally included are rare variants which flare distally, resulting in widely spaced costae (Pl. 17, Fig. 2, 4; see also Iwata & Tajika 1986, pl. 2, fig. 10). The species compared to *M. regina* by Riedel & Sanfilippo (1974) differs by having a distinctive bulge in the distal part of the test.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, WH, FX, MD, Mara, DSDP 275 & 208); RP1-3, rare to very rare (WO, WH, CH, FX, MD, DSDP 208); RP4-5, rare to very rare (WO, DSDP 208); isolated occurrence and may be reworked (TK). Campanian-Maastrichtian of California, Hokkaido, and Weddell Sea; Early Paleocene of Hokkaido.

SOUTHWEST PACIFIC RANGE: RK9 to lower RP5, Mh to eDt, Maastrichtian to Late Paleocene.

Mita cf. *regina* (Campbell & Clark)
(Plate 17, Figures 6-10)

Mita sp. A, Hollis 1991, p. 120, pl. 16, fig. 6-10.
? *Archaeodictyomitra*? sp., Takemura 1992, p. 744, pl. 3, fig. 1, 2.
? *Mita* sp., Strong *et al.* 1995, p. 209, fig. 10x.

DESCRIPTION: Small, bullet-shaped test of 5-7 segments, possibly more. Small cephalis is sparsely perforate, slightly offset from main axis. First 4-5 segments increase more or less regularly in size, distal segments narrow (not seen complete). Test outline may be smooth or lobate with strictures indistinct to distinct. On each side 9-11 continuous costae extend from cephalis to base of test. Longitudinal rows of 3-5 pores on post-thoracic segments, generally not transversely aligned.

REMARKS: Its small size, offset cephalis and lobate outline distinguish this species from *M. regina*.

Distribution: Southwest Pacific: RK9, rare (WO, WH, MD, Mara, DSDP 208); RP1-3, rare to very rare (WO, WH, CH, FX); RP4-5, rare (WO). A similar species with a smooth outline occurs in the Eocene at Mead Stream and Oligocene of the southern Indian Ocean (Takemura 1992).

Range: Upper RK9 to lower RP5, lMh to eDt, Maastrichtian to Late Paleocene.

Family PLECTOPYRAMIDIDAE Haecker

Plectopyramidae Haecker 1908, p. 457.
Plectopyramidinae Haecker, emend. Petrushevskaya 1971a, p. 986.

Diagnosis: Test of two segments. Small dome-shaped cephalis. Very large thorax forms an open pyramid or cone.

Genus *BATHROPYRAMIS* Haeckel

Bathropyramis Haeckel 1881, p. 428. Campbell 1954, p. D118. Petrushevskaya & Kozlova 1972, p. 551.

Type species: *Bathropyramis quadrata* Haeckel 1887, p. 1159, pl. 54, fig. 1 (*fide* Petrushevskaya & Kozlova 1972). Central Pacific, Recent.

Diagnosis: Small cephalis with or without apical spine. Thorax pyramidal, comprising a lattice of radial ribs joined by transversely aligned bars.

Remarks: Unlike the type species indicated by Campbell (1954: *B. acephala* Haeckel 1887, p. 1159) which was not illustrated, *B. quadrata* fulfils the requirement of the ICZN (69A), that preference should be given to a species that is adequately figured when designating a type species for a genus.

Bathropyramis sanjoaquinensis s.l. Campbell & Clark
(Plate 17, Figures 5, 11, 12)

Bathropyramis sanjoaquinensis Campbell & Clark 1944a, p. 22, pl. 7, fig. 2. Hollis 1991, p. 121, pl. 16, fig. 11-14; 1993a, p. 324. Strong *et al.* 1995, p. 205.
Bathropyramis? *sanjoaquinensis* Campbell & Clark. Petrushevskaya & Kozlova 1972, p. 551, pl. 7, fig. 20.
Bathropyramis sp., Dumitrica 1973, p. 789, pl. 4, fig. 8; pl. 10, fig. 2.
Bathropyramis spp., Riedel & Sanfilippo 1974, p. 775, pl. 3, fig. 9-11; pl. 14, fig. 9.
Cinclopyramis sp., Pessagno 1975, p. 1017, pl. 5, fig. 11, 12.
Cinclopyramis sanjoaquinensis (Campbell & Clark). Foreman 1978, p. 746, pl. 5, fig. 15, 23.
Bathropyramis campbelli Taketani 1982, p. 64, pl. 6, fig. 8a, b, 9; pl. 13, fig. 6. Iwata & Tajika 1986, pl. 3, fig. 5; pl. 7, fig. 3.

Description: Broad pyramidal test of two segments. Cephalis small, imperforate to sparsely perforate with a small apical spine. Thorax consists of 7-10 radial beams connected by 6-15 transversely aligned bars. Beams and bars very thick in upper part, both elements but bars in particular more slender in lower part of thorax. Upper openings are slit-like, becoming more broadly quadrangular distally. In well preserved specimens upper openings may be filled with a fine meshwork. Secondary radial beams develop in lower thorax.

Remarks: Typical *B. sanjoaquinensis* is characterised by a relatively small squat test with equally thick beams and bars, slit-like pores on the upper thorax, and without internal subdivisions. However in the Marlborough material it has proven impossible to delimit this species from its larger, more elegant counterpart characterised by subdivided openings and secondary radial beams (e.g. Pessagno 1975, pl. 5, figure 11 & 12). A range of variants between these two end-members is included here. Foreman's placement of *B. sanjoaquinensis* in *Cinclopyramis* suggests that specimens in her material possessed fenestrated pores, the feature Haeckel (1881, 1887) used to distinguish between the two genera.

Distribution: Southwest Pacific: RK9, rare (WO, WH, Mara, DSDP 275); RP1-RP3, rare (WO, WH, CH, FX, MD); RP4-RP6, rare to few (WO, CH, MD, TK, DSDP 208). *B. sanjoaquinensis s.l.* is widespread in the Late Cretaceous and occurs in the Early Paleocene of Hokkaido.

Southwest Pacific range: RK9 to RP6, Mh to lDt, late Campanian-Maastrichtian to Late Paleocene.

Genus *CORNUTELLA* Ehrenberg

Cornutella Ehrenberg 1838, p. 128. Emend. Nigrini 1967, p. 60.

Type species: *Cornutella clathrata* Ehrenberg 1838, p. 129; 1854, pl. 22, fig. 39a-c (*fide* Campbell 1954, p. D121). Barbados, Eocene.

Diagnosis: Cephalis reduced to eucephalic lobe. Thorax cone-shaped, pores longitudinally aligned.

Range: Jurassic (Takemura 1986) to Recent.

Cornutella californica Campbell & Clark
(Plate 17, Figures 13-15)

Cornutella californica Campbell & Clark 1944a, p. 22, pl. 7, fig. 33,34,42,43; Foreman 1968, p. 21, pl. 3, fig. 1a-c; Dumitrica 1973, p. 788, pl. 10, fig. 1; Renz 1974, p. 789, pl. 4, fig. 10,11; pl. 12, fig. 6,7; Taketani 1982, p. 65, pl. 6, fig. 6a,b, 7; pl. 13, fig. 7,8; Kozlova 1984, Tables 1, 2; Iwata & Tajika 1986, pl. 3, fig. 6; Ling & Lazarus 1990, p. 355, pl. 3, fig. 17. Hollis 1991, p. 122, pl. 16, fig. 15-18; 1993a, p. 324. Strong *et al.* 1995, p. 205.

Cornutella cf. *californica* Campbell & Clark. Petrushevskaya & Kozlova 1972, p. 551, pl. 30, fig. 10.
Cornutella sp., Dumitrica 1973, p. 788, pl. 9, fig. 2; pl. 13, fig. 1.

Description: Conical test. Cephalis tiny, largely enclosed in basal buttress of a sturdy elongate apical spine that is circular in cross-section throughout. Thorax varies from a narrow cone with well-separated pores to a widely flaring open meshwork. Pores longitudinally but not transversely aligned; circular proximally becoming polygonal distally.

Remarks: This species name is applied in the broad sense of Foreman (1968). The distinctions between *C. californica* and both the type species *C. clathrata* and the common recent species *C. profunda* Ehrenberg (sens. lat. Nigrini 1967) are by no means clear. None of the distinguishing features recommended by Foreman (1968) has been usefully employed in the present study, nor is it evident from records of the species that these features have been utilised by other workers. *C. californica* is said to differ from the other two species by exhibiting one or more of the following features: larger apical horn, subdivided proximal pores (i.e. internal meshwork), pores with marginal prongs, slightly spiny surface and/or more greatly flared thorax. Given the range of variation accepted for *C. profunda*, at least, these distinctions do not appear adequate for species-level discrimination, especially for one feature in isolation. It seem likely that stratigraphic rather than morphologic criteria have been applied by previous workers when identifying Late Cretaceous members of the genus as *C. californica*.

Distribution: Southwest Pacific: RK9, rare (WO, WH, FX, Mara, DSDP 275 & 208); RP1-5, rare to few (WO, WH, CH, FX, MD, KW, TK, DSDP 208); RP6-12, very rare (MD). Widely distributed in Late Cretaceous; Early Paleocene of California, Hokkaido and Volga region to West Siberia; Tropical Atlantic, Eocene-Oligocene.

Southwest Pacific range: RK9 to RP13, Mh to Ab, late Campanian-Maastrichtian to Middle Eocene.

Family NEOSCIADIOCAPSIDAE Pessagno

Neosciadiocapsidae Pessagno 1969, p. 392.

Diagnosis: Test of two segments. Cephalis bears vertical pore or vertical tube ("cephalopyle" of Pessagno). Thorax subconical proximally, flared distally to form a broad thoracic skirt. Mouth of thorax usually covered by a perforate or imperforate plate (thoracic velum).

Genus *NEOSCIADIOCAPSA* Pessagno

Neosciadiocapsa Pessagno 1969, p. 409.

Type species: *Neosciadiocapsa diabloensis* Pessagno 1969, p. 410, pl. 35, fig. 3-10; pl. 36, fig. 1 (OD). California, late Campanian.

Diagnosis: Sombrero-shaped test of two segments. Cephalis conical with sturdy apical horn and short obliquely upward-directed vertical tube. Thorax subconical proximally, flared distally. Velum convex in distal direction, sparsely perforate.

Remarks: Differs from *Sciadiocapsa* Squinabol by having an apical horn, and from *Microsciadiocapsa* Pessagno by having a stronger apical horn and velum which is arched rather than flat.

Range: Late Cretaceous to Early Paleocene (revised herein).

***Neosciadiocapsa jenkinsi* Pessagno**
(Plate 18, Figures 1,2)

Neosciadiocapsa jenkinsi Pessagno 1975, p. 1016, pl. 3, fig. 1-12. Hollis 1991, p. 123, pl. 17, fig. 1-3; 1993a, p. 324. Strong *et al.* 1995, p. 205.

Description: Large sombrero-shaped test. Cephalis sparsely perforate with short vertical tube and sturdy long apical horn, triradiate proximally, becoming smoothly conical distally. Collar stricture indistinct. Thorax rounded conical proximally, widely flared and almost discoidal distally. Thoracic wall consists of an open meshwork of circular to rounded hexagonal pores which increase in size from cephalis to base of conical part of thorax and then decrease towards the margin. Pores of conical part of thorax filled with fine meshwork. Velum moderately arched, perforate, almost entire on well-preserved specimens.

Remarks: This species differs from *N. diabloensis* by having a test of lower relief, the proximal thorax being more conical and the thoracic skirt very broad. Other distinguishing features noted by Pessagno (1975), such as thoracic ridges and shape of apical spine, have not been clearly observed.

Distribution: Southwest Pacific: RK9, rare to few, (WO, WH, MD, Mara, DSDP 275); RP1-RP3, few to very rare (WO, WH, CH, FX); RP4, very rare (WO). Uncertain identification in RP5 (TK).

Range: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Family EUCYRTIDIIDAE Ehrenberg

Eucyrtidina Ehrenberg 1847, p. 53 (*part.*).
Theoperidae Haeckel, Riedel 1967b, p. 296 (*part.*).
Eucyrtidiidae Ehrenberg, Petrushevskaya 1971a, p. 985 (*part.*); 1975, p. 578 (*part.*). Petrushevskaya & Kozlova 1972, p. 545.

DIAGNOSIS: Test usually consists of at least three well-differentiated segments (cephalis, thorax, and abdomen) and numerous additional segments, rarely only two segments. Cephalis small, usually spheroidal, imperforate to sparsely perforate; only eucephalic lobe is well-developed. Pores of thorax and subsequent segments are usually quincuncially arranged.

REMARKS: Although in common usage, the family name Theoperidae is not used here because Eucyrtidiidae has both priority and a more clearly defined type genus (*Eucyrtidium* Ehrenberg). Definition of the family has changed considerably since Petrushevskaya (1971b) first published an emended diagnosis. Usage here follows Petrushevskaya & Kozlova (1972), except that lychnocaniids are included (i.e. *Dictyophimus*) while archaeodictyomitrids are excluded. In these latter respects, usage mirrors that current for the Theoperidae (e.g. Sanfilippo *et al.* 1985). Earlier and subsequent classification schemes by Petrushevskaya (1971a,b, 1975, 1981) have included amphipyndacids, artostrobiids, plectopyramidiids, and pterocorythiids within the family.

Phylogenetic relationships remain poorly resolved within the group of species that Foreman (1968) placed in the eucyrtidiid genus *Stichomitra* with varying degrees of uncertainty. Because it is unlikely that these species represent a monophyletic group earlier attempts (e.g. Campbell & Clark 1944a) to split the group into separate genera are broadly supported here. *Stichomitra* is applied to species with a conical outline, inflated chambers, distinct strictures, and a relatively small cephalis, usually with an apical horn. Species included in the genus here are: *S. bertrandi* Cayeux (= *S. compsa* Foreman), *S. carnegiensis* (Campbell & Clark), *S.* cf. *carnegiensis* and *S. grandis* Campbell & Clark (= *S. asymbatos* Foreman). Other genera which have in the past been conflated with *Stichomitra* are discussed below.

Eucyrtidium (Ehrenberg 1847, *sens.* emend. Petrushevskaya 1971b, p. 215) is characterised by (1) a smooth fusiform test in which proximal segments increase gradually in size and distal segments decrease, (2) post-thoracic segments which lack external strictures but are instead delimited by internal ridges, (3) a relatively thin wall with numerous closely- and regularly-spaced pores, and (4) a cephalis which often has lateral and dorsal bars prolonged as ribs or furrows in the thoracic wall. Type species: *Lithocampe acuminata* Ehrenberg 1844, p. 84 (figured as *Eucyrtidium acuminatum* in Ehrenberg 1854, pl. 22, fig. 27. SD Frizzell & Middour 1951).

Lithostrobus Bütschli (1882, *sens.* Petrushevskaya & Kozlova 1972, p. 546) is characterised by a very narrow thorax and abdomen, numerous post-abdominal segments which increase gradually in size, and distinct strictures. *Lithocampe granulata* Petrushevskaya (1977) and *Stichomitra wero* Hollis (1993a) are ascribed to this genus here.

Four genera similar to *Stichomitra* were erected by Haeckel in 1881: *Artocapsa* (p. 438), *Eucyrtis* (p. 438) *Stichocapsa* (p. 439) and *Cyrtocapsa* (p. 439). Because Haeckel did not nominate type species or describe any constituent species until 1887, subsequent workers designated the first species allocated to these genera as types. Unfortunately for three of the genera, *Eucyrtis, Stichocapsa,* and *Cyrtocapsa*, the types were from Rüst's (1885) collection of Mesozoic radiolarians and unlikely to be closely related to the Cenozoic material upon which Haeckel based his descriptions. In the present study an attempt is made to apply these names in the original sense.

Artocapsa is characterised by a smooth fusiform test, a large spheroidal cephalis bearing a sturdy apical horn, and a basal spine. The large cephalis and broad triradiate basal spine of the type species indicate that it is not closely related to Cretaceous species ascribed to the genus by Tan (1927) and Campbell & Clark (1944a). Type species: *A. fusiformis* Haeckel 1887, p. 1519, pl. 76, fig. 5 (SD Campbell 1954, p. D143). Tropical Pacific, Quaternary.

Eucyrtis has been applied to species similar to *Lithostrobus*, except with rounded final segment, based on the very general original description and subsequent usage by Rüst (1885). However, Haeckel (1887) clearly considered the taxon to be the nominate subgenus within *Eucyrtidium*, and Campbell (1954, p. D140) was justified in treating the taxon as an objective synonym for *Eucyrtidium (Eucyrtidium)*. Indications by subsequent workers (Foreman 1973b, p. 264; Pessagno 1977b, p. 58; Petrushevskaya 1981, p. 179; Sanfilippo & Riedel 1985, p. 618) that this is a valid genus quite distinct from *Eucyrtidium* with type species *Eucyrtis conoidea* Rüst (1885, pl. 40, fig. 10) are not accepted here.

Cyrtocapsa is characterised by a fusiform test, a small spheroidal cephalis with an apical horn and a rounded final segment. Usage of the name was complicated when Haeckel (1887) subdivided the genus into two subgenera. Those with four segments were placed in *Cyrtocapsella* and those with five or more segments were placed in *Cyrtocapsoma*. Campbell (1954) persisted with this artificial separation, but treated the latter as an objective synonym of *Cyrtocapsa* because the type species (*C. ovalis* Rüst) appears to have 6 segments. Riedel & Sanfilippo (1970) were probably justified in elevating *Cyrtocapsella* to genus level. With its lobate outline, moderately large cephalis and large open pores, the type species *Cyrtocapsa (Cyrtocapsella) tetrapera* Haeckel (1887, p. 1512, pl. 78, fig. 5) is quite different from *C.*

ovalis. In fact, most of the species Haeckel (1887) ascribed to *Cyrtocapsa (Cyrtocapsoma)* (i.e. *Cyrtocapsa s.s.*) appear to bear closer resemblance to *Cyrtocapsella* (e.g. *C. chrysalium* Haeckel) than to *C. ovalis*, apart from having more segments. Nevertheless, here *Cyrtocapsa* is applied in the conservative sense of Campbell (1954). For reasons discussed below, both *Artocapsa livermorensis* and *Cyrtocapsa campi* (both of Campbell & Clark 1944a) are referred to the genus.

Stichocapsa (type species = Mesozoic *S. jaspidea* Rüst 1885, p. 317, pl. 41, fig. 6), however, appears to have been intended for quite a different group of species than indicated by both Rüst's type species and subsequent usage. All the species Haeckel (1887) ascribed to the genus are characterised by a broadly fusiform but markedly lobate outline due to very distinct strictures, a prominent spherical cephalis lacking an apical horn, and a closed inverted conical final chamber. These features are essentially the diagnostic criteria of *Lithocampe* and it is suggested here that *Stichocapsa* be treated as a junior synonym of *Lithocampe*.

Genus *CLATHROCYCLAS* Haeckel

Clathrocyclas Haeckel 1881, p. 434. Campbell 1954, p. D132. Petrushevskaya & Kozlova 1972, p. 540. Petrushevskaya 1975, p. 586.
Clathrocyclas (Clathrocyclia) Haeckel 1887, p. 1386.
Clathrocyclas (Clathrocycloma) Haeckel 1887, p. 1388.
Clathrocycloma Haeckel. Dumitrica 1973, p. 788. Foreman, 1973a, p. 434. Hollis 1993a, p. 322.

Type species: *Clathrocyclas principessa* Haeckel 1887, p. 1386, pl. 74, fig. 7 (SD Campbell 1954). Tropical Pacific, Quaternary.

Diagnosis: Campanulate test of 2-3 segments. Cephalis bears a sturdy apical horn, in many instances with a dorsal horn, and rarely with a vertical tube. Thorax narrowly conical to widely flared with a ragged margin. An incomplete flared abdomen may be present.

Remarks: Because a vertical tube is not a diagnostic feature of the genus, previous workers (Petrushevskaya & Kozlova 1972; Petrushevskaya 1975) placement of *Clathrocyclas* in the Neosciadiocapsidae is not supported here. The subgenus *Clathrocycloma* was erected by Haeckel (1887) to accommodate widely campanulate forms with two or more horns, and has subsequently been used erroneously as a generic name (e.g. Hollis 1993a).

Range: Paleocene to Recent.

Clathrocyclas australis n.sp.

(Plate 22, Figures 1-4)

Clathrocyclas? spp., Dumitrica 1973, p. 788, pl. 2, fig. 3; pl. 9, fig. 3; pl. 10, fig. 5.
Clathrocycloma sp. A., Hollis 1991, p. 136, pl. 20, fig. 13-16; 1993a, p. 322. Strong *et al.* p. 208, fig. 8P.

Description: Narrowly campanulate test of two segments. Spheroidal, regularly perforate cephalis with a slender, slightly curved, conical, apical horn. Thorax campanulate with a distinct shoulder separating upper and central parts; upper part conical with elliptical pores irregular in size and arrangement; central part cylindrical with circular to elliptical in 3-5 transverse rows; when present, basal part short, slightly to moderately flared with elliptical pores in 2-3 transverse rows. Basal margin ragged.

Dimensions: (range of seven specimens [mean]): total length (with horn) = 119-179 µm [139]; apical horn length = 7-22 µm [16]; cephalis length = 22-28 µm [24], width = 30-39 µm [33]; thorax length = 78-137 [101], width at shoulder = 61-78 µm [68], width at base = 81-110 µm (89).

Remarks: This species encompasses the range of variation shown by the specimens figured by Dumitrica (1973). It is distinguished from most other members of the genus by its campanulate thorax which has a distinctive cylindrical central part. *C. australis* is distinguished from the Maastrichtian species doubtfully ascribed to *Clathrocyclas* by Foreman (1968) by the lack of a vertical tube. Other distinguishing features are: *C ? diceros* has two basally connected apical horns and a conical thorax; *C ? lepta* also has a conical thorax; *C ? hyronia* has a thorax which lacks a distinct shoulder and is not flared distally. *C. australis* is distinguished from the Late Paleocene species *Diplocyclas pseudobicorona* Nishimura (1992), by the absence of a distinct corona on the thoracic shoulder (separating thorax and abdomen as used by Nishimura), and of a widely flared thoracic skirt; from the Late Paleocene subspecies *D. pseudobicorona teres* Nishimura (1992) by the absence of a strong apical horn and of a pronounced constriction below the thoracic shoulder.

Holotype and type locality: Rxxx (Pl. 22, Fig. 1); P30/f374 (WO74), RP4, Mead Hill Formation, Woodside Creek.

Distribution: Southwest Pacific: RP2, very rare WO, DSDP 208); RP3-6, rare to few (WO, CH, FX, MD, KW, TK, DSDP 208).

Range: RP2 to RP6, Dt, Early to Late Paleocene.

Genus *CYRTOCAPSA* Haeckel

Cyrtocapsa Haeckel 1881, p. 439. Campbell 1954, p. D143.
Cyrtocapsoma Haeckel 1887, p. 1514.

Type species: *C. ovalis* Rüst 1885, p. 50, pl. 42, fig. 11 (SD Campbell 1954). Germany, Jurassic.

Diagnosis: Multisegmented fusiform test with smooth to slightly lobate outline. Small cephalis bears an apical horn. Final chamber rounded, with a narrow aperture usually without a neck, tube, or basal spine.

Remarks: See remarks for family.

Range: Jurassic to Paleocene, possibly Quaternary. As discussed above, later members of the genus recorded by Haeckel (1887) may be more properly placed in *Cyrtocapsella* or a related genus.

Cyrtocapsa campi Campbell & Clark
(Plate 20, Figures 10-13)

- ? *Cyrtocapsa rottensis* Tan Sin Hok 1927, p. 67, pl. 14, fig. 121.
- *Cyrtocapsa campi* Campbell & Clark 1944a, p. 43, pl. 8, fig. 14-17, 20.
- *Stichomitra*? *campi* (Campbell & Clark). Foreman 1968, p. 75, pl. 8, fig. 3a-c. Johnson 1974, pl. 1, fig. 11, 12. Renz 1974, p. 797, pl. 11, fig. 16. Taketani 1982, p. 54, pl. 3, fig. 4a, b. Yamasaki 1987, pl. 2, fig. 7.
- ? *Stichomitra foraminosa* Taketani 1982, p. 55, pl. 3, fig. 5a-6b.
- ? *Stichomitra* sp. B, Taketani 1982, p. 56, pl. 3, fig. 7a-c.
- *Stichomitra campi* (Campbell & Clark). Hollis 1991, p. 132, pl. 19, fig. 15-18; 1993a, p. 324. Strong *et al.* 1995. p. 205.

Description: Small, fusiform test of 4-8 segments. Small, spherical cephalis bears a short apical horn. Strictures absent or weakly developed. Final segment hemispherical with small circular aperture, rarely with a short neck (e.g. Campbell & Clark, 1944a, pl. 8, fig. 16).

Remarks: Variation encountered within this species appears to encompass two similar morphotypes which were separated from *C. campi* by Taketani (1982) because of slight differences in size, stricture development, and arrangement and size of pores. Re-examination of another similar form described by Tan Sin Hok (1927) may show it to be the senior synonym of *C. campi*. *C. ovalis* is distinguished by a broader test and longitudinal alignment of post-thoracic pores.

Distribution: Southwest Pacific: RK9-RP3, rare (WO, WH, CH, FX, MD); RP4, very rare (WO). Albian-Turonian to Campanian-Maastrichtian in Indian Ocean, South Atlantic and Hokkaido; late Campanian to possible Paleocene in California.

Southwest Pacific range: Upper RK9 to RP4, lMh to eDt, Maastrichtian to Early Paleocene.

Cyrtocapsa livermorensis (Campbell & Clark)
(Plate 20, Figures 1-5)

- ? *Eusyringium niobeae* Tan Sin Hok 1927, p. 61, pl. 12, fig. 98-102.
- ? *Artocapsa bicornis* Tan Sin Hok 1927, p. 74, pl. 16, fig. 142. Renz 1974, p. 788, pl. 6, fig. 21-23; pl. 11, fig. 12a, b.
- ? *Artocapsa ultima* Tan Sin Hok 1927, p. 74, pl. 16, fig. 143; Renz 1974, p. 788, pl. 6, fig. 24; pl. 11, fig. 13.
- *Artocapsa livermorensis* Campbell & Clark 1944a, p. 45, pl. 8, fig. 10, 19, 21, 27.
- *Stichomitra*? *livermorensis* (Campbell & Clark). Foreman 1968, p. 76, pl. 8, fig. 2a, b. Dumitrica 1973, p. 789, pl. 2, fig. 9. Iwata & Tajika 1986, pl. 1, fig. 4 (also fig. 5, possibly fig. 7, 9). Yamasaki 1987, pl. 2, fig. 6.
- *Stichomitra liveromorensis* (Campbell & Clark). Hollis 1991, p. 131, pl. 19, fig. 6-14; 1993a, p. 324. Strong *et al.* 1995. p. 205.

Description: Fusiform test of 5-10 segments. Small cephalis bears sturdy apical horn. Outline smooth, except for weak collar stricture. Final chamber inverted conical to funnel shaped with a basal spine.

Remarks: This species is placed in *Cyrtocapsa* because it lacks the large cephalis of *Artocapsa* and appears closely related to *C. campi*, from which it differs by a stronger apical horn, less lobate segments, and a well developed basal neck and/or spine. Similar species were described by Tan (1927) from the Albian-Turonian of Rotti, Indonesia. Of these, *Artocapsa bicornis* and *A. ultima* differ only by having a slightly broader test, while *Eusyringium niobeae* differs by having an apertural tube rather than a basal spine extending from the final chamber. The distinction between an apertural tube and the neck-like termination of the final chamber in some specimens of *C. livermorensis* is arbitrary, and these latter may well conform with Tan's concept of *E. niobeae*.

Distribution: Southwest Pacific: RK9, rare (WO, WH, FX, MD, Mara, DSDP 275); RP1-RP3, rare (WO, WH, CH, FX, MD); RP4, very rare (WO, DSDP 208); RP5, isolated occurrence (CH). Campanian to Maastrichtian in California, S Atlantic, Shikoku (Japan), possible Paleocene in California; Early Paleocene in Hokkaido. Possibly Albian-Turonian in Indonesia and Indian Ocean.

Southwest Pacific range: RK9 to RP4, possibly RP5, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Genus *EUSYRINGIUM* Haeckel

Eusyringium Haeckel 1881, p. 437.

TYPE SPECIES: *Eusyringium conosiphon* Haeckel 1887, p. 1496, pl. 78, fig. 10 (SD Frizzell & Middour 1951, p. 35); Pacific, Quaternary?

DIAGNOSIS: Test of 2-3 segments. Small, subspherical cephalis typically bears an apical horn. Final segment usually pyriform with a narrow neck extending from the cephalis, widening distally and terminating with an apertural tube or siphon. An additional segment may be present in the neck directly below the cephalis.

REMARKS: The type species is almost certainly the junior synonym of the Eocene-Oligocene index species *E. fistuligerum*, indicating that the Challenger sample from which it was obtained was either of Paleogene age or contained reworked Paleogene material. Comparable species are unknown from Neogene or Recent sediments. Sanfilippo *et al.* (1985) prefer to restrict usage of this genus name to the two species comprising the *E. lagena* - *E. fistuligerum* lineage which they believe evolved from the *Sethochyrtis babylonis* group in the Middle Eocene. For this reason the species described below is only uncertainly placed in *Eusyringium*.

RANGE: Middle to Late Eocene; Early Oligocene in Northland, New Zealand (Hollis & O'Connor, 1994); possibly Late Cretaceous to Paleocene; possibly Neogene-Recent.

***Eusyringium*? *woodsidensis* n.sp.**
(Plate 18, Figures 3-7)

Eusyringium sp. A, Hollis 1991, p. 125, pl. 17, fig. 4-8.

DESCRIPTION: Pyriform test, usually of two segments. Small, spherical cephalis with few pores and no apical horn. Pores of subsequent segments quincuncial, and set in hexagonal frames. Final segment flask-shaped, with a narrow neck which expands abruptly or gradually into a ellipsoidal chamber, and is either closed basally or bears an apertural tube. An additional segment is in some cases present in the neck directly below the cephalis.

DIMENSIONS: (range of 14 specimens [mean]): total length = 147-285 μm [227]; maximum width = 77-138 μm [112]; cephalis diameter = 18-20 μm; thoracic neck length = 36-135 μm [67], width = 40-75 μm [57]; apertural tube length = 0-37 μm [20].

REMARKS: This species differs from other members of the genus by lacking an apical horn. As with *E. lagena*, an apertural tube is not always present. Absence of an apical horn and the phylogenetic consideration outlined under the genus preclude confident placement of this species in *Eusyringium*.

HOLOTYPE & TYPE LOCALITY: R992 (Pl. 18, Fig. 4); P30/f375 (WO75), RP4, Mead Hill Formation, Woodside Creek.

ETYMOLOGY: Refers to the type locality.

DISTRIBUTION: Southwest Pacific: RK9, rare (WO, WH, Mara); RP1-5, rare to very rare (WO, WH, CH, FX, DSDP 208); uRP5, very rare (TK, DSDP 208).

RANGE: RK9 to uRP5, Mh to lDt, late Campanian-Maastrichtian to Late Paleocene.

Genus *LITHOCAMPE* Ehrenberg

Lithocampe Ehrenberg 1838, p. 128. Campbell 1954, p. D140.

TYPE SPECIES: *Lithocampe radicula* Ehrenberg 1838, p. 130; 1854, pl. 22, fig. 23a (SD Campbell 1954). Barbados, Eocene.

DIAGNOSIS: Lobate test of 4-8 segments. Medium-sized spheroidal cephalis and large hemispherical thorax, always smaller than abdomen. Last segment closed or nearly closed.

REMARKS: This name is applied broadly to forms which may have a weak apical horn and a basal aperture with a tubular collar. Given a stratigraphic gap of some 30 m.y. it is thought unlikely that the species described below are closely related to similar species included in the Oligocene-Neogene genera *Stichocorys* and *Cyrtocapsella*.

RANGE: Late Cretaceous to Eocene.

***Lithocampe wharanui* n.sp.**
(Plate 18, Figures 8-10)

Lithocampe aff. *marinae* Gorbovetz. Dumitrica 1973, p. 789, pl. 6, fig. 2; pl. 8, fig. 7 (*non* Gorbovetz 1966).
Theoperid gen. *et* sp. indet., Johnson 1974, pl. 1, fig. 19, 20.
Stichomitra manifesta Foreman. Taketani 1982, p. 55, pl. 3, fig. 8a,b (*non* Foreman 1978).
Stichomitra compsa Foreman, Yamasaki 1987, pl. 2, fig. 5 (*non* Foreman 1968).
Lithocampe sp. A, Hollis 1991, p. 126, pl. 17, fig. 9-15.

DESCRIPTION: Test of up to five segments; first three comprising almost half total length, last 1-2 segments thinner-walled and often not preserved. Cephalis spherical, sparsely perforate, may be partly enclosed in thorax, rarely with a weak apical horn. Thorax large, hemispherical, and approximately equal in length to abdomen, but always narrower. Pores of thorax and abdomen small, circular with hexagonal frames, in close quincuncial arrangement consisting of 6-7 transverse rows on each segment. Hemispheroidal final chamber has a small aperture, usually without a collar.

DIMENSIONS: (range of 12 specimens [mean]): length of five segments (without horn) = 189-270 µm [224], first four segments = 164-230 µm [181], first 3 segments = 98-138 µm [118]; cephalis length = 10-20 µm [16], width = 20-33 µm [26]; thorax length = 36-56 µm [47], width = 56-83 µm [71]; abdomen length = 36-61 µm [52], width = 86-130 µm [107]; fourth segment length = 29-90 µm [57], width = 86-154 µm [117]; fifth segment width = 83-135 µm [115]; number of pore rows on thorax = 6-7 [7], on abdomen = 4-8 [7], on fourth segment = 4-11 [7].

REMARKS: Pores of this species are smaller and more densely distributed than in species assigned to *Lithocampe* by Petrushevskaya & Kozlova (1972, Petrushevskaya 1975). Some specimens resemble *Theocapsomma amphora,* but are distinguished by having a series of 2-3 post-thoracic segments rather than a single inflated abdomen. The thorax is considerably larger than that of *L. marinae* Gorbovetz (Kozlova & Gorbovetz 1966, pl. 15, fig. 10, 11).

HOLOTYPE AND TYPE LOCALITY: R949 (Pl. 18, Fig. 10); P30/f368 (WO56), RP1, Mead Hill Formation, Woodside Creek.

ETYMOLOGY: Wharanui is the local name for the area that includes the type locality and the Wharanui Point section, and is used as a noun in apposition.

DISTRIBUTION: Southwest Pacific: RK9, rare to few (WO, WH, Mara, DSDP 275); RP1-RP3, rare to few (WO, WH, CH, FX, MD, DSDP 208); RP4-5, very rare (WO, CH, MD, TK, DSDP 208). Indian Ocean, late Maastrichtian. Japan, Campanian-Maastrichtian.

SOUTHWEST PACIFIC RANGE: RK9 to uRP5, Mh to lDt, late Campanian-Maastrichtian to Late Paleocene.

Lithocampe* aff. *subligata Stöhr
(Plate 18, Figures 11-12)

aff. *Lithocampe subligata* Stöhr 1880, p. 102, pl. 4, fig. 1.
aff. *Lithocampe subligata* (Stöhr) gr., Petrushevskaya & Kozlova 1972, p. 546, pl. 25, fig. 7-10; Petrushevskaya 1975, p. 581, pl. 14, fig. 6-9, 12.
Theoperid gen *et* sp. indet., Johnson 1974, pl. 1, fig. 15.
Lithocampe sp. B, Hollis 1991, p. 127, pl. 17, fig. 16-18.

DESCRIPTION: Lobate test of five or more segments. First four segments increase regularly in size, thereafter number and size of segments variable. Last segment inverted campanulate with a perforate apertural neck.

DIMENSIONS: (range of three specimens): length of five segments = 220-350 µm; length of first three segments = 80-100 µm; cephalis diameter = 35 µm; thorax length = 25-40 µm, width = 50 µm; abdomen length = 40 µm, width = 70-80 µm.

REMARKS: Distinguished from *Lithocampe wharanui* n.sp. by smaller size of first three segments in relation to remainder of test, significantly smaller thorax with fewer rows of pores (3-4), and the presence of an apertural neck at the base. *L. subligata s.s.* is distinguished by the abdomen being the widest segment. The form described here may fall within the range of *L. subligata* gp (Petrusvskaya & Kozlova 1972; Petrushevskaya, 1975, pl. 14, fig. 6-9), the limits of which have not been defined.

DISTRIBUTION: Southwest Pacific: RK9, very rare (WO, Mara); RP1-4, very rare (WO). Indian Ocean, late Maastrichtian.

SOUTHWEST PACIFIC RANGE: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Genus *STICHOMITRA* Cayeux

Stichomitra Cayeux 1897, p. 204. Foreman 1968. p. 71 (*part.*). O'Dogherty 1994, p. 138 (*part.*).

TYPE SPECIES: *Stichomitra bertrandi* Cayeux 1897, p. 204, pl. 8, fig. 69 (SD O'Dogherty 1994). France, Late Cretaceous.

DIAGNOSIS: Multisegmented test with a relatively small cephalis and thorax. Cephalis usually bears an apical horn. Post-thoracic strictures distinct. Pores of thorax and subsequent segments quincuncially arranged.

REMARKS: O'Dogherty's (1994) designation of *S. bertrandi* as type species resolves much uncertainty relating to the status of this genus. The first species ascribed to *Stichomitra* by Cayeux (*S. costata*), and which Campbell (1954) indicated as type species, clearly belongs in *Dictyomitra*. O'Dogherty's (1994) modification of the generic description to admit only forms with a transverse division in the cephalis (i.e. = *Amphipyndax* herein), however, is not accepted. There is no indication that either the type species or the subjective synonym (*S. compsa* Foreman, see below) possess a subdivided cephalis.

RANGE: Cretaceous to Early Eocene.

Stichomitra bertrandi Cayeux
(Plate 20, Figures 6-9)

Stichomitra bertrandi Cayeux 1897, p. 204, pl. 8, fig. 69
Stichomitra compsa Foreman 1968, p. 72, pl. 8, fig. 8a, b; 1978, p. 748, pl. 5, fig. 3. Dumitrica 1973, p. 789, pl. 1, fig. 4; pl. 8, fig. 6. Kozlova 1984, Table 1. Hollis 1991, p. 130, pl. 19, fig. 1-4; 1993a, p. 324. Strong *et al.* 1995, p. 205.
? *Stichomitra communis* Squinabol. Taketani 1982, p. 54, pl. 3, fig. 9; pl. 11, fig. 5 (*non* Squinabol 1903).
? *Stichomitra* aff. *communis* Squinabol. Iwata & Tajika 1986, pl. 1, fig. 6.

Description: Narrowly conical test of 6-11 segments. Cephalis spheroidal, sparsely perforate with tiny apical and vertical horns. Thorax inflated, almost hemispherical, collar stricture moderately distinct, lumbar and subsequent strictures well-defined. Subsequent segments moderately inflated; proximal segments subtrapezoidal in outline, distal ones subcylindrical, final 1-2 segments narrow. Basal margin open, ragged. Pores of thorax and subsequent segments quincuncial in 3-4 rows (rarely 5).

Remarks: This definition follows that of *S. compsa* which is treated as a junior synonym of *S. bertrandi* following O'Dogherty's (1994) re-examination of the two species. *S. bertrandi* is distinguished from *S. communis* by its post-thoracic segments which are less inflated, have less incised strictures, and fewer rows of pores (see O'Dogherty 1994, p. 144, pl. 17, fig. 6-16 for a current concept of *S. communis*).

Distribution: Southwest Pacific: RK9, rare (WO, WH, FX, MD, Mara, DSDP 275 & 208); RP1-3, rare to very rare (WO, WH, CH, FX, MD); RP4, very rare (WO, DSDP 208). Widely distributed in the Late Cretaceous. Also occurs in possible Paleocene in California and Early Paleocene of Hokkaido and the Volga region.

Southwest Pacific range: RK9 to RP4, Mh to eDt, Maastrichtian to Early Paleocene.

Stichomitra grandis (Campbell & Clark), emend. herein
(Plate 19, Figures 1-4, ?5-6)

Cyrtophormis (Acanthocyrtis) grandis Campbell & Clark 1944a, p. 38, pl. 8, fig. 18, 39. = *Cyrtophormis (Phormostichoartus) grandis* in Campbell 1954, p. D139, fig. 71.7c.
Stichomitra asymbatos Foreman 1968, p. 73, pl. 8, fig. 10a-c. Dumitrica 1973, p. 789, pl. 2, fig. 2. Renz 1974, p. 797, pl. 11, fig. 21.
Stichocapsa asymbatos (Foreman). Petrushevskaya & Kozlova 1972, p. 546, pl. 8, fig. 1-3. Kozlova 1984, Table 2. Hollis 1991, p. 128, pl. 18, fig. 1-6; 1993a, p. 324. Strong *et al.* 1995, p. 205.
Stichomitra asymbatos Foreman gp, Riedel & Sanfilippo 1974, p. 780. pl. 10, fig. 1-4, pl. 15, fig. 5. (? pl. 10, fig. 5-7). Foreman 1978, p. 748, pl. 4, fig. 15.
Xitus? *asymbatos* (Foreman). Iwata & Tajika 1986, pl. 2, fig. 11, 12 (also pl. 3, fig. 1,2).

Description: Large lobate conical test of 6-10 segments, tending to become cylindrical distally. Cephalis spheroidal, smooth, imperforate, with thickened wall merging with base of apical horn; horn sturdy, conical, oblique to axis. Thorax usually smooth, imperforate apart from single rows of pores at well-defined collar and lumbar strictures; may have circular quincuncially-arranged pores in 4-5 rows. Abdomen and subsequent 2-7 segments increase regularly in size, pores quincuncial with thickened frames producing nodes or thorns at pore bar junctions. Subsequent segments subcylindrical, thinner-walled, without thickened pore-frames. Basal margin open and ragged.

Remarks: The definition is widened to accept the level of variation accorded to *S. asymbatos* by Foreman (1968). There is little doubt that the species described by Campbell & Clark (1944a) is equivalent to the most complete specimens of *S. asymbatos* encountered by Foreman (1968; e.g. pl. 8, fig. 10b) in which the final segment is "considerably longer than any...other" (*ibid* p. 74).

The characteristic surface ornament of this species is diagnostic of the Xitidae of Pessagno (1977b). However, *S. carnegiense* and a related form described below lack surface ornament, yet appear closely related to *S. asymbatos*. For this reason the Xitidae is not used here, and it is not considered appropriate to refer this species to the type genus *Xitus* as has been suggested by some authors. The relationship between *S. grandis* and the Late Jurassic to Early Cretaceous forms recorded by Riedel & Sanfilippo (1974, pl. 10, fig. 5-7) remains uncertain.

Distribution: Southwest Pacific: RK9, common to few (WO, WH, FX, MD, Mara, DSDP 275 & 208); RP1-3, few to rare (WO, WH, CH, FX, MD); RP4, very rare (WO). A similar species (Pl. 19, Fig. 5, 6), possibly a variant of *S. carnegiense*, is rare in RP5 (TK, DSDP 208). *S. grandis* is widely distributed in the Late Cretaceous and occurs in possible Paleocene in California and Early Paleocene in Hokkaido, Urals, and western Siberia.

Southwest Pacific range: RK9 to RP4, Mh to eDt, late Campanian-Maastrichtian to Early Paleocene.

Stichomitra carnegiense (Campbell & Clark)
(Plate 19, Figures 7-12)

Eucyrtidium (Eucyrtis) carnegiense Campbell & Clark, p. 42, pl. 8, fig. 36, 37.
Stichomitra sp. A, Dumitrica 1973, p. 789, pl. 3, fig. 9,10; pl. 8, fig. 5. Hollis 1991, p. 129, pl. 18, fig. 7-16.
Stichomitra warzigita (Empson-Morin). Taketani 1982, p. 56, pl. 3, fig. 10a,b; pl. 11, fig. 9 (*non* Empson-Morin 1981).
Stichomitra sp., Iwata & Tajika 1986, pl. 1, fig. 10 (also fig. 8).

Description: Large lobate conical test of 6-9 segments, tending to become cylindrical distally. Cephalis spheroidal, smooth, imperforate, with thickened wall merging with base of apical horn; horn sturdy, conical, oblique to axis. A single row of pores at collar stricture. Thorax, inflated, with circular pores quincuncial in 4-5 rows. Abdomen and subsequent 2-6 segments increase regularly in size; pores circular, quincuncial within regular subhexagonal frames; small thorns may arise from nodes at pore bar junctions. Basal margin open and ragged.

REMARKS: Distinguished from *S. grandis* and *S. warzigita* by the absence of nodes or spines at pore bar junctions on post-thoracic segments. Taketani's (1982) Cretaceous specimens (especially pl. 11, fig. 9) accord well with *S. carnegiense*.

DISTRIBUTION: Southwest Pacific: RK9, rare to few (WO, WH, FX, MD, Mara, DSDP 208); RP1-3, few to rare (WO, WH, CH, FX, MD, DSDP 208); RP4-5, rare (WO, MD, DSDP 208); RP6, very rare (MD). Hokkaido, Late Cretaceous and Early Paleocene.

SOUTHWEST PACIFIC RANGE: RK9 to RP6, Mh to lDt, late Campanian-Maastrichtian to Late Paleocene.

Stichomitra* cf. *carnegiense (Campbell & Clark)
(Plate 19, Figure 13-18)

? *Stichomitra* sp. B, Dumitrica 1973, p. 789, pl. 13, fig. 3.
Stichomitra sp. B, Hollis 1991, p. 130, pl. 18, fig. 17-20.

DESCRIPTION: Large conical test of 6-8 segments, with change of contour below abdomen. Cephalis spheroidal, smooth, imperforate, with thickened wall merging with base of apical horn; horn sturdy, conical, oblique to axis.

Single row of pores at collar stricture. First three segments inflated, widest medially, increase regularly in size; subsequent segments only slightly inflated, tending to be truncate conical, and increase slightly in width but not in length. Pores of thorax and subsequent segments circular, quincuncial, with regular subhexagonal frames; small thorns may arise from nodes at pore bar junctions. Basal margin open, ragged.

REMARKS: This species is distinguished from *S. grandis* by absence of nodes; and from *S. carnegiense* by the abrupt change of contour between the inflated abdomen and truncate-conical to cylindrical post-abdominal segments. Forms in which this change of contour is less pronounced, such as that figured by Dumitrica (1973), are provisionally included (Pl. 19, Fig. 17, 18).

DISTRIBUTION: Southwest Pacific: RK9, few (Mara); RP3-4, rare (WO); RP5, very rare (DSDP 208). This species has not been observed in the Cretaceous of Marlborough.

SOUTHWEST PACIFIC RANGE: RK9 to uRP5, Mh to lDt, late Campanian-Maastrichtian to Early Paleocene.

Genus *LITHOSTROBUS* Bütschli

Lithostrobus Bütschli 1881, p. 529. Haeckel 1887, p. 1469. Campbell 1954, p. D141. Petrushevskaya & Kozlova 1972, p. 546. = *Cyrtostrobus* Haeckel 1887, p. 1471.

TYPE SPECIES: *Eucyrtidium argus* Ehrenberg 1873, p. 225, 1875, pl. 9, fig. 1 (SD Campbell 1954). Barbados, Paleogene.

DIAGNOSIS: Narrowly conical multisegmented test. Small spheroidal cephalis bears an apical horn. Thorax and abdomen narrow, not greatly inflated, and trapezoidal in outline. Post-abdominal segments increase gradually in size. Strictures distinct. Basal margin open, ragged.

REMARKS: The distinction between this genus and *Stichomitra* is somewhat arbitrary. It appears likely that the species described below arose from a species of *Stichomitra* in the latest Cretaceous-earliest Paleocene.

RANGE: Cretaceous-Paleocene to Quaternary.

Lithostrobus wero (Hollis)
(Plate 20, Figures 14-17)

Lithostrobus sp., Petrushevskaya 1977, pl. 3i.
Lithostrobus spp., Iwata & Tajika 1986, pl. 8, fig. 2, 3.
Stichopodium? cf. *microporum* (Ehrenberg). Suyari & Yamasaki 1988, pl. 7, fig. 9 (probably also pl. 1, fig. 7; pl. 7, fig. 5,7).
Stichomitra wero Hollis 1991, p. 132, pl. 20, fig. 1-6; 1993a, p. 320, pl. 1, fig. 8, 9. Strong *et al.* 1995, p. 209, fig. 8H-I.

DESCRIPTION: Narrowly conical test, in many cases slightly curved, of at least ten segments. Small perforate cephalis bears slender apical horn and small vertical spine. Thorax and succeeding three or more segments slightly inflated, truncate conical, and gradually increasing in size. Distal segments annular, of more-or-less equal size. Pores of post-thoracic segments large, circular, set in hexagonal pore frames, and quincuncial in 3-4 rows per segment. Strictures weakly to moderately developed.

REMARKS: This species appears similar to the type species *L. argus*, but internal features of the latter remain obscure. *L. wero* is thought to be ancestral to *Buryella granulata* which differs by having a more fusiform test with thickened, irregularly nodular pore frames.

DISTRIBUTION: Southwest Pacific: RP2, very rare (WO, WH, FX, DSDP 208); RP3-4, common to rare (WO, CH, FX, MD, KW, DSDP 208); RP5-6, very rare (MD, DSDP 208). Early Paleocene of Hokkaido and Eocene of Shikoku. A possible Late Cretaceous record at DSDP 275 (Petrushevskaya 1977) may be due to downhole contamination (see discussion in Hollis 1993a).

SOUTHWEST PACIFIC RANGE: RP2 to RP6, Dt, Early to Late Paleocene.

Genus *BURYELLA* Foreman

Buryella Foreman 1973a, p. 433.

TYPE SPECIES: *Buryella tetradica* Foreman 1973a, p. 433, pl. 8, fig. 4, 5; pl. 9, fig. 13, 14 (OD). Gulf of Mexico, Paleocene-Eocene.

Diagnosis: Fusiform test of four or more segments. Cephalis bears sturdy apical horn and vertical tube or pore at collar stricture. At least one segment with pores in transverse rows; last segment not flared.

Remarks: Early Paleocene to earliest Oligocene (Hollis & O'Connor 1994)

Buryella granulata (Petrushevskaya)
(Plate 21, Figures 1-5)

? *Eusyringium royi* Frizzell & Middour 1951, p. 35, pl. 3, fig. 12, 13.
Lithocampe sp. A, Dumitrica 1973, p. 789, pl. 10, fig. 3; pl. 11, fig. 3.
Lithocampe? granulata Petrushevskaya 1977, p. 18, pl. 3, fig. a, b, v. Kozlova 1983, pl. 3, fig. 7; 1984, Table 1.
Eucyrtidium sp. A, Iwata & Tajika 1986, pl. 7, fig. 10, 11. Suyari & Yamasaki 1988, pl. 1, fig. 5, 6; pl. 7, fig. 4, 6.
Stichomitra granulata (Petrushevskaya). Hollis 1991, p. 134, pl. 20, fig. 7-12; 1993a, p. 321, pl. 1, fig. 10, 11. Strong *et al.* 1995, p. 209, fig. 8J.

Description: Fusiform test of 5-10 segments. Cephalis spheroidal with short apical horn; small vertical pore above collar stricture sometimes with vertical spine; dorsal and/or lateral bars may project outside thorax or lower segments as downward-directed spines or wings. Thorax and succeeding 2-3 segments, slightly inflated, truncate-conical. Central 1-2 segments inflated medially. Distal segments annular, tend to decrease irregularly in width and length. Pores of thorax and succeeding segments small, circular, irregularly to quincuncially arranged, with weak transverse alignment developing in distal segments; surrounded by irregular nodular pore frames. Final 1-2 segments may be thinner-walled with irregularly arranged unframed pores.

Dimensions: (range of 12 specimens): total length (with horn) = 150-200 µm; length of five segments (without horn) = 90-110 µm; maximum width = 70-80 µm.

Remarks: Petrushevskaya's (1977) illustrations of this species (from DSDP 208 material) clearly show the vertical pore that suggests a close relationship with the genus *Buryella*. This feature, together with weak transverse pore alignment, justify inclusion of the species in *Buryella*. My own examination of well-preserved specimens of *B. granulata, B. foremanae* and *B. dumitricai* from DSDP 208 as part of a re-examination of Dumitrica's (1973) DSDP 208 material leads me to conclude that *B. granulata* is the ancestral species of the genus, possibly evolving from *Lithostrobus wero* which appears to have a rudimentary vertical pore. These two species appear to have given rise to the *B. foremanae/ dumitricai* complex through reduction in number and increase in size of segments, widening of the test and strengthening of a vertical pore. The lateral spines on the upper thorax noted for *B. granulata* are also observed in *B. dumitricai* (see below).

B. granulata is distinguished from *L. wero* by thickened irregular pore frames and narrow distal segments; from *B. formanae* and *B. dumitricai* by irregular pore frames, a less lobate outline, and usually more numerous segments.

Foreman (1978, p. 748) erroneously synomised this species (*Lithocampe* sp. A of Dumitrica) with *Stichomitra asymmetra,* presumably because Dumitrica's figures do not show the vertical pore, but do show that the cephalis and apical horn are set slightly askew to the main axes of the test. However, this results in an asymmetric collar stricture, rather than the asymmetric lumbar stricture of *S. asymmetra.* A possible senior synonym of the species, *Eusyringium royi,* should be regarded as a *nomen dubium,* as it cannot be confidently identified from poor illustrations.

Distribution: Southwest Pacific: RP3, rare to common (WO, CH, FX, MD, DSDP 208); RP4-5, common to rare (WO, CH, MD, TK, DSDP 208); RP6-9, very rare (MD). Boreal Russia, Early Paleocene; Japan, Early Paleocene (Hokkaido) and Eocene (Shikoku).

Southwest Pacific range: RP3 to RP9, eDt to Dw, Early Paleocene to Early Eocene.

Buryella foremanae Petrushevskaya
(Plate 21, Figures 6-9)

Buryella sp. A, Dumitrica 1973, p. 789, pl. 1, fig. 1, pl. 4, fig. 1-4.
Buryella? foremanae Petrushevskaya 1977, p. 16, pl. 3, fig. d, e.
? *Buryella? alifera* Kozlova 1983, p. 93, pl. 3, fig. 3 (not fig. 1, 2), but pos. fig. 4, 5); Kozlova 1984, Tables 1, 2, pl. 12, fig. 18.
Eusyringium? sp., Iwata & Tajika 1986, pl. 6, fig. 1-4 (fig. 1, 2 are internal moulds).
Buryella foremanae Petrushevskaya. Hollis 1991, p. 137, pl. 21, fig. 1-6; 1993a, p. 322, pl. 1, fig. 12. Strong *et al.* 1995, p. 208, fig. 8K.

Description: Fusiform test of four segments. Outline lobate with well-defined strictures. Cephalis sparsely perforate with sturdy apical horn and horizontally-directed vertical tube, opening at collar stricture; lateral spines not observed. Thorax and abdomen inflated medially, increase progressively in size. Fourth segment narrower than abdomen, inverted conical to subcylindrical, of variable length, open basally; sometimes terminating in a short peristome. Pores of thorax and abdomen quincuncial, in 3-5 rows; those of fourth segment in 2-5 transverse rows.

REMARKS: It is not clear why Petrushevskaya hesitated to place this and the following species in *Buryella*, as both appear to fulfil the criteria for the genus. Moreover, the succession of species at DSDP 208 (which forms the basis of her descriptions) has all the hallmarks of an evolutionary lineage consisting of *B. granulata, B. foremanae, B. dumitricai, B. tetradica, B. petrushevskayae* (= *Buryella* sp. C of Dumitrica, 1973), and *B. pentadica* Foreman (see Hollis 1993a).

B. foremanae differs from *B. dumitricai* only by lacking an inflated fourth segment. Both species differ from most other members of the genus by having well-defined strictures which give the test a lobate outline. A similar species *B*? *alifera*, described from boreal Russia, is distinguished by an enlarged cephalis and well-developed lateral wings.

SOUTHWEST PACIFIC DISTRIBUTION: RP4-5, few to rare (WO, CH, MD, DSDP 208); RP6, very rare (MD). Hokkaido, Early Paleocene.

RANGE: RP4 to RP6, Dt, Early to Late Paleocene.

Buryella dumitricai (Petrushevskaya)
(Plate 21, Figures 10-13)

Buryella sp. B, Dumitrica 1973, p. 789, pl. 6, fig. 1; pl. 10, fig. 4,6; pl. 11, fig. 1.
Buryella? *dumitricai* Petrushevskaya 1977, p. 17, pl. 3g.
Buryella dumitricai Petrushevskaya. Hollis 1991, p. 138, pl. 21, fig. 7-12; 1993a, p. 323, pl. 1, fig. 13. Strong *et al.* 1995, p. 208, fig. 8L-M.

DESCRIPTION: Fusiform test of five segments. Outline lobate with well-defined strictures. Cephalis sparsely perforate with sturdy apical horn and horizontally-directed vertical tube, opening at collar stricture; lateral spines or wings rarely observed. Thorax and abdomen inflated medially, and increase progressively in size. Fourth segment similar in size to abdomen. Final segment narrower than fourth, inverted conical to subcylindrical, of variable length and open basally; sometimes terminating in a short apertural collar. Pores of thorax and abdomen quincuncial in 3-5 rows; those of fourth quincuncially or transversely arranged in 4-5 rows, those of fifth in 2-4 transverse rows.

SOUTHWEST PACIFIC DISTRIBUTION: RP4-5, few to rare (WO, CH, KW, TK, DSDP 208); RP6-7, very rare (MD).

REMARKS: RP4 to RP7, eDt to eDw, Early to Late Paleocene.

Buryella tetradica Foreman
(Plate 21, Figures 16-19)

Lithocampium sp. A, Riedel & Sanfilippo 1971, pl. 7, fig. 2.
Buryella tetradica Foreman 1973a, p. 433, pl. 8, fig. 4, 5; pl. 9, fig. 13, 14. Westberg *et al.* 1980, p. 431, pl. 1, fig. 9. Kozlova 1984, Tables 1,2, pl. 12, fig. 16; Sanfilippo *et al.* 1985, p. 668, fig. 14.3a,b; Nishimura 1987, p. 721, pl. 2, fig. 8; 1992, p. 329, pl. 10, fig. 18. Hollis 1991, p. 139, pl. 21, fig. 13-16; 1993a, p. 323. Strong *et al.* 1991, p. 208, fig. 8N, 9Q.
Buryella cf. *tetradica* Foreman. Dumitrica 1973, p. 790.
Buryella sp. C, Dumitrica 1973, p. 11, fig. 5, 7.

DESCRIPTION: Fusiform test of four segments with smooth outline. Cephalis spheroidal, sparsely perforate, with short apical horn and distinct vertical pore directly above indistinct collar stricture. Thorax inflated conical, with circular pores loosely quincuncial in three rows. Third segment largest, inflated medially, pores in 4-6 transverse rows; pores also longitudinally aligned. Final segment thinner, inverted truncate-conical, with circular to elliptical pores arranged in 2-7 transverse rows.

REMARKS: Longitudinal alignment of abdominal pores, and transverse alignment in some specimens, is poorly developed in early forms of this species (e.g. Pl. 21, Fig. 16; *Buryella* sp. C in Dumitrica 1973).

DISTRIBUTION: Southwest Pacific: RP5, common to abundant (WO, CH, MD, TK, DSDP 208); RP6-9, common to few (MD); RP11, rare to very rare (MD); earliest Oligocene, very rare (Northland). Widely distributed from Late Paleocene to earliest Eocene.

SOUTHWEST PACIFIC RANGE: RP5 to RP10, eDt to Dm, Late Paleocene to Early Eocene in Marlborough; *Cryptocarpium ornatum* Zone, eLwh, earliest Oligocene in Northland.

Buryella kaikoura **n.sp.**
(Plate 21, Figures 14, 15)

Buryella tetradica Foreman. Hollis 1991 (*part.*), p. 139; 1993a (*part.*), p. 323.
Buryella sp., Hollis 1991, p. 139, pl. 21, fig. 17.

DESCRIPTION: Fusiform test of four segments with smooth outline. Cephalis ellipsoidal, sparsely perforate with short apical horn and distinct vertical pore directly above indistinct collar stricture. Thorax inflated conical with circular pores loosely quincuncial in three rows. Third segment largest, inflated medially, pores quincuncial in 5-7 rows. Final segment thinner, rarely preserved, inverted truncate-conical with circular to elliptical pores arranged in at least two transverse rows.

DIMENSIONS: (range of seven specimens): length of first three segments = 110-138 µm [123]; apical horn length = 5-9 µm [7]; cephalis length = 7-12 µm [10], width = 15-25 µm [21]; thorax length = 32-39 µm [35], width = 42-69 µm [60]; abdomen length = 61-91 µm [77], maximum width = 96-120 µm [105], basal width = 54-86 µm [71]; number of pore rows on thorax = 4-5 [4], on abdomen = 6-8 [7].

REMARKS: Distinguished from *B. tetradica* by regular quincuncial arrangement of abdominal pores (i.e. not longitudinally aligned); from *B. foremanae* by smooth outline, more rows of pores on the abdomen and a delicate fourth segment that has, as yet, not been observed intact; from *B. clinata* by a broader test, a much weaker apical horn, and by not having abdominal pores arranged in distinct diagonal rows.

HOLOTYPE AND TYPE LOCALITY: R986 (Pl. 21, Fig. 14); P30/f461 (WO25) RP5, Mead Hill Formation, Woodside Creek.

ETYMOLOGY: Kaikoura is the informal name for the coastal area which includes the type locality and is bounded by Kaikoura township to the south and Cape Campbell to the north. It is used as a noun in apposition.

DISTRIBUTION: RP5, rare to few (WO, CH DSDP 208).

RANGE: RP5, Dt, Late Paleocene.

Genus *DICTYOPHIMUS* Ehrenberg

Dictyophimus Ehrenberg 1847, p. 54. Emend. Nigrini 1967, p. 66. Petrushevskaya & Kozlova 1972, p. 553. Petrushevskaya 1975, p. 583; 1981, p. 234. *Non* Campbell 1954, p. D122.

TYPE SPECIES: *Dictyophimus crisae* Ehrenberg 1854, p. 241, not figured but see Petrushevskaya 1975, pl. 25, fig. 8 (by subsequent monotypy). Barbados, Eocene. (= *Lychnocanium arabicum* Ehrenberg 1872, pl. 10, fig. 3).

DIAGNOSIS: Conical test of 2-3 segments. Cephalis with apical horn. Dorsal and lateral cephalic bars form three ribs in thoracic wall, and extend as lateral wings from lower part of thorax. Thorax may not be distinctly separated from abdomen.

REMARKS: Distinguished from similar genera by a conical thorax which is usually not distinctly separated from the abdomen. In *Pterocyrtidium* Bütschli the thorax is almost spherical; in *Rhopalocanium* lateral spines extend from the abdomen; in *Pterocanium* Ehrenberg the thorax is more inflated with smaller and more numerous pores. The pterocorythid genus *Pterocorys* is distinguished by its elongate lobed cephalis.

Dictyophimus* aff. *archipilium Petrushevskaya
(Plate 22, Figures 5-7)

Dictyophimus? spp., Dumitrica 1973, p. 788, pl. 7, fig. 3-6, 8, 9; pl. 8, fig. 4; pl. 12, fig. 6, 7. Hollis 1991, p. 137, pl. 20, fig. 17-20; 1993a, p. 322.

aff. *Dictyophimus archipilium* Petrushevskaya 1975, p. 583, pl 25, fig. 1, 2.

DESCRIPTION: Small subconical test of three segments. Spheroidal perforate cephalis with a short apical horn. Thorax conical, and broadly triangular in section. Lateral ribs extending as wings from lower part of thorax, and connected to abdomen by 2-3 bridges. Lumbar stricture well-defined externally, but no internal septum between thorax and abdomen. Pores of thorax circular, and quincuncial in 3-4 rows. Abdomen subcylindrical, thin-walled, with circular pores in loose longitudinal alignment, open basally.

REMARKS: As with the Miocene *D. archipilium*, this species is distinguished from *D. hirundo* (Haeckel) by its small size and weak apical horn. It differs from *D. archipilium* by having a more distinct lumbar stricture and stronger wings, usually with distinctive bridges.

SOUTHWEST PACIFIC DISTRIBUTION: RP1, uncertain record (WO); RP3, very rare (WO, MD); RP4-5, few to rare (WO, CH, MD, DSDP 208); RP6, rare (MD).

RANGE: RP3 to RP6, Dt, Early to Late Paleocene.

Dictyophimus* aff. *pocillum Ehrenberg
(Plate 22, Figures 10, 11)

aff. *Dictyophimus pocillum* Ehrenberg 1873, p. 223; 1875, pl. 5, fig. 6. Petrushevskaya & Kozlova 1972, p. 553, pl. 29, fig. 5. O'Connor 1993, p. 72, pl. 7, fig. 28-30.

Dictyophimus sp., Dumitrica 1973, p. 788, pl. 7, fig. 8; pl. 9, fig. 8.

Clathrocycloma spp. gr. B., Hollis 1991 (*part.*), p. 136; 1993a, p. 322.

DESCRIPTION: Large broadly conical test of two segments. Large spheroidal cephalis, perforate, with 3 horns; a central long apical horn and two shorter symmetrically placed secondary horns; dorsal and lateral bars extend as wings from lower thorax. Thorax campanulate, with subcylindrical sides directly below base of wings, flaring distally; ragged basal. Thoracic pores circular in loosely quincuncial polygonal frames proximally; larger, forming open hexagonal meshwork distally.

REMARKS: Distinguished from Eocene-Oligocene *D. pocillum* by the distinctive arrangement of apical horns.

SOUTHWEST PACIFIC DISTRIBUTION: RP4, very rare (WO, DSDP 208); RP5, very rare (WO, CH, DSDP 208).

Southwest Pacific range: uRP4 to uRP5, lDt, Early to Late Paleocene.

Family TRISSOCYCLIDAE Haeckel

Trissocyclida Haeckel 1881, p. 446; 1887, p. 986.
Acanthodesmiidae Haeckel. Riedel 1967b, p. 296 (*non* Haeckel 1881).
Trissocyclidae Haeckel, emend. Goll 1968, p. 1416.
Spyrida Ehrenberg, emend. Petrushevskaya 1971a, p. 990.

Diagnosis: Test of 1-2 segments. Enlarged cephalis with apical, vertical, and median bars combined to form a sagittal ring separating two latticed chambers.

Remarks: Paleocene to Recent.

Genus *DORCADOSPYRIS* Haeckel, emend. Goll 1969

Dorcadospyris Haeckel 1881, p. 441; 1887, p. 1040. Campbell 1954, p. D112. Goll 1969, p. 335.

Type species: *Dorcadospyris dentata* Haeckel 1887, p. 1040, pl. 85, fig. 6 (SD Campbell 1954). Tropical Pacific, Quaternary.

Diagnosis: Test consists of bilobed cephalis with nine or more basal spines or feet, and an odd number of basal pores.

Remarks: Paleocene to Recent.

Dorcadospyris* aff. *confluens (Ehrenberg)
(Plate 22, Figures 13-16)

Petalospyris confluens Ehrenberg 1873, p. 146; 1875, pl. 22, fig. 5.
Dorcadospyris confluens (Ehrenberg). Goll 1969, p. 337, pl. 58, fig. 9-12, text-fig. 2.
Acanthodesmids, gen. *et* spp. indet. (*part.*), Dumitrica 1973, p. 788, pl. 9, fig. 5.
Spyrida fam., gen. *et* spp. indet., Hollis 1991, p. 141, pl. 21, fig 19, 20; 1993a, p. 323. Strong *et al.* 1995 (*part.*), p. 209.

Description: Small bilobed test with 9-12 basal spines. Cephalis with very weak apical horn and five basal pores, three large and two small. Lattice pores large, circular, in polygonal frames with small thorns at pore bar junctions. Basal feet divergent, smooth, bladed, and may be connected by smooth, imperforate shell material; rarely connected by latticed meshwork of a rudimentary thorax.

Remarks: Distinguished from Eocene *D. confluens* by a wider, more lobate cephalis with a weaker apical horn and larger pores in a more open lattice, and by divergent feet.

Southwest Pacific distribution: RP2-3, very rare (WO, FX, MD); RP4-5, rare to few (WO, CH, MD, TK); RP6, very rare (MD).

Remarks: RP2 to RP6, eDt to lDt, Early to Late Paleocene.

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APPENDICES

APPENDIX 1

Sample details. Explanation. *Catalogue numbers*: RA = University of Auckland, RD = Institute of Geological & Nuclear Sciences (IGNS), Lower Hutt, NZFR = New Zealand fossil record file. *Lithology*: LST = limestone, PRC = porcellanite, CHT = chert, MST = mudstone; colour: l,m,d = light, medium, dark; gy = grey, yl = yellow, gn = green, bn = brown, pp - purple; pk = pink, cm = cream, wh = white, bk = black; carbonate content: s./m./v.calc = slightly/moderately/very calcareous; other: sil - siliceous, cht nod = chert nodule, lam = laminated, biot. = bioturbated, vn = veined.

A/P (Abundance/Preservation, defined in Section 1.4): B = barren; R = rare, F = few, C = common, A = abundant; P = poor, M = moderate, G = good, SS = number of strewn slides: PS = number of picked faunal slides; SM = number of SEM stubs. For Flaxbourne River samples F2nn = IGNS foraminiferal catalogue number.

WOODSIDE CREEK

Field #	Curation # AU	NZFR# P30/f	Metres ± KTB	Lithology	Radiolaria A/P	SS	PS	SM	AGE
WO27	RA199	767	-32	LST l.yl-gy, m.calc, sil	CM				
WO28	RA198	363	-30	LST l.gn-gy, m.calc, sil	AM	4	2	1	RK9
WO30	RA197	768	-20	LST l.gn-gy, v.calc, sil	RP				
WO31	RA196	364	-18	LST l.yl-gy, v calc, sil,lam	AM	4	1	2	RK9
WO32	RA185	769	-16	LST l.gn-gy, m.calc, sil	B				
WO33	RA184	770	-14	LST l.gn-gy, v.calc, sil	RP				
WO34	RA183	771	-13	LST m.gn-gy, v.calc, sil	RP				
WO35	RA182	772	-12	LST l.gn-gy, v.calc; cht nod	RP				
WO36	RA181	773	-11	LST m.gn-gy, v.calc, sil	B				
WO37	RA180	365	-10	LST l.gn-gy, v.calc, sil	CM	2	1	1	RK9
WO38	RA179	774	-9	LST l.gn-gy, v.calc, sil	B				
WO39	RA178	775	-8	LST m.gn-gy, m.calc; cht nod	RP				
WO40	RA169	776	-7	LST l.gn-gy, v.calc, sil	FP				
WO41	RA168	777	-6.1	LST m.gn-gy, m.calc, sil	B				
WO42	RA167	778	-5.1	LST m.gn-gy, m.calc, sil	CP				
WO43	RA166	779	-4.1	LST m.gn-gy, v.calc, sil	RP				
WO44	RA165	780	-3.6	LST m.gn-gy, m.calc, sil	FM		1		RK9
WO45	RA159	781	-3	LST m.gn-gy, v.calc, sil	RP				
WO46	RA158	782	-2.4	LST m.gn-gy, m.calc, sil	RM				
WO47	RA157	783	-2	LST m.gn-gy, m.calc, sil	RP				
WO01	RA771	784	-1.4	LST l.gn-gy, v.calc, sil	RP				
WO48	RA156	366	-0.9	LST l.gn-gy, v.calc, sil	FG	4	1		RK9
WO49	RA155	785	-0.6	LST l.gn-gy, v.calc, sil	RM				
WO02	RA772	786	-0.4	LST l.gn-gy, v.calc, sil	RP				
WO03	RA773	787	-0.4	LST l.gn-gy, v.calc, sil	RP				
WO04	RA774	455	-0.2	LST l.gn-gy, v.calc, sil	FM	2	1	1	RK9
WO50	RA154	788	-0.1	LST l.gn-gy, v.calc, sil	RP				
WO51	RA153	607	0.005	PRC d.gy, sl.calc, lam	RM		1		RK9
WO52	RA239	789	0.2	PRC m.gy, m.calc, sil, lam	RM				
WO53	RA240	456	0.5	PRC m.gy, m.calc, sil, lam	RM				RP1
WO54	RA241	367	0.9	PRC m.gy, m.calc, sil, lam	RM		1		RP1
WO55	RA258	790	1.5	PRC m.gy, m.calc, sil, lam	RM				
WO56	RA259	368	2	PRC l.gn-gy, m.calc, sil	CG	6	1	1	RP1
WO57	RA260	791	2.5	PRC l.gn-gy, m.calc, sil	RM				
WO58	RA281	608	3	PRC l.gn-gy, m.calc, sil	CM	2	1		RP1
WO59	RA282	609	4	PRC l.gn-gy, m.calc, sil	RP				
WO60	RA283	369	5	PRC l.yl-gy, m.calc,sil; cht	CG	2	1		RP2
WO61	RA301	457	6	PRC l.yl-gy, m.calc, sil	CM	2	1		RP2
WO62	RA302	370	7	PRC l.yl-gy, m.calc, sil	CG	2	1		RP2
WO63	RA303	610	8	PRC l.bn-gy, m.calc,sil; cht	RP				
WO65	RA361	371	9	LST l.gn-gy, v.calc, sil	AG	2	1	2	RP2
WO66	RA362	611	10	LST l.gn-gy, v.calc, sil	CG		1		RP3
WO67	RA363	792	12	LST l.gn-gy, v.calc, sil	B				

WOODSIDE CREEK

Field #	Curation #	NZFR#	Metres	Lithology	Radiolaria				
	AU	P30/f	± KTB		A/P	SS	PS	SM	AGE
WO68	RA364	458	13	LST l.gn-gy, v.calc, sil	CG	2	1		RP3
WO69	RA365	372	14	LST l.gn-gy, v.calc, sil	AG	2	1	2	RP3
WO70	RA366	793	19	LST l.gn-gy, v.calc; vn	FG				
WO71	RA375	794	22	LST l.gn-gy, v.calc	RM				
WO72	RA376	373	24	LST l.pp-gn-gy, v.calc, sil	CG	2	1		RP3
WO73	RA377	795	25	LST l.pp-gy, v.calc, sil					
WO74	RA378	374	27	LST l.gn-gy, v.calc, sil	CG	2	1	1	RP4
WO75	RA379	375	31	LST m.pp-gy, v.calc	AG	2	1	1	RP4
WO19	RA890	459	33	LST m.pp-gy, v.calc	AG	4			RP4
WO20	RA891	796	33.5	LST m.pp-gy, v.calc	CG				
WO21	RA892	797	34	LST m.pp-gy, v.calc	CG				
WO22	RA893	798	34.5	LST m.pk-gy, v.calc, biot	CG				
WO76	RA387	799	35	sLST m.pk-gy, v.calc	RM				
WO23	RA894	460	35.5	sLST m.pk-gy, v.calc, biot	CG	4			RP4
WO77	RA388	800	36.5	sLST l.pk-gy, v.calc	RG				
WO24	RA895	801	37	sLST m.pp-gy, v.calc	RG		1		RP4
WO78	RA389	376	38	sLST l yl-bn, v.calc	RM		1	1	RP5
WO25	RA896	461	38	sLST l yl-bn, v.calc	FG	4		1	RP5
WO26	RA897	802	39	sLST l yl-bn, v.calc	RM				

WHARANUI POINT

Field #	Curation #	NZFR #	Metres	Lithology	Radiolaria				
	RA/	P30/f	±KTB		A/P	SS	PS	SM	AGE
WH09	794	868	-60	CHT bk nod; l.gy, s.calc rim	CM	2			RK9
WH08	795	462	-40	CHT bk nod; l.gy, s.calc rim	CM	2			RK9
WH07	796		-10	LST l.gn-gy, m.calc sil	B				
WH06	797		-5	LST l.gy, m.calc sil	RP				
WH05	798		-0.2	LST l.gy, v.calc	RP				
WH10	799		0.01	PRC dk gy, s.calc	B				
WH04	800	463	0.2	PRC md gy, m.calc, sil, lam	FM		1		RP1
WH03	801	464	1	PRC yl-gn m.calc, sil	FM	2			RP1
WH02	802	465	2	PRC yl-gn m.calc, sil	CM	2			RP1
WH01	803	466	4	PRC gn-gy, m.calc, sil	FM	2			RP2

CHANCET ROCKS

Field #	Curation #	NZFR #	Metres	Lithology	Radiolaria				
	AU	P29/f	±KTB		A/P	SS	PS	SM	AGE
CH01	804		-15	LST gn-gy, v.calc, s.sil	CM				
CH02	805		-12	LST gn-gy, v.calc, s.sil	CM				RK9
CH03	806		-9	LST gn-gy, v.calc	B				
CH04	807		-7	LST gn-gy, v.calc	B				
CH05	808		-5.5	LST pk-gy, v.calc	B				
CH06	809		-1.5	LST pk-gy, v.calc	B				
CH07	810		-0.5	LST gn-gy, v.calc; cht nod	RP				
CH08	789	500	0.1	PRC dk gy, s.calc, lam	FM		1		RP1
CH09	790	387	0.5	PRC gn-gy, m.calc, sil	FM	2			RP1
CH10	791	388	1.5	PRC gn-gy, m.calc, sil	CM	2			RP2
CH11	792		2	CHT bk, l.gy, s.calc rim	RM				
CH12	793	389	4	CHT bk, l.gy, s.calc rim	FM	2			RP3
CH13	814		6	PRC l.gn-gy, m.calc, sil	FM				
CH14	815		8	PRC l.gn-gy, m.calc, sil	RM				
CH15	816		9	PRC l.gn-gy, m.calc, sil	FM				
CH16	817	390	10	LST gn-wh, v.calc	FM				
CH17	818		11	LST gn-wh, v.calc	FM	2			RP3
CH18	819		13	LST pk-gn, v.calc, bn cht nod	B				

CHANCET ROCKS

Field #	Curation #	NZFR #	Metres	Lithology	Radiolaria				
	AU	P29/f	±KTB		A/P	SS	PS	SM	AGE
CH19	820		14	LST pk, v.calc, biot	B				
CH20	821		16	LST pk, v.calc	B				
CH21	822		18	LST cm-wh, v.calc	B				
CH22	823		20	LST pk, v.calc	B				
CH23	824		21	LST pk to gn-gy, v.calc	B				
CH24	825		22	LST wh, v.calc	B				
CH25	884		24	LST wh, v.calc	B				
CH26	885		27	LST wh, m.calc, sil	FG				
CH27	886	391	30	LST l.gn-gy, m.calc, sil	CG	2			RP5
CH28	887		36	LST wh, v.calc	RG				
CH29	888	392	38	LST wh, v.calc	FG	2			RP5
CH30	889		41	LST wh, v.calc	FG				

FLAXBOURNE RIVER

Curation #s		NZFR #	Metres	Lithology	Radiolaria				
GNS Foram	AU/GNS Rad	P29/f	±KTB		A/P	SS	PS	SM	AGE
F27670	RA789	250	-8.7	LST					
F27671	RA752	251	-7.3	LST yl-gy, v.calc	FM		1		RK9
F26316	RA753	253	-1.4	LST yl-gy, v.calc	CM		1		RK9
F27673	RA754	254	-1.2	LST yl-gy, v.calc	AM	2			RK9
F26315	RD310	235	-0.07	MRL	CM				
F27689	RD311	280	-0.02	MRL	CM				
F27690	RD312	281	0	PRC	CP		1		RK9
F27688	RD313	279	0.003	PRC	RP		1		RP1
F26313	RD314	278	0.005	PRC	FP				
F27687	RD315	277	0.03	PRC md-gy, s.calc	FP		1		
F27686	RD316	276	0.04	PRC	FP		1		RP1
F26312	RD317	275	0.05	PRC	CM		1		RP1
F27685	RD318	274	0.07	PRC	FM				
F26311	RD319	273	0.09	PRC	RM				
F27683	RA756	271	0.12	PRC l.gy, m.calc	B				
F27682	RA757	270	0.14	PRC l.gy, m.calc	CM	2			RP1
F27681	RA758	269	0.16	PRC l.gy, m.calc	B				
F26309	RA759	268	0.18	PRC l.bn-gy, m.calc	FM				
F26308	RA760	267	0.20	PRC l.bn-gy, m.calc	FM				
F26307	RA761	266	0.22	PRC l.bn-gy, m.calc	CM	2			RP1
F26306	RA762	265	0.33	PRC l.gn-gy, m.calc	FM		1		RP1
F26305	RA763	264	0.40	PRC l.gn-gy, m.calc	FM		1		RP1
F26304	RA764	263	0.50	PRC l.gy, m.calc	FM		1		RP1
F27679	RA765	261	1.1	PRC l.gy, m.calc	RM				
F26303	RA766	260	1.4	PRC l.gy, s.calc	AG	2			RP2
F27678	RA767	259	1.8	PRC l.gy, s.calc	FG				
F28811	RA781	412	2.5	PRC n. calc.	CM	3			RP3
F27677	RA768	258	2.7	PRC l.gy, s.calc	AG	2			RP3
F27676	RA769	257	3.3	PRC yl-gy, n.calc	FM				
F27675	RA770	256	3.9	PRC yl-gy, n.calc	CM	2	1		RP3
F28812	RA782	413	4.5	PRC s. calc	CM	3			RP3
F27674	RA771	255	4.7	PRC gy-wh, m.calc	FM		1		RP3
F28813	RA783	414	8.5	PRC s. calc	FM		1		RP3
F28814	RA784	415	11	LST m. calc.	CG	3	1		RP3
F28815	RA785	416	11.5	LST v.calc	RG		1		RP5
F28816	RA786	417	25	LST v.calc	RG		1		RP5
F28817	RA787	418	30	MRL v.calc	RP		1		RP5
F28818	RA788	419	38	MRL v.calc	RG		1		RP5

Appendix 2.1. Radiolaria from Woodside Creek (relative abundance, %). Codes explained on p. 97.

AGE	LATE CRETACEOUS					EARLY PALEOCENE																		L PALEOC.	
Radiolarian Zone	RK9					RP1				RP2					RP3				RP4					RP5	
Metres +/- K-T boundary	-30	-18	-10	-0.9	-0.2	0.01	0.5	0.9	2	3	5	6	7	9	10	13	14	24	27	31	33	35	37	38	38
NZ Fossil Record No. P30/	f363	f364	f365	f366	f455	f788	f456	f367	f368	f608	f369	f457	f370	f371	f611	f458	f372	f373	f374	f375	f459	f460	f801	f461	f376
Field no. WO-	28	31	37	48	4	51	53	54	56	58	60	61	62	65	66	68	69	72	74	75	19	23	24	25	78
Abundance	A	A	C	F	F	R	R	R	C	C	C	C	C	A	C	C	A	C	C	A	A	C	C	F	F
Preservation	M	M	M	G	M	M	M	M	G	M	G	M	G	G	G	G	G	G	G	G	G	G	G	G	M
Total count	466	649	309	188	255	67	150	144	437	444	345	296	402	388	280	273	538	257	340	372	501	488	NC	175	201
SPUMELLARIA indet.						6.0	12.0	3.5							7.1										
Actinommidae indet.	5.6	14.6	6.5	7.4	12.2	3.0	6.7		20.6	14.2	10.1	18.6	12.4	15.5	3.6	22.0	29.7	8.2	8.2	15.1	14.0	14.3		8.6	13.4
Amphisphaera spp.					0.4					+	+	0.3	+	0.8	0.4	+	+			+					
Amphisphaera priva	0.6	0.2	+	1.1	0.8			0.7	0.7	1.1	0.6	0.3	1.2	0.8	1.1	1.1	0.7	0.4	1.5	0.8	1.0	0.2	+	1.1	2.5
Amphisphaera aotea							26.7	9.7	2.5	7.0	0.6	+	+												
Amphisphaera kina										1.4	14.5	22.0	19.9	11.6	11.1	3.7	2.8	1.9	1.2	0.8	+	+	+	1.1	0.5
Amphisphaera goruna											0.3	+		+			+		+	11.3	18.0	6.1	+	12.6	3.0
Amphisphaera macrosphaera													+				3.7			+		2.0	+	1.1	
Amphisphaera coronata s.l.																						+	+	0.6	1.0
Conocaryomma aff. *universa*		+								0.2	+	+	+	+	0.4	0.7	0.2	+	+	0.3				+	
Haliomma teuria n.sp.										+	1.4	+	+	+	0.4	0.4	0.9	?	?	?				?	
Haliomma gr. b										0.2	0.3					0.7	2.8	1.2	3.2	3.2	24.0	5.1	+	6.3	2.0
Hexadorium cf. *magnificum*										0.2	1.4	1.7	2.5	1.3	0.4	0.4	+								
Lithomespilus coronatus	1.5	1.2	0.6	1.1	5.1	10.4	17.3	5.6	25.2	2.5	2.9	1.7	1.2	1.8	6.1	6.2	5.6	+	0.3	0.5	0.2	0.4	+	1.1	0.5
Protoxiphotractus wilsoni n.sp.	0.6	0.5	+	+	1.6				0.9	1.6	1.2	0.7	1.2	1.0	2.5	1.1	1.9	1.2	0.6	0.8	1.0	0.6	+	0.6	3.0
Protoxiphotractus perplexus														+						+					
Prunocarpus sp. A	0.4	+							+	+	+				0.4		0.2		+	+		?	+	+	
Stylosphaera pusilla	0.2	0.5	1.0	+	1.2		6.7	2.1	0.7	4.3	0.9	1.0	1.2	0.5		1.8	0.6	0.4	0.3			0.2			
Stylosphaera aff. *hastata*	0.4		+					0.7	+	0.2	0.3		+	+	0.4		0.2	0.4	+	+					
Stylosphaera minor																	0.7	+	0.3	0.8	1.4	1.0	+	1.7	1.5
Phacodiscidae indet.	0.2	0.5	+		1.2				+		+		+	+		+	0.2		+		1.4			1.1	
Heliodiscus spp.	0.4	?	?		?				0.5	0.5	2.9	1.7	2.5	1.3	0.4	1.1	0.4								
Heliosestrum? spp.	0.4	+			+				+	1.1	1.4	0.7	1.2	+											
Periphaena heliasteriscus																			+	+					
Saturnalidae indet.	0.9	+			1.6	1.5	2.0	2.8	+	+	+		+	0.3	0.4		0.2	+	+	+					
Acanthocircus campbelli																	+								
Acanthocircus ellipticus		0.2			0.4			0.7	+		+		0.2	0.3			0.4	+		+		0.2			
Saturnalis kennetti									+	0.2						+	0.2	+		0.3	2.0			+	
Peritiviator cf. *labyrinthi*					+				+	+	+														
Palaeotetrapyle muelleri																	?					0.2			
Litheliidae indet.										+						+			1.2	0.3					
Lithelius aff. *foremanae*								2.1	+		+		+				0.4	+	1.2	0.5	0.2	0.4		0.6	
Lithelius cf. *hexaxyphophora*																				+				+	
Lithelius marshalli n.sp.										+							6.5								
Lithelius? minor gr.	1.5	0.3	1.6	34.0	+			+	2.3	2.3	3.5	4.1	4.2	5.2	5.0	3.7	4.3	23.7	39.7	17.5	7.2	29.7	+	6.9	2.0
Lithelius? aff. *minor*									0.2	0.5	1.4	1.7	2.0	0.3	0.4	0.4	0.9	1.9	1.5	0.8		0.4			
Sponguridae indet.	+			+		1.5		4.2	0.2	1.8	1.7	2.0	+	1.0	0.4	1.8	1.1	0.4	1.2	1.1		+			
Amphymenium concentricum	+										?														
Amphymenium cf. *splendiarmatum*											0.3		1.2	0.3	1.4	0.7	0.4	1.2	0.6	0.5	0.2			0.6	
Prunobrachium kennetti	0.2	+															+			+					
Prunopyle spp.																	+		+	+					

AGE	LATE CRETACEOUS					EARLY PALEOCENE																		L PALEOC.	
Radiolarian Zone	RK9					RP1				RP2					RP3				RP4					RP5	
Metres +/- K-T boundary	-30	-18	-10	-0.9	-0.2	0.01	0.5	0.9	2	3	5	6	7	9	10	13	14	24	27	31	33	35	37	38	38
NZ Fossil Record No. P30/	f363	f364	f365	f366	f455	f788	f456	f367	f368	f608	f369	f457	f370	f371	f611	f458	f372	f373	f374	f375	f459	f460	f801	f461	f376
Field no. WO-	28	31	37	48	4	51	53	54	56	58	60	61	62	65	66	68	69	72	74	75	19	23	24	25	78
Spongoprunum cf. *markleyense*											0.6	+	1.2				+								
Spongurus spongiosus	+	0.3	1.6		0.8			?	?								0.2			+					
Spongurus cf. *bilobatus*									0.2	0.7	0.3	3.4	1.2	0.5	0.4		0.4		0.3	1.3	0.4	0.4			
Spongurus aff. *prolixum*											+	+	0.5												
Phaseliforma laxa	0.2	0.3	0.3	1.1	1.2		0.7		+	0.5	0.9		+	+		+	0.2	+	0.3	+	0.2	0.8		?	0.5
Phaseliforma subcarinata	+	+	+	0.5	+				+	+	+			+	0.4		0.4	0.8	+	0.5	0.2	0.2	+	0.6	3.5
Amphibrachium aff. *sansalvadorensis*	+	0.2							+		?		+	0.3		+	+								
Patulibracchium spp.	0.4	+	+	+	0.8	1.5		1.4	0.7	0.5			+				+			+					
Spongodiscidae indet.							1.3		1.6					1.3		0.4	0.6	+	1.2	+	+	0.6		+	0.5
Orbiculiforma renillaeformis s.l.	+	+	+	+	+		?		+					0.3			0.9	+	+	+					?
Orbiculiforma renillaeformis s.s.	0.2	0.2	+	+	+				+	+	+	+	+	0.3	0.4		0.6	+	+	+					
Spongodiscus spp.	1.3	0.8	1.6	4.8	2.7	3.0	0.7		+	4.3	2.9	3.4	6.2	6.4	6.4	3.3	2.4	2.3	0.3	0.8	1.2	1.0		+	
Spongodiscus rhabdostylus	0.4		+		0.8				0.7			+		+	0.4	0.4	0.2	0.4	+	0.8			+	+	2.5
Spongodiscus alvaetus																			1.2	0.5	0.2	+	+	+	
Spongopyle insolita																				+		+			
Spongotripus spp.		?			+	1.5			+				+				+			+					
Spongotrochus spp.					+					+	+														0.5
Spongotrochus cf. antiquus	3.0	0.9	0.6	0.5	2.4	3.0	1.3	5.6	4.6	5.6	4.3	1.7	2.5	3.9	15.0	10.3	1.9								
Spongotrochus polygonatus	+				+					+			+	+			+								
Spongotrochus cf. *glacialis*									0.5	1.1	3.8	10.1	6.2	1.8	0.4	1.8	1.9				0.4				
Porodiscidae indet.	+	0.3			+		1.3			+	+	+			0.4	0.7	0.2	0.8		+	0.2	0.2			0.5
Flustrella cretacea	0.4								0.2	?			+	0.3			+	?							
Flustrella ruesti	+								0.2					0.3			+								
Stylodictya cf. *sexispinata*																	?	+	0.9	0.3	0.6	+		+	
Stylodictya spp.																						+			
Tholodiscus cf. *densus*	1.5	0.5	+	+	+				0.5	+	0.3		+				0.6	0.8	+	0.3	+	0.2		0.6	2.0
Tholodiscus cf. *ocellatus*	+	+	+	0.5					1.6	1.6	0.3	0.7	0.7	0.8	?	0.7	0.2	+		1.9	0.4	0.4		0.6	0.5
Tholodiscus cf. *targaeformis*																			+	0.5	0.2	0.6		+	?
NASSELLARIA indet.																									
Plagiacanthidae indet.	0.9	0.6			3.9	1.5			+	1.1	0.6			0.3		1.1		1.2							
Lithomelissa? aitai n.sp.	4.3	0.6	1.0	0.5	4.7			2.1	1.1	2.3	0.3		+	0.5	0.7	0.4	1.1	+	0.9	0.3	1.0	0.4	+		
Lithomelissa? hoplites	0.9	+	0.3	+	1.2				0.7	0.7	0.3		0.5	0.3			+		?						
Lithomelissa cf. *heros*	0.2	0.3	+		0.4			0.7	0.7	0.2	+						0.2	?	0.3	0.3					
Lithomelissa cf. *gelasinus*																						+			
Artostrobiidae indet.	+	3.7	0.3	+					0.2	0.2	+	1.0	0.7	0.3			+	1.2	+	0.3	+	0.2		+	
Artostrobus pusillus	+	0.3	1.0	0.5	1.2								2.2	2.6	1.4	3.7				0.8	0.2	+		+	
Botryostrobus? parsonsae n.sp.	+								+	+	+	+	+			0.4	0.4		0.9	+				0.6	
Phormostichoartus? strongi n.sp.	+									0.2									0.3		+	+			
Siphocampe altamontensis	1.1	1.1	+		0.8			1.4	0.2	0.7	+	0.3	0.2	0.5	0.4	+	0.2	+	+						
Siphocampe cf. *altamontenis*			+		0.4	1.5			+	0.7	+		0.2	+		+	0.6	?	+	+			+		
Theocampe cf. *vanderhoofi*	+	25.9	4.5	0.5	2.4		4.7	3.5	2.5	4.3	1.2	1.0	0.7	0.8	0.4	+	0.7	0.4	0.6						

Appendix 2.1. Radiolaria from Woodside Creek (continued). Codes explained on p. 97.

AGE	LATE CRETACEOUS					EARLY PALEOCENE																		L PALEOC.	
Radiolarian Zone	RK9					RP1				RP2					RP3				RP4					RP5	
Metres +/- K-T boundary	-30	-18	-10	-0.9	-0.2	0.01	0.5	0.9	2	3	5	6	7	9	10	13	14	24	27	31	33	35	37	38	38
NZ Fossil Record No. P30/	f363	f364	f365	f366	f455	f788	f456	f367	f368	f608	f369	f457	f370	f371	f611	f458	f372	f373	f374	f375	f459	f460	f801	f461	f376
Field no. WO-	28	31	37	48	4	51	53	54	56	58	60	61	62	65	66	68	69	72	74	75	19	23	24	25	78
"Carpocaniidae" indet.	0.4	0.8	+	2.1	1.6				0.7	+	0.6		0.2				+	0.4	0.3	0.3	0.2			1.1	
Cryptocarpium? cf. ornatum	0.2	0.5			0.4				+	0.5	0.3	+		+		+	+		+		+				
Myllocercion acineton	2.4	11.4	9.7	0.5	2.7	4.5	5.3	8.3	2.1	1.8	0.9	1.7	0.2	0.5	2.5	0.7	0.2	0.4	0.6	+		?		?	
Myllocercion aff. *echtus*	1.5	10.6	9.7	2.1	0.8	1.5	4.7	13.9	1.1	0.9	0.9	0.7	2.5	2.6	0.7	0.4	0.2	0.8	1.2	0.3					
Theocapsomma spp.	0.2	0.8	1.3	1.6	0.4		1.3	0.7	0.7	1.1	0.9	1.7	0.7	0.5		0.4	0.2	0.4	+	+	0.2	0.4		0.6	+
Theocapsomma amphora	0.2	0.5	0.3		1.2	1.5		2.8	0.2	0.5	0.3	0.7	+	0.3	0.7	1.1	1.3	+	+	0.8	+	0.8			
Theocapsomma erdnussa	0.6	1.1	1.0	1.1	0.4	1.5	2.0	1.4	0.9	1.8	1.4	1.0	1.5	1.5	0.4	1.8	0.6	0.8	0.3	2.4	0.6	0.8	+	+	0.5
Amphipyndax aff. *conicus*	?	8.2	+	+	2.0	3.0			0.5	0.5	0.3		0.2	0.5	0.4										
Amphipyndax stocki gr.	48.5	1.2	25.9	27.1	7.5	13.4	3.3	4.2	8.0	9.5	15.1	6.1	6.5	10.1	12.9	6.2	9.3	24.5	10.6	15.1	7.8	13.3	+	28.6	32.8
Amphipternis alamedaensis	0.4	+	0.6	1.1	0.8		0.7		0.2	0.7	0.6	0.3	+		1.1	1.1	0.2	0.4			0.2	+		0.6	
Archaeodictyomitra cf. *lamellicostata*	0.2	0.2	0.6	1.6	0.4				1.1	0.9	1.2	+	0.2	1.3	2.5	1.5	0.4	2.7	1.5	2.4	0.2	0.2	+	2.3	6.0
Dictyomitra spp.		0.2	0.3		0.4						0.3	0.3							0.3	0.5	0.2	0.2			
Dictyomitra andersoni	4.5	3.5	11.3	5.3	4.3	26.9	3.3	8.3	4.1	6.8	3.5	2.7	3.2	2.6	1.8	4.0	1.9	3.1	2.6	2.7	1.8	1.6	+	4.6	4.5
Dictyomitra aff. *rhadina*	+	+	+		+		0.7	0.7	+		+		+												
Dictyomitra multicostata	0.9	0.8	3.2	2.1	2.4	6.0	0.7	1.4	0.5	0.5	0.9	0.3	0.2	+		0.7	0.2	1.2	0.6	1.3	0.4	0.2		0.6	
Mita regina	1.1	0.5	0.3	+	+			0.7	+	0.5	+		0.5	0.8	0.4	0.4	0.4	0.4	0.6	+	0.4	+	+	+	0.5
Mita cf. *regina*	+	0.5	1.0	+	1.2			2.1	0.2	0.5	+	1.4	0.5	0.5		1.1	0.6	+	0.3	+	0.4	+		0.6	1.0
Bathropyramis sanjoaquinensis s.l.	1.1	0.2	+		1.6		0.7	0.7	0.2	0.7	0.3	1.7	0.5	0.8		1.1	0.4	1.9	1.2	1.1	1.0	0.6	+	+	
Cornutella californica	1.3	0.9	+	+	0.4		0.7	0.7	+	0.9	0.9	0.7	1.2	1.5	0.4	0.4	0.2	1.2	1.5	0.3	1.0	0.8	+	1.1	1.0
Neosciadiacapsa jenkinsi	2.8	0.5	0.6	0.5	7.8	3.0	1.3	0.7	0.7	0.5	2.9	1.0	1.2	1.0		0.7	0.6	0.8	0.3	1.1	0.8				
Eucyrtidiidae indet.	0.9	1.1	4.9		3.5	3.0		0.7	2.1	0.9	2.0	1.0	1.2	2.1	0.7	0.4	0.4	0.8	1.5	0.5	1.4	3.9		0.6	1.0
Cyrtocapsa campi	0.6	+	0.3	+	0.4			4.2	0.5	0.2	+		+	+	0.7	0.4	+	+	+	+	0.2				
Cyrtocapsa livermorensis	+	0.3	0.6	0.5	0.8	1.5	1.3		0.5	0.9	0.9		0.2	0.3	0.4	1.5	0.9	+	+	0.3		+	+		
Eusyringium aoteanum n.sp.	0.4	0.3	0.3	0.5	+	1.5			+	0.2	0.9		0.5	0.5		0.4	0.6	1.2	0.6	0.5	0.4	1.0	+	+	1.0
Lithocampe wharanui n.sp.	1.9	0.3	0.3	0.5	0.4		1.3		0.7	0.7	1.4	+	1.5	2.6	0.7	1.5	0.7	1.9	0.9	0.8	0.4	0.2	+	+	2.0
Lithocampe aff. *subligata*	+								+					+			+		+	+					
Stichomitra bertrandi	0.4	0.8	+		1.2			1.4	0.9	0.7	+		+				+	0.4	0.3						
Stichomitra grandis	1.3	1.2	4.9	0.5	5.5	1.5	2.0	2.8	1.4	1.8	0.6	0.3	0.2	+	0.4	+	0.2	0.4	0.3	0.3	0.2				
Stichomitra carnegiensis	0.2	0.2	1.6	+	4.3	3.0	1.3	1.4	2.7	2.7	1.7	0.3	1.5	1.5	1.8	+	0.7	1.9	1.8	0.3	+	+	+		0.5
Stichomitra cf. *carnegiensis*																	+	0.8	+	1.3	1.0	+		+	1.0
Lithostrobus wero											+		0.2	3.9	5.7	2.2	0.6	0.4	+	0.5	0.6	0.2			
Buryella spp.																				+		3.1		1.1	0.5
Buryella granulata															5.4	1.8	1.1	4.3	1.2	0.3	0.4	0.4		+	0.5
Buryella foremanae																			0.9	1.6	0.6	0.2	+	+	
Buryella dumitricai																				1.9	3.0	2.0	+	+	
Buryella tetradica																								9.1	4.5
Buryella kaikoura n.sp.																								2.3	2.0
Clathrocyclas australis n.sp.													0.2	1.8		1.5	+		2.1	0.3	0.6	3.1		0.6	
Dictyophimus aff. *archipilium*									?							+	+	0.4	0.9	+	0.4	0.6			0.5
Dictyophimus aff. *pocillum*																						+	+		0.5
Dorcadospyris aff. *confluens*														+	0.4	+	+	0.4	1.2	+		0.6	+		

Codes for sample abundance and preservation defined in Section 1.4. Taxon abundance as percentage in representative count; + = present but not in count, ? = uncertain identication. NC = No count (P30/f801)

Appendix 2.2. Radiolaria from Wharanui Point (relative abundance, %). Codes as for Appendix 2.1 (p. 97)

AGE	LATE CRET.		EARLY PALEOCENE			
Radiolarian Zone	RK9		RP1			RP2
Metres +/- K-T boundary		-40	0.2	1	2	4
NZ Fossil Record No. P30/	f868	f462	f463	f464	f465	f466
Field No. WH-	9	8	4	3	2	1
Abundance	C	C	F	F	C	F
Preservation	M	M	M	M	M	M
Total Count	291	218	154	162	222	153
SPUMELLARIA						
Actinommidae indet:	23.0	9.2	2.6	12.3	15.8	20.9
Amphisphaera priva	1.0	0.9	0.6		0.9	+
Amphisphaera aotea			1.3	13.0	6.8	2.0
Amphisphaera kina						24.2
Lithomespilus coronatus	1.0	0.9	9.1	6.2	2.3	2.0
Protoxiphotractus wilsoni n.sp.	0.7	2.3	0.6		0.5	1.3
Stylosphaera pusilla	1.4	1.8	2.6	1.9	0.5	+
Stylosphaera aff. *hastata*					+	
Phacodiscidae indet.					0.5	2.0
Heliodiscus spp.	0.7	+				
Heliosestrum? spp.				2.5	1.4	3.3
Salurnalidae indet.	0.3	0.9				
Acanthocircus campbelli		0.5				
Acanthocircus ellipticus		+	+			
Peritiviator cf. *labyrinthi*		+	0.6			
Litheliidae indet.			+	+	1.4	1.3
Lithelius aff. *foremanae*				0.6		
Lithelius? minor gr.	2.7	1.8	1.3	12.3	9.9	3.3
Sponguridae indet.	0.7	0.5	1.3	0.6	+	+
Amphymenium cf. *splendiarmatum*				+		
Spongurus cf. *bilobatus*			0.6	+		
Phaseliforma laxa		+	+	+	1.8	
Phaseliforma subcarinata		+			?	
Amphibrachium aff. *sansalvadorensis*				0.6		
Patulibracchium spp.		0.9		1.2		
Spongodiscidae indet.	1.4	+		+	+	+
Orbiculiforma renillaeformis s.l.		+				
Orbiculiforma renillaeformis s.s.	+	+		0.6	+	
Spongodiscus spp.	0.7		4.5	3.1	+	+
Spongotripus spp.		0.5				
Spongotrochus spp.	0.3	0.9	+	1.2	+	1.3
Spongotrochus antiquus		1.4	1.3			
Spongotrochus cf. *polygonatus*	0.3					
Porodiscidae indet.		0.9		2.5	1.4	
Porodiscus cretaceus		0.5				
Tholodiscus cf. *densus*				0.6		
Tholodiscus cf. *ocellatus*		0.5	1.3	0.6	0.5	+

	LATE CRET.		EARLY PALEOCENE			
	RK9		RP1			RP2
		-40	0.2	1	2	4
	f868	f462	f463	f464	f465	f466
	9	8	4	3	2	1
	C	C	F	F	C	F
	M	M	M	M	M	M
	291	218	154	162	222	153
NASSELLARIA						
Plagiacanthidae indet.	0.3					
Lithomelissa cf. *heros*					0.5	
Lithomelissa? aitai n.sp.	0.3	3.2	?	1.2	1.8	
Lithomelissa? hoplites		0.5	?	0.6		
Artostrobiidae indet.		+				
Artostrobus pusillus		+		+	0.5	4.6
Botryostrobus? parsonsae n.sp.	0.7	+	0.6			
Phormostichoartus? strongi n.sp.		+			0.5	
Siphocampe altamontensis	+	+	+	+	0.5	+
Siphocampe cf. *altamontensis*	4.1	0.5	0.6	+	0.5	0.7
Siphocampe bassilis		0.5			1.4	
Theocampe lispa			0.6	+		1.3
Theocampe cf. *vanderhoofi*	0.3	1.8	11.0	6.2	5.0	0.7
"Carpocaniidae" indet.	0.3	+			+	
Cryptocarpium cf. *ornatum*		1.4		+	+	
Myllocercion acineton	+	2.3	4.5	5.6	7.7	3.3
Myllocercion aff. *echtus*	0.7	0.5	1.3	1.9	2.3	0.7
Theocapsomma spp.	+	+	1.3	+	2.3	0.7
Theocapsomma amphora		0.5	0.6		0.5	0.7
Theocapsomma erdnussa	3.4	0.5	1.9	1.2	1.4	+
Amphipyndax aff. *conicus*	+	+	1.3	0.6	1.8	
Amphipyndax stocki gr.	38.8	32.6	12.3	3.1	16.7	11.1
Amphipternis alamedaensis	+	0.9		0.6		+
Archaeodictyomitra cf. *lamellicostata*	+	+		+	0.5	0.7
Dictyomitra andersoni	5.5	5.0	14.3	7.4	3.2	2.6
Dictyomitra multicostata		1.4	7.1	+	0.5	2.0
Dictyomitra aff. *rhadina*	+		1.3	+	0.5	+
Mita regina	0.3	2.3	1.3	1.2	0.5	0.7
Mita cf. *regina*		+	0.6	0.6		
Bathropyramis sanjoaquinensis s.l.	0.3	2.3	0.6	+	0.5	0.7
Cornutella californica	1.0	3.7	0.6	1.2		0.7
Neosciadiacapsa jenkinsi	+	2.8	0.6	+	+	+
Eucyrtidiidae indet.	0.3	0.5	1.3	1.2	1.8	2.0
Cyrtocapsa campi		0.9	0.6	+	0.5	0.7
Cyrtocapsa livermorensis	+	0.5	0.6	1.2	0.9	1.3
Eusyringium woodsidensis n.sp.	1.0	1.4	0.6	0.6	+	+
Lithocampe wharanui n.sp.	5.2	6.0	+	0.6	2.3	0.7
Stichomitra bertrandi	1.0	+	0.6	+		0.7
Stichomitra grandis	0.3	2.8	4.5	3.1	1.8	+
Stichomitra carnegiensis	1.4	1.4	0.6	1.9	1.4	2.6
Lithostrobus wero	?				?	+

Appendix 2.3. Radiolaria from Chancet Rocks (relative abundance, %). Codes as for Appendix 2.1 (p. 97)

AGE	EARLY PALEOCENE					L PALEOC.			EARLY PALEOCENE					L PALEOC.	
Radiolarian Zone	RP1		RP2		RP3	RP5			RP1		RP2		RP3	RP5	
Metres above K-T boundary	0.05	1	1.5	4	11	30	38		0.05	+1	1.5	4	11	30	38
NZ Fossil Record No. P29/	f613	f387	f388	f389	f390	f391	f392		f613	f387	f388	f389	f390	f391	f392
Field No. CH-	8	9	10	12	17	27	29		8	9	10	12	17	27	29
Abundance	F	F	C	F	F	C	R		F	F	C	F	F	C	R
Preservation	P	M	M	M	M	G	G		P	M	M	M	M	G	G
Total Count	110	254	206	167	161	419	89		110	254	206	167	161	419	89
SPUMELLARIA								"Carpocaniidae" indet.			+			0.2	1.1
Actinommidae indet.		45.3	24.3	44.9	12.4	14.3	22.5	*Cryptocarpium?* cf. *ornatum*		+	1.0				
Amphisphaera priva		?	0.5		+	0.2		*Myllocercion acineton*		5.5	2.9		+	?	
Amphisphaera aotea	16.4	9.8	14.6	0.6				*Myllocercion* aff. *echtus*		+	+	+		?	
Amphisphaera kina			10.2	29.9	1.2	1.4		*Theocapsomma* spp.		0.4	0.5			+	
Amphisphaera goruna						17.9	11.2	*Theocapsomma amphora*		0.4	1.0	0.6	0.6		
Amphisphaera macrosphaera						7.2	1.1	*Theocapsomma erdnussa*		0.4	2.9		+		
Amphisphaera coronata s.l.						3.6	2.2								
Haliomma sp. gr. B					1.2	3.6	5.6	*Amphipyndax* aff. *conicus*			0.5				
Lithomespilus coronatus	77.3	3.9	1.5	5.4	3.7	0.2		*Amphipyndax stocki* gr.		2.8	8.3	1.2	6.2	2.1	1.1
Protoxiphotractus wilsoni n.sp.		0.8	0.5	+		0.2		*Amphipternis alamedaensis*		0.4	0.5	3.0	1.9	+	
Stylosphaera pusilla		2.0	3.9	+				*Archaeodictyomitra* cf. *lamellicostata*		0.4	1.0				
Stylosphaera aff. *hastata*				0.6				*Dictyomitra andersoni*	3.6	2.4	2.4	1.2	3.7	0.7	1.1
Stylosphaera minor					0.6	3.6		*Dictyomitra multicostata*		0.8	1.0		0.6	?	
								Mita regina		1.2	+				
Phacodiscidae indet.					1.2			*Mita* cf. *regina*		+	0.5				
Heliosestrum? spp.		0.8	1.5		0.6			*Bathropyramis sanjoaquinensis s.l.*				1.2	1.2	1.9	
Saturnalidae indet.		0.4		1.8		3.6		*Cornutella californica*		2.0	1.9	1.2	+	0.5	1.1
Saturnalis kennetti						0.2		*Neosciadiacapsa jenkinsi*			0.5	+	+		
Litheliidae indet.					1.2	0.2	+								
Lithelius aff. *foremanae*						+	2.2	Eucyrtidiidae indet.		1.2	2.4				2.2
Lithelius? minor gr.		2.0	2.4	3.0	3.7	7.2	16.9	*Cyrtocapsa campi*		0.8	0.5				
								Cyrtocapsa livermorensis			0.5	+		0.2	
Sponguridae indet.			0.5	1.8				*Eusyringium woodsidensis* n.sp.			0.5	+	0.6	0.2	1.1
Phaseliforma laxa			+					*Lithocampe wharanui* n.sp.		+	1.0	+	+	0.2	1.1
Phaseliforma subcarinata					+			*Stichomitra bertrandi*		0.8	1.5				
Spongodiscidae indet.		0.8						*Stichomitra grandis*	0.9	0.4	1.9		0.6		
Orbiculiforma renillaeformis s.s.			+					*Stichomitra carnegiensis*		1.2	+	0.6			
Spongodiscus spp.		1.2	1.0		12.4	0.5									
Spongotrochus spp.		2.0	1.0		8.1			*Lithostrobus wero*			?	?	28.6	0.5	
Porodiscidae indet.		+		1.8	0.6	1.0	4.5	*Buryella granulata*				?	3.7	0.7	
Tholodiscus cf. *ocellatus*	0.9	+		1.2	+			*Buryella foremanae*						1.2	
								Buryella dumitricai						2.4	
NASSELLARIA								*Buryella kaikoura* n.sp.						7.2	
Plagiacanthidae indet.					1.9	0.2		*Buryella tetradica*						7.2	19.1
Lithomelissa cf. *heros*		+	0.5					*Clathrocyclas australis* n.sp.					?	1.7	
Lithomelissa? aitai n.sp.		1.2						*Dictyophimus* aff. *archipilium*						7.2	1.1
Lithomelissa? hoplites			+					*Dictyophimus* aff. *pocillum*						0.5	2.2
								Dorcadospyris aff. *confluens*						+	2.2
Artostrobiidae indet.		0.8	1.5	+		+									
Artostrobus pusillus		1.6		+	2.5										
Botryostrobus? parsonsae n.sp.					0.6										
Phormostichoartus? strongi ns.p.			0.5			0.2									
Siphocampe altamontensis		0.8	0.5												
Siphocampe cf. *altamontensis*				+											
Theocampe spp.		+	+												
Theocampe cf. *vanderhoofi*	0.9	5.9	2.4	+	+										

Appendix 2.4. Radiolaria from Flaxbourne River (relative abundance, %). Codes as for Appendix 2.1. (p. 97)

AGE	MAASTRICHTIAN			EARLY PALEOCENE													
Foraminiferal Zone	A. mayaroensis			P0				P1a		P1b	? P1c ?						
Radiolarian Zone	RK9				RP1						RP2	RP3					
Metres +/- K-T Boundary	-7.3	-1.4	-1.2	0	0.003	0.03	0.04	0.14	0.22	0.4	1.4	2.5	2.7	3.9	4.5	4.7	11
NZ Fossil Record No. P29/	f251	f253	f254	f281	f279	f277	f276	f270	f266	f264	f260	f412	f258	f256	f413	f255	f415
GNS Curation No. F2-	7671	6316	7673	7690	7688	7687	7686	7682	6307	6305	6303	8811	7677	7675	8812	7674	8814
Abundance	F	C	C	F	F	F	F	C	C	F	A	C	A	C	C	F	C
Preservation	M	M	M	P	P	P	P	M	M	M	G	M	G	M	M	M	G
Total Count	142	232	328	49	100	51	115	416	318	179	491	288	667	217	201	283	207
SPUMELLARIA																	
Actinommidae indet.	8.5	0.9	7.6	2.0	30.0	3.9	20.9	28.4	36.2	14.0	26.5	55.6	42.0	36.9	47.3	12.0	24.6
Amphisphaera priva										0.6	0.2			0.5			
Amphisphaera aotea					24.0	23.5	14.8	13.5	12.6	1.1	2.0		+				
Amphisphaera kina											21.4	13.9	11.2	13.8	19.9	26.9	21.7
Amphisphaera goruna											1.0	0.3			0.5	0.4	
Amphisphaera macrosphaera													0.6	0.5	1.0		
Haliomma sp. gr. B												0.3					
Hexadorium cf. *magnificum*											2.0	4.9	3.0	2.3	1.5	6.0	
Lithomespilus coronatus	1.4	3.9	3.4	4.1	4.0	47.1	18.3	14.9	18.9	3.4	1.4	0.7	2.5	2.3	0.5	2.8	2.4
Protoxiphotractus wilsoni n.sp.	0.7							0.2		2.2	0.4	+	0.1	+	+	0.4	+
Stylosphaera pusilla			0.3					0.7	0.9	2.2	4.1	+	1.0	0.9	1.0	0.4	+
Stylosphaera aff. *hastata*											+	0.3	0.1				
Phacodiscidae indet.											0.4		0.3	0.9		3.2	1.0
Heliodiscus spp.												0.7			0.5		0.5
Heliosestrum? spp.											0.2		0.9	+		0.7	
Saturnalidae indet.											0.6		0.7	+			
Acanthocircus ellipticus													+			0.4	
Saturnalis kennetti											0.4		+	+	0.5	0.7	+
Peritiviator cf. *labyrinthi*											??		0.7				0.5
Litheliidae indet.																	1.0
Lithelius aff. *foremanae*											0.2				+		
Lithelius? minor gr.	3.5							1.4	1.3		1.8	5.9	1.5	6.9	7.5	1.1	6.8
Lithelius? aff. *minor*											0.4		0.7	1.8	0.5	3.2	
Sponguridae indet.			0.6					1.0	1.3		6.1	0.7	5.2	1.8		2.8	2.4
Amphymenium cf. *splendiarmatum*								0.2		0.6	0.8	1.7	0.7	2.8	1.5	1.4	
Prunobracchium kennetti			0.3														
Spongoprunum cf. *markleyense*																1.8	
Spongurus spongiosa												+					
Spongurus cf. *bilobatus*												0.3			1.0	1.4	
Phaseliforma laxa			+					0.2	0.3		0.4		+	0.5			
Phaseliforma subcarinata		0.4									0.2						
Patulibracchium spp.								0.2	+		0.2		+				
Spongodiscidae indet.		1.3	2.1	8.2	2.0	2.0	6.1					1.7	+	0.9	5.0	1.8	5.8
Orbiculiforma renillaeformis s.l.			0.6					0.2	0.3		+						
Spongodiscus spp.			4.6					1.7	7.9	0.6	2.4		3.9	1.4		0.4	1.0
Spongotripus spp.												+					
Spongotrochus spp.			1.5					1.0	4.4		7.7	1.0	8.8	4.6	2.5	12.4	4.8
Spongotrochus antiquus			2.1					1.7	3.1			0.3	0.6				
Porodiscidae indet.												+	0.1				
Tholodiscus cf. *densus*											0.4	0.3					
Tholodiscus cf. *ocellatus*								0.7	+		1.0	0.7	1.2	+	+	1.1	1.0

Appendix 2.4. Radiolaria from Flaxbourne River (continued). Codes as for Appendix 2.1. (p. 97)

AGE	MAASTRICHTIAN			EARLY PALEOCENE													
Foraminiferal Zone	A. mayaroensis			P0				P1a		P1b	? P1c ?						
Radiolarian Zone	RK9				RP1						RP2	RP3					
Metres +/- K-T Boundary	-7.3	-1.4	-1.2	0	0.003	0.03	0.04	0.14	0.22	0.4	1.4	2.5	2.7	3.9	4.5	4.7	11
NZ Fossil Record No. P29/	f251	f253	f254	f281	f279	f277	f276	f270	f266	f264	f260	f412	f258	f256	f413	f255	f415
GNS Curation No. F2-	7671	6316	7673	7690	7688	7687	7686	7682	6307	6305	6303	8811	7677	7675	8812	7674	8814
NASSELLARIA																	
Plagiacanthidae indet.		0.4	0.3					0.2			0.4	+	+		+		
Lithomelissa cf. *heros*		0.4	3.0	2.0				+				+	+				
Lithomelissa? aitai		1.3	1.8	4.1				1.0		0.6		+	+				0.5
Lithomelissa? hoplites	0.7	3.4	0.6	2.0									+				+
Artostrobiidae indet.															+	0.4	
Artostrobus pusillus									1.6	2.2	0.6	3.8	1.0	6.9	5.0	1.8	4.8
Botryostrobus? parsonsae n.sp.																	+
Phormostichoartus? strongi n.sp.															+		
Siphocampe altamontensis	0.7						0.9	0.2	0.3		0.2	+	+	+	+	0.7	+
Siphocampe cf. *altamontensis*											0.2	0.3	0.1				+
Theocampe spp.								0.2					+				
Theocampe cf. *vanderhoofi*	21.1	12.5	22.9	6.1	3.0		1.7	4.3	1.3	5.0	2.0	+	+	1.4	+	0.4	+
"Carpocaniidae" indet.			0.3					0.2						0.5			
Cryptocarpium? cf. *ornatum*								+			0.2						+
Myllocercion acineton	9.2	10.3	7.6	4.1	6.0	3.9	0.9	4.3	0.6	3.9	0.4	0.7	0.3	+	1.0		+
Myllocercion aff. *echtus*	1.4	0.9	6.1		1.0		0.9	4.8	0.9	11.2	0.6	+	0.7	1.4			+
Theocapsomma spp.	1.4	1.3	2.7						1.6	0.6	0.4	+	0.3	+			+
Theocapsomma amphora		3.9	2.7					0.7	0.3		0.2				+		+
Theocapsomma erdnussa	1.4	0.4	1.8					1.9		3.4	0.6	+	0.1	+			+
Theocapsomma erdnussa?	0.7																
Amphipyndax aff. *conicus*	+	0.9	0.9					+				+			+		+
Amphipyndax stocki gr.	10.6	2.2	1.5		2.0	3.9	3.5	2.6	2.2	7.3	2.9	0.7	3.9	2.3	0.5	2.5	1.0
Amphipternis alamedaensis	2.1				1.0		2.6	0.7	+		+	1.7	+	0.5	1.0	3.2	1.0
Archaeodictyomitra cf. *lamellicostata*			0.3				1.7	0.2		1.7		+	0.1	+		0.4	+
Dictyomitra spp.	0.7	0.4	0.3							3.4				0.9			
Dictyomitra andersoni	4.2	8.2	5.5	22.4	13.0	5.9	11.3	1.9	1.3	15.1	1.6	0.7	0.6	0.5	0.5	1.8	1.4
Dictyomitra minima n.sp.		1.3								1.1	+	+					
Dictyomitra multicostata	3.5	1.7	1.2	8.2	2.0		0.9	0.5	0.6	1.1	0.2	+	0.1	0.5	?		+
Mita regina	1.4							0.2	0.3		0.2	0.7	+		+	0.4	+
Mita cf. *regina*											0.4	+	0.7	0.9	+		+
Bathropyramis sanjoaquinensis s.l.	'										0.4	0.3	0.3	0.5	+	0.4	1.9
Cornutella californica			0.3					0.2			0.2	0.3	1.0	0.5	+	1.4	1.0
Neosciadiacapsa jenkinsi											0.6	+	0.7	+	+	0.7	+
Eucyrtidiidae indet.	7.0		0.3			9.8	10.4			1.7	0.6	0.7	0.9	0.5	1.0		1.0
Cyrtocapsa campi	2.1			2.0			1.7			1.1	+	+			+		+
Cyrtocapsa livermorensis		1.3	1.8	10.2	2.0			0.5		1.1	0.6	+	0.1		+	1.8	+
Eusyringium? woodsidensis n.sp.												+	0.1				+
Lithocampe wharanui n.sp.									0.3	0.6	0.8	+	0.6		0.5		0.5
Stichomitra bertrandi	1.4	4.7	0.9	10.2	3.0	?	?	0.7	0.3	2.8		+	+			0.4	+
Stichomitra grandis	2.1	25.9	10.7	12.2	2.0		2.6	6.5	0.9	7.8	1.0	+	0.6	+			
Stichomitra carnegiensis	14.1	12.1	3.0	2.0	5.0	?	0.9	1.7	0.3	3.9	1.2	+	0.6	1.4	+	0.4	+
Lithostrobus wero											0.8	+	0.1	0.5	+	1.4	12.6
Buryella granulata											?	+	0.1	2.3	+	1.1	1.0
Clathrocyclas australis n.sp.												0.3	+			0.4	+
Dorcadospyris aff. *confluens*																	+

PLATES 1-22

All images are digitally captured and computer enhanced. Transmitted light images (Tx-Xnn/n) were captured via video attached to a Leitz Ortholux microscope. Some scanning electron microscope (SEM) images were scanned from photographic negatives (Sx-nnn). Remaining SEM images were captured directly via an analog digital converter (CH00n-nnn).

The following details are given for each figured specimen:

Rnnn	University of Auckland, Geology Department figured specimen catalogue number
P30/fnnn	New Zealand Fossil Record File number
XXn	Field number or DSDP sample location
(Tx-Xnn/n)	Specimen location by England Finder on strewn slide Tx
(Sx-nnn)	Mounted specimen number on SEM stub Sx (1988-91)
(CH00n-nnn)	Same on SEM stub CH00n (1993-96)

Plate 1

Scale bar = 100 µm

Fig. 1 ***Amphisphaera priva*** (Foreman). R66, P30/f368, WO56 (Sa-9), RP1, Early Paleocene.

2 ***Amphisphaera priva*** (Foreman). R708, P30/f374, WO74 (Sa-13), RP4, Early Paleocene.

3 ***Amphisphaera priva*** (Foreman). R709, P30/f459, WO19 (Tb-S44/0), RP4, Early Paleocene.

4 ***Amphisphaera priva*** (Foreman). R710, P30/f461, WO25 (Tb-F45/0), RP5, Early Paleocene.

5 ***Stylosphaera pusilla*** Campbell & Clark. R68, P30/f368, WO56 (Sa-10), RP1, Early Paleocene.

6 ***Stylosphaera pusilla*** Campbell & Clark. R711, P30/f372, WO69 (Ta-M54/0), RP3, Early Paleocene.

7 ***Stylosphaera? pusilla*** Campbell & Clark. R712, P30/f460, WO23 (Tb-F34/0), RP4, Early Paleocene.

8 ***Protoxiphotractus wilsoni* n.sp.** Paratype. R713, P30/f368, WO56 (Sa-18), RP1, Early Paleocene.

9 ***Protoxiphotractus wilsoni* n.sp.** Holotype. R714, P30/f374, WO74 (Sa-16), RP4, Early Paleocene.

10 ***Protoxiphotractus wilsoni* n.sp.** Paratype. R90, P30/f375, WO75 (Sa-9), RP4, Early Paleocene.

11 ***Protoxiphotractus wilsoni* n.sp.** Paratype. R715, P30/f375, WO75 (Tb-C45/4), RP4, Early Paleocene.

12 ***Protoxiphotractus wilsoni* n.sp.** Paratype. R716, P30/f460, WO23 (Ta-G29/2), RP4, Early Paleocene.

13 ***Protoxiphotractus perplexus*** Pessagno. R717, P30/f375, WO75 (Sa-8), RP5, Early Paleocene.

14 ***Stylosphaera* aff. *hastata*** Campbell & Clark. R718, P30/f372, WO69 (Sa-20), RP3, Early Paleocene.

15 ***Stylosphaera* aff. *hastata*** Campbell & Clark. R91, P30/f374, WO74 (Sa-20), RP4, Early Paleocene.

16 ***Stylosphaera* aff. *hastata*** Campbell & Clark. R719, P30/f373, WO72 (Ta-P23/4), RP3, Early Paleocene.

17 ***Stylosphaera minor*** Clark & Campbell. R720, P30/f374, WO74 (Sa-20), RP4, Early Paleocene.

18 ***Stylosphaera minor*** Clark & Campbell. R721, P30/f372, WO69 (Ta-E43/3), RP3, Early Paleocene.


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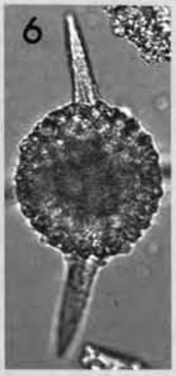
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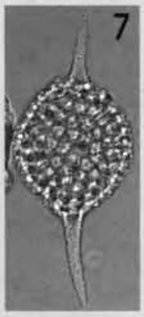
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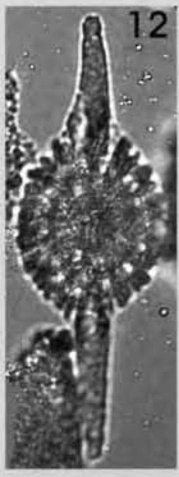
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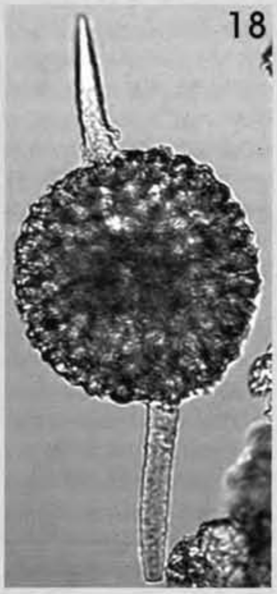
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Plate 2

Scale bars = 100 μm

Fig. 1 ***Amphisphaera aotea*** Hollis. Holotype. R11, P30/f368, WO56 (Sa-17), RP1, Early Paleocene.

2 ***Amphisphaera aotea*** Hollis. Paratype. R13, P30/f368, WO56 (Tb-E53/0), RP1, Early Paleocene.

3 ***Amphisphaera aotea*** Hollis. R12, P30/f608, WO58 (Tb-L48/2), RP2, Early Paleocene.

4 ***Amphisphaera aotea*?** Hollis. R722, P30/f460, WO23 (Tc-M33/0), RP4, Early Paleocene.

5 ***Amphisphaera kina*** Hollis. Holotype. R14, P30/f371, WO65 (Sb-26), RP3, Early Paleocene.

6 ***Amphisphaera kina*** Hollis. Paratype. R723, P30/f371, WO65 (Sb-28), RP3, Early Paleocene.

7 ***Amphisphaera kina*** Hollis. R17, P30/f372, WO69 (Ta-Y45/0), RP3, Early Paleocene.

8 ***Amphisphaera kina*** Hollis. R724, DSDP 208-33-1, 60-62 cm (Te-N29/1), RP2, Early Paleocene.

9 ***Amphisphaera kina*** Hollis. R725, DSDP 208-33-1, 60-62 cm (Tf-T38/2), RP2, Early Paleocene.

10 ***Amphisphaera goruna*** (Sanfilippo & Riedel). R19, P30/f375, WO75 (Sa-19), RP4, Early Paleocene.

11 ***Amphisphaera goruna*** (Sanfilippo & Riedel). R726, P30/f459, WO19 (Ta-G48/1), RP4, Early Paleocene.

12 ***Amphisphaera macrosphaera*** (Nishimura). R727, P30/f372, WO69 (Sa-28), RP3, Early Paleocene.

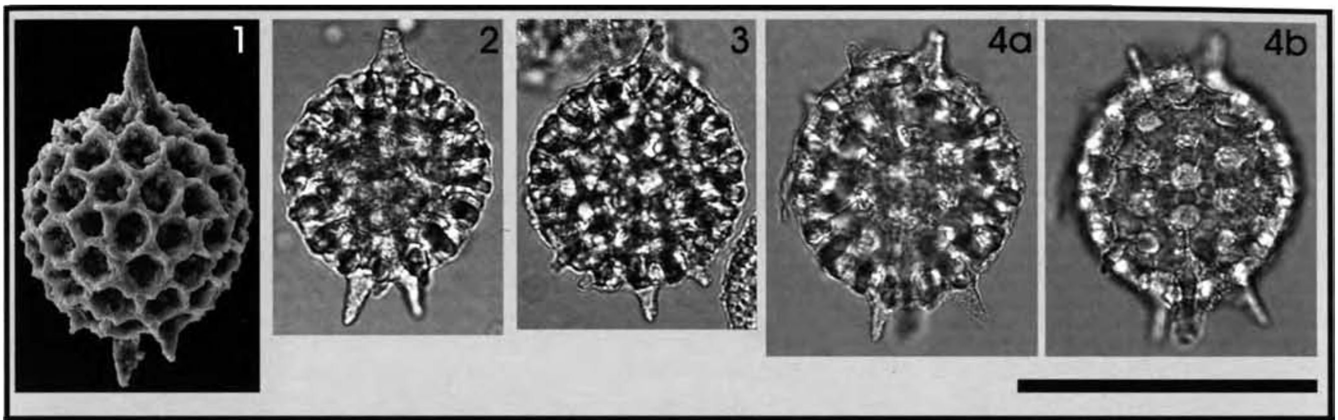
13 ***Amphisphaera macrosphaera*** (Nishimura). R20, P30/f372, WO69 (Ta-M36/0), RP3, Early Paleocene.

14 ***Amphisphaera coronata s.l.*** (Ehrenberg) R728, P30/f801, WO24 (CH08-1), RP4, Early Paleocene.

15 ***Amphisphaera coronata s.l.*** (Ehrenberg) R729, P30/f460, WO23 (Tc-M41/0), RP4, Early Paleocene.

16 ***Amphisphaera coronata s.l.*** (Ehrenberg) R730, P30/f460, WO23 (Tb-J45/0), RP4, Early Paleocene.

17 ***Amphisphaera coronata s.l.*** (Ehrenberg) R731, P30/f460, WO23 (Tb-V28/3), RP4, Early Paleocene.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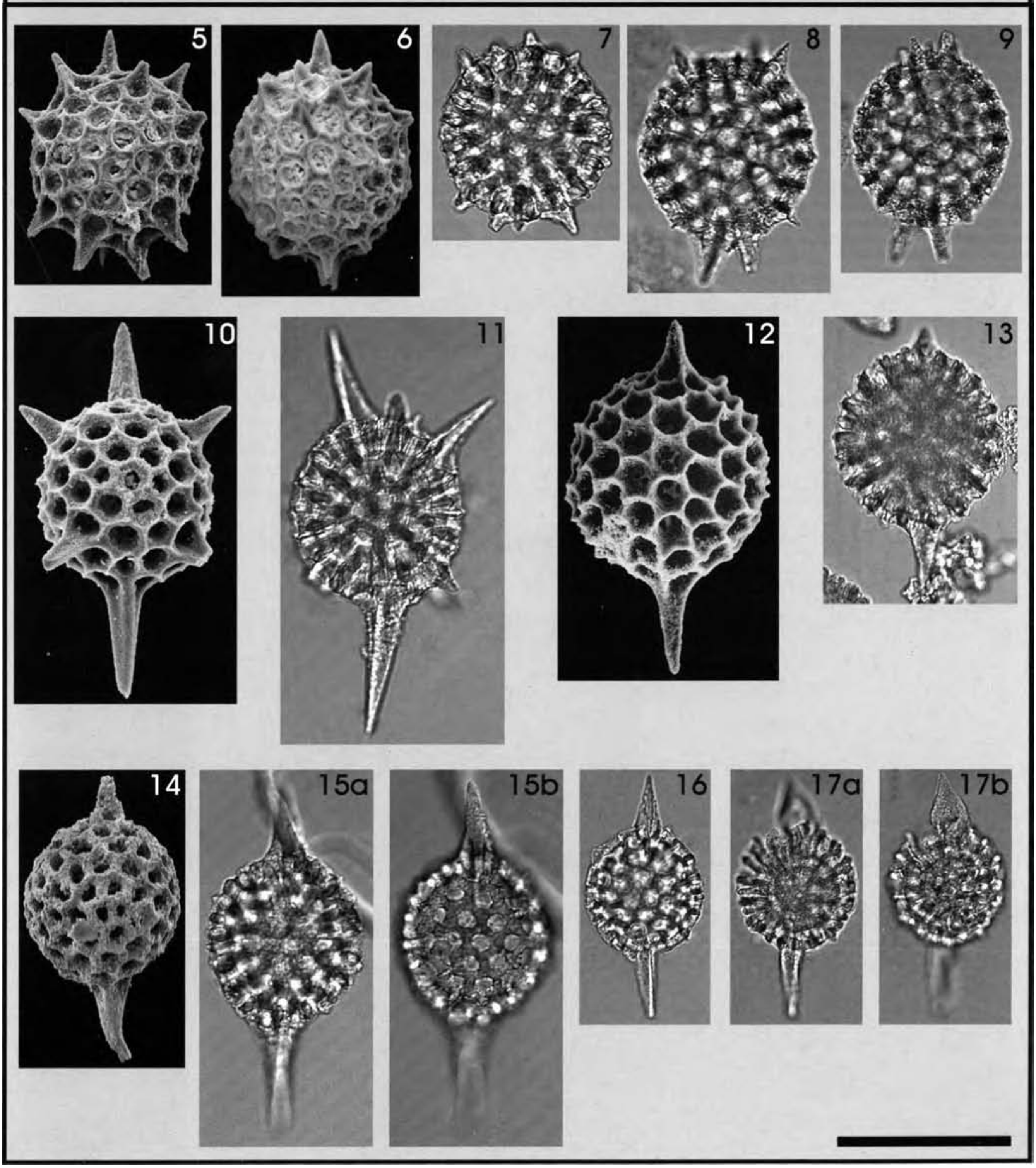
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Plate 3

Scale bars = 100 μm

Fig. 1 ***Conocaryomma* aff. *universa*** (Pessagno). R732, P30/f374, WO74 (Sa-1), RP4, Early Paleocene.

2 ***Conocaryomma* aff. *universa*** (Pessagno). R733, P30/f375, WO75 (Tb-J46/0), RP4, Early Paleocene.

3 ***Haliomma teuria* n.sp.** Holotype. R734, P30/f369, WO60 (CH08-10), RP2, Early Paleocene.

4 ***Haliomma teuria* n.sp.** Paratype. R735, P30/f369, WO60 (CH08-8), RP2, Early Paleocene.

5 ***Haliomma teuria* n.sp.** Paratype. R736, P30/f369, WO60 (CH08-9), RP2, Early Paleocene.

6 ***Haliomma teuria* n.sp.** Paratype. R737, P30/f369, WO60 (CH08-12), RP2, Early Paleocene.

7 ***Haliomma* spp. gr. B.** R738, P30/f375, WO75 (Sa-4), RP4, Early Paleocene.

8 ***Haliomma* spp. gr. B.** R739, P30/f460, WO23 (Tb-M35/0), RP4, Early Paleocene.

9 ***Haliomma* spp. gr. B.** R740, P30/f373, WO72 (Ta-H39/3), RP3, Early Paleocene.

10 **Actinommidae gen. *et* sp. indet.** R741, P30/f375, WO75 (Sa-5), RP4, Early Paleocene.

11 **Actinommidae? gen et. sp. indet.** R742, P30/f370, WO62 (CH08-16), RP2, Early Paleocene.

12 ***Hexadoridium* cf. *magnificum*** Campbell & Clark. R743, P30/f370, WO62 (Ta-H44/0), RP2, Early Paleocene.

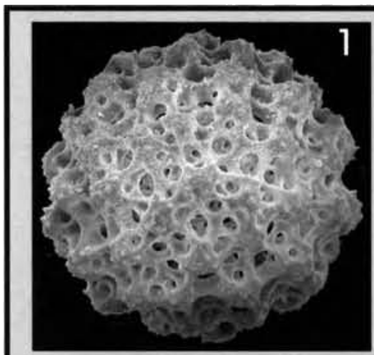
13 ***Hexadoridium* cf. *magnificum*** Campbell & Clark. R744, P30/f370, WO62 (Tb-E39/0), RP2, Early Paleocene.

14 ***Hexadoridium* cf. *magnificum*?** Campbell & Clark. R745, P30/f370, WO62 (CH08-17), RP2, Early Paleocene.

15 **Actinommidae? gen. *et* sp. indet.** R746, P30/f370, WO62 (CH08-18), RP2, Early Paleocene.

16 **Actinommidae gen. *et* sp. indet.** R747, P30/f370, WO62 (CH08-40), RP3, Early Paleocene.

17 **Actinommidae gen. *et* sp. indet.** (probably compressed *Amphisphaera kina*). R748, P30/f371, WO65 (CH08-38), RP2, Early Paleocene.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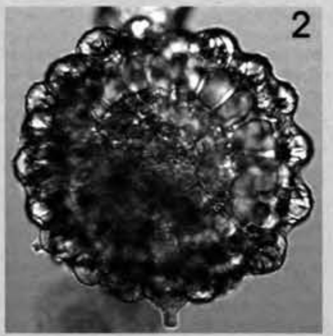
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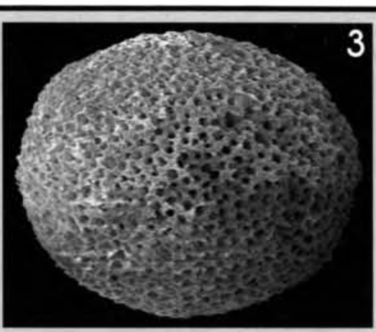
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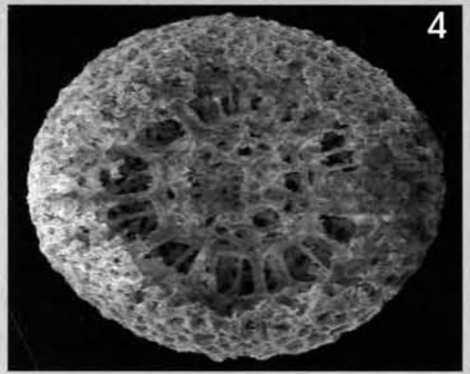
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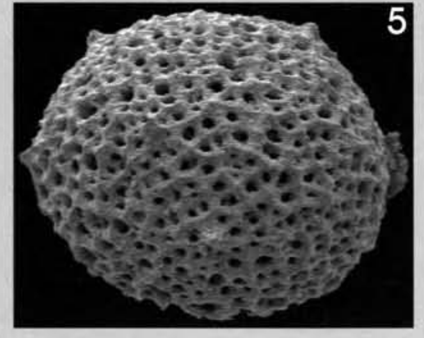
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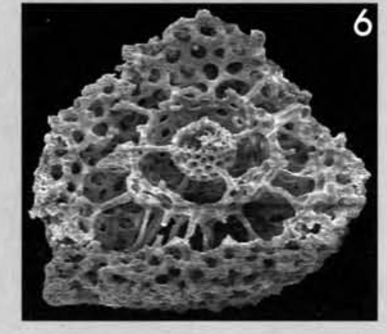
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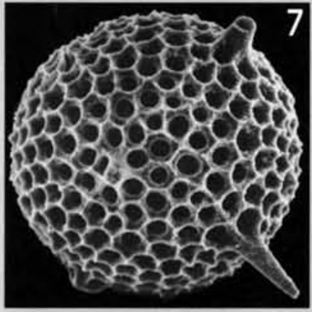
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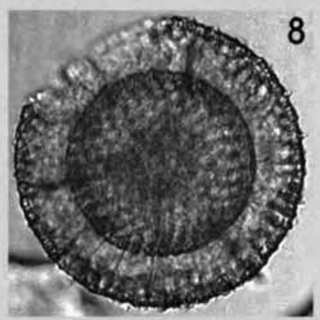
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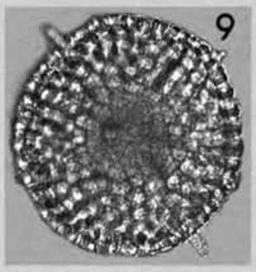
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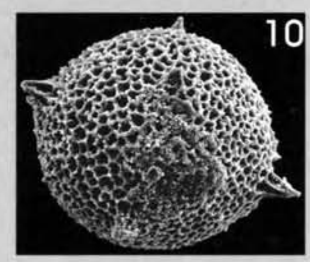
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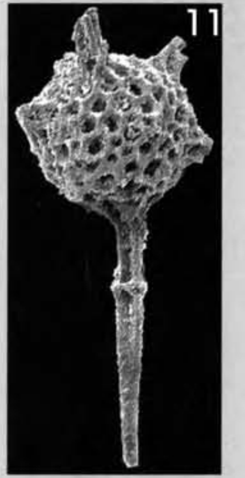
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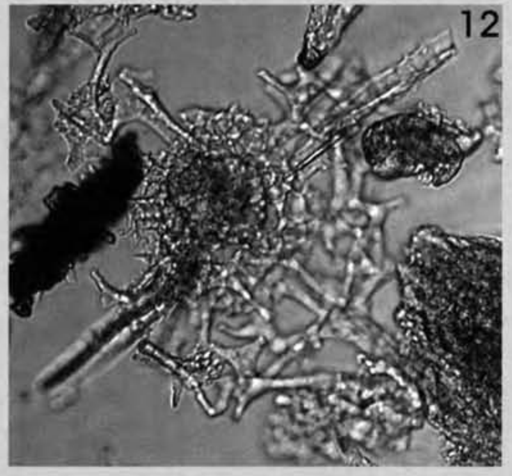
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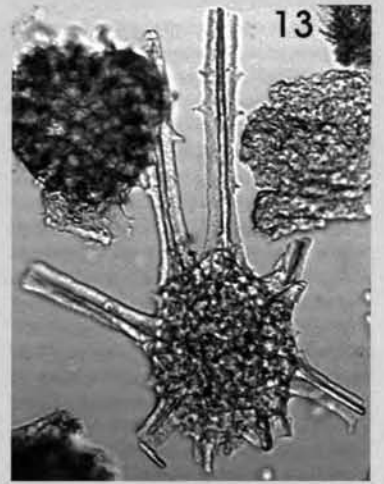
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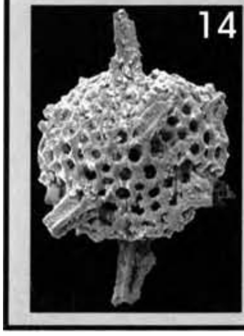
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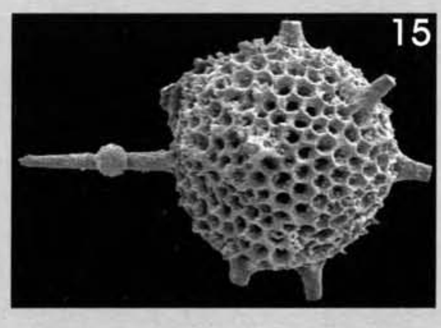
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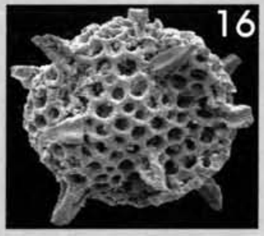
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Plate 4

Scale bars = 100 µm

Fig. 1 ***Lithomespilus coronatus*** Squinabol. R749, P30/f364, WO31 (Sa-2), RK9, Maastrichtian.

2 ***Lithomespilus coronatus*** Squinabol. R69, P30/f371, WO65 (Sb-2), RP2, Early Paleocene.

3 ***Lithomespilus coronatus*** Squinabol. R750, P30/f370, WO62 (Tb-T29/0), RP2, Early Paleocene.

4 ***Prunocarpus* sp. A.** R751, P30/f363, WO28 (Ta-J33/0), RK9, Maastrichtian.

5 ***Prunocarpus* sp. A.** R752, P30/f371, WO65 (Tb-R27/0), RP2, Early Paleocene.

6 ***Prunocarpus* sp. A.** R753, P30/f374, WO74 (Sa-2), RP4, Early Paleocene.

7 ***Prunocarpus* sp. A.** R754, P30/f375, WO75 (Sa-1), RP4, Early Paleocene.

8 ***Prunocarpus* sp. A.** 755, P30/f460, WO23 (Tb-V28/4), RP4, Early Paleocene.

9 ***Prunocarpus* sp. A.** Paratype. R756, P30/f461, WO25 (Tc-Q39/2), RP5, Early Paleocene.

10 ***Acanthocircus ellipticus*** (Campbell & Clark). R757, P30/f455, WO04 (Ta-U37/0), RK9, Maastrichtian.

11 ***Acanthocircus ellipticus*** (Campbell & Clark). R758, P30/f801, WO24 (CH08-3), RP4, Early Paleocene.

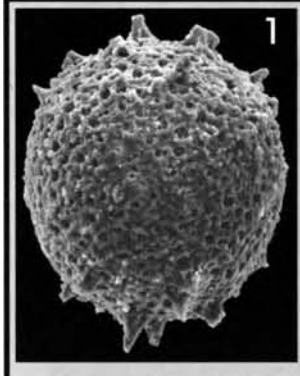
12 ***Acanthocircus campbelli*** (Foreman). R759, P30/f372, WO69 (Sa-2), RP3, Early Paleocene.

13 ***Acanthocircus* sp.** R760, P30/f460, WO23 (Ta-X36/3), RP4, Early Paleocene.

14 ***Saturnalis kennetti*** Dumitrica. R761, P30/f375, WO75 (Tb-W35/2), RP4, Early Paleocene.

15 ***Peritiviator*? sp.** R762, P30/f460, WO23 (Tc-G53/0), RP4, Early Paleocene.

16 ***Peritiviator* cf. *labyrinthi*** Pessagno. R763, P30/f369, WO60 (Ta-F25/3), RP2, Early Paleocene.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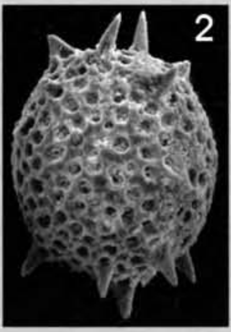
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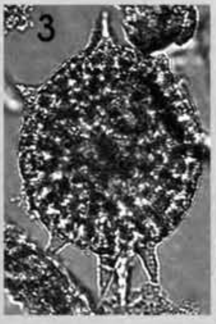
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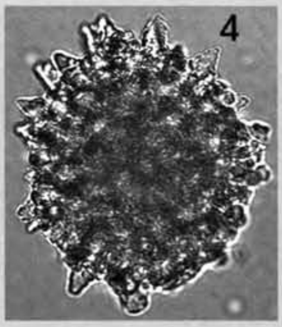
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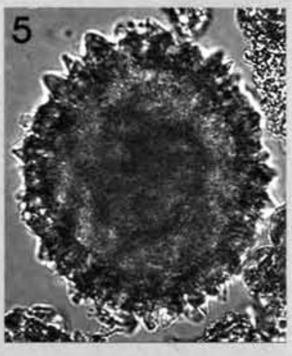
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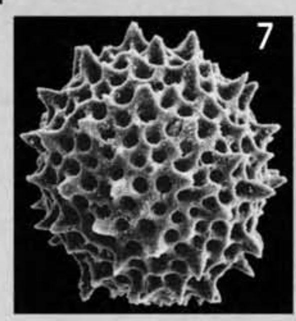
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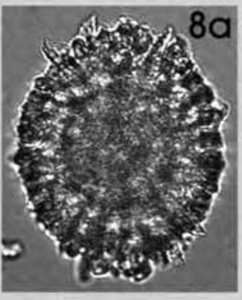
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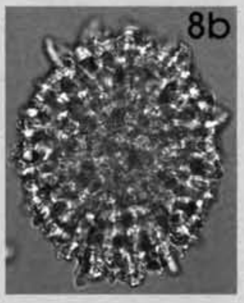
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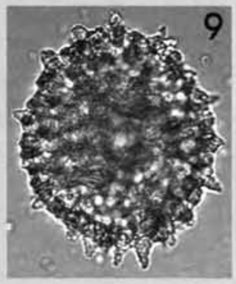
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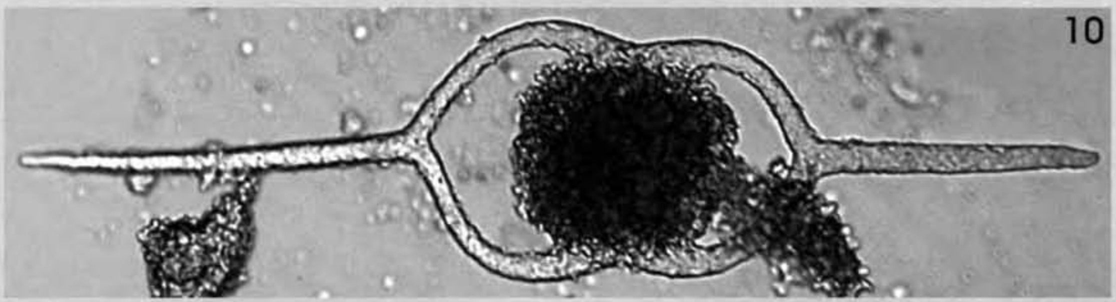
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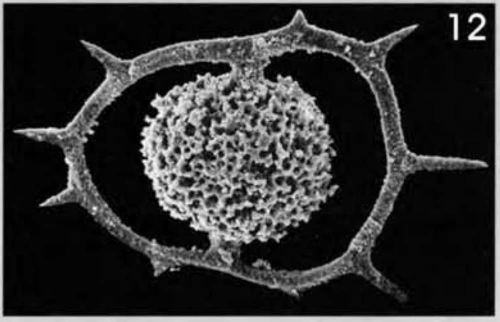
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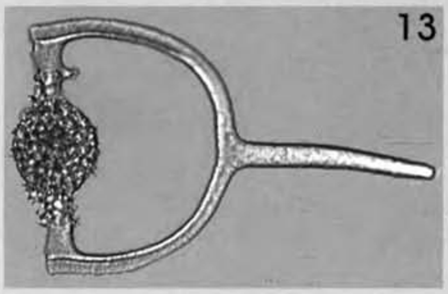
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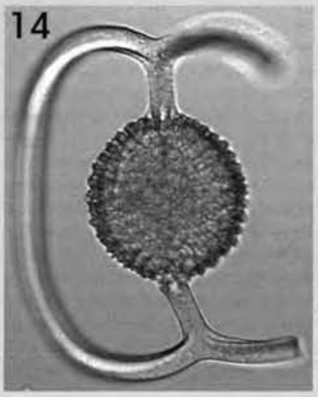
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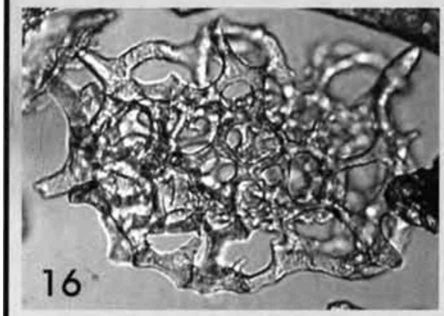
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Plate 5

Scale bars = 100 μm

Fig. 1 ***Heliosestrum*? sp.** R764, P30/f371, WO65 (CH08-35), RP2, Early Paleocene.

2 ***Heliosestrum*? sp.** R765, P30/f371, WO65 (Sa-19), RP2, Early Paleocene.

3 ***Periphaena* sp.** R766, P30/f375, WO75 (Sa-22), RP4, Early Paleocene.

4 ***Heliodiscus* sp.** R767, P30/f369, WO60 (CH08-15), RP2, Early Paleocene.

5 ***Tetrapyle*? sp.** R768, P30/f372, WO69 (Ta-F33/1), RP3, Early Paleocene.

6 ***Palaeotetrapyle muelleri*** Dumitrica. R769, P30/f460, WO23 (Ta-S27/2), RP4, Early Paleocene.

7 ***Lithelius*** aff. ***foremanae*** Sanfilippo & Riedel. R21, P30/f368, WO56 (Tb-H49/0). RP1, Early Paleocene.

8 ***Lithelius*** aff. ***foremanae*** Sanfilippo & Riedel. R770, P30/f459, WO19 (Tb-F54/1). RP4, Early Paleocene.

9 ***Lithelius*** aff. ***foremanae*** Sanfilippo & Riedel. R771, P30/f460, WO23 (Tb-G46/2), RP4, Early Paleocene.

10 ***Lithelius* cf. *hexaxyphopora*** (Clark & Campbell). R772, P30/f461, WO25 (Td-E24/4), RP5, Early Paleocene.


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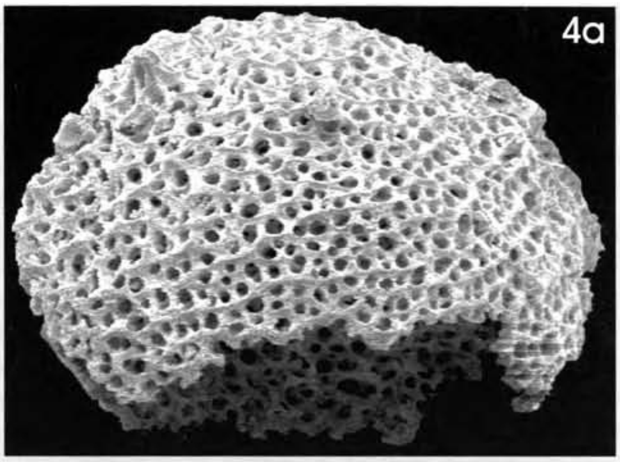
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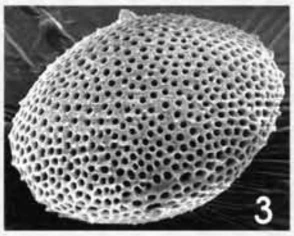
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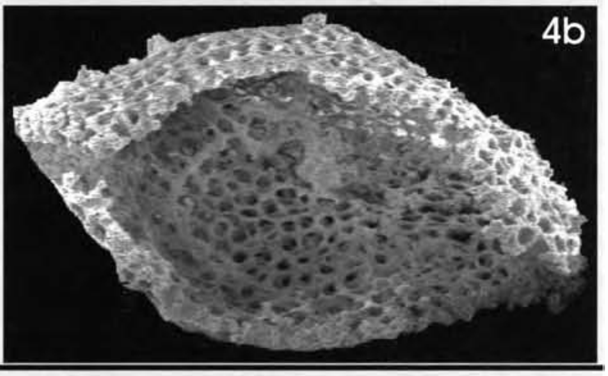
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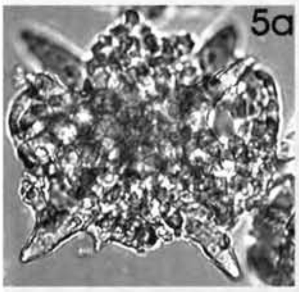
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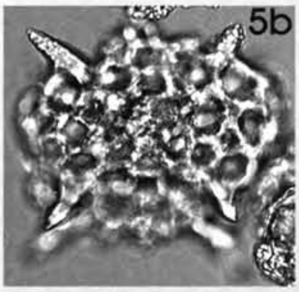
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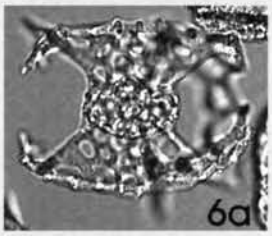
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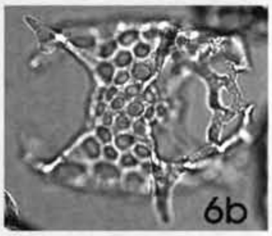
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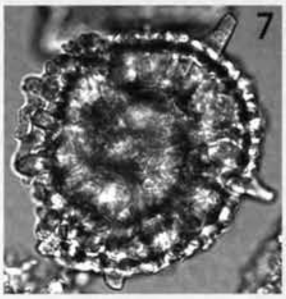
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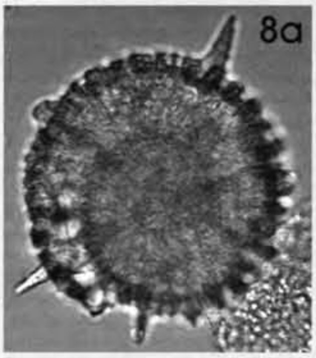
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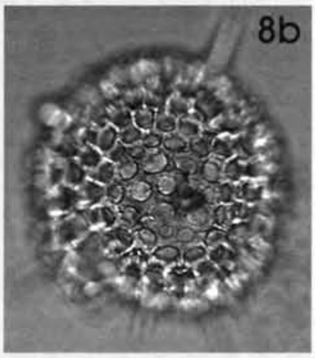
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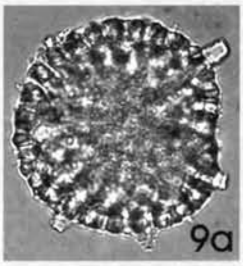
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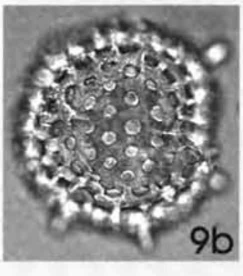
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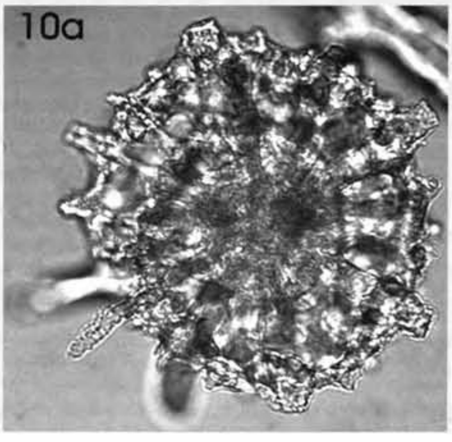
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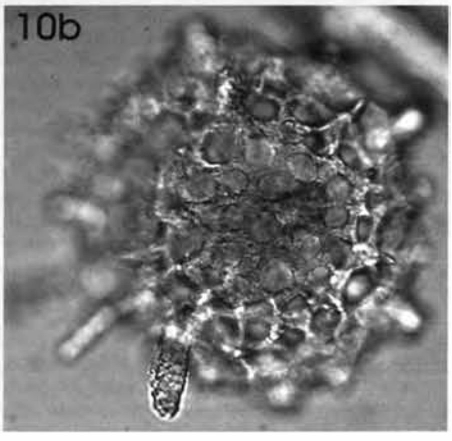
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Plate 6

Scale bars = 100 µm

Fig. 1 ***Lithelius marshalli*** **n.sp.** Holotype. R773, P30/f372, WO69 (CH08-67), RP3, Early Paleocene.

2 ***Lithelius marshalli*** **n.sp.** Paratype. R774, P30/f372, WO69 (CH08-61), RP3, Early Paleocene.

3 ***Lithelius marshalli*** **n.sp.** Paratype. R775, P30/f372, WO69 (CH08-64), RP3, Early Paleocene.

4 ***Lithelius marshalli*** **n.sp.** Paratype. R776, P30/f372, WO69 (Ta-J45/3), RP3, Early Paleocene.

5 ***Lithelius marshalli*** **n.sp.** Paratype. R777, P30/f372, WO69 (Ta-R40/1), RP3, Early Paleocene.

6 ***Lithelius minor*** Jörgensen **gr., n.gr.** R778, P30/f801, WO24 (CH08-5), RP4, Early Paleocene.

7 ***Lithelius minor*** Jörgensen **gr., n.gr.** R779, P30/f366, WO48 (Ta-X23/3), RK9, Maastrichtian.

8 ***Lithelius minor*** Jörgensen **gr., n.gr.** R780, P30/f366, WO48 (Ta-U46/4), RK9, Maastrichtian.

9 ***Lithelius minor*** Jörgensen **gr., n.gr.** R781, P30/f375, WO75 (Tb-H38/0), RP4, Early Paleocene.

10 ***Lithelius minor*** Jörgensen **gr., n.gr.** R782, P30/f375, WO75 (Ta-W51/2), RP4, Early Paleocene.

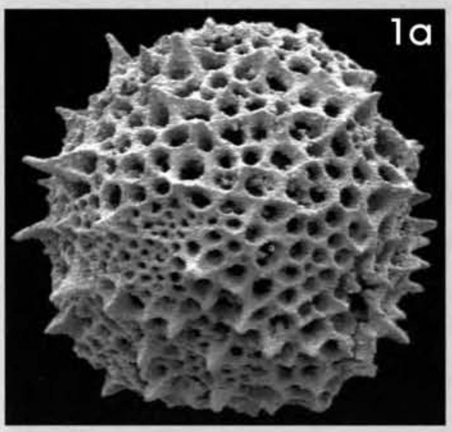
11 ***Lithelius minor*** Jörgensen **gr., n.gr.** R783, P30/f374, WO74 (Tb-R30/0), RP4, Early Paleocene.

12 ***Lithelius minor*** Jörgensen **gr., n.gr.** R784, P30/f375, WO75 (Tb-K44/3), RP4, Early Paleocene.

13 ***Lithelius minor*** Jörgensen **gr., n.gr.** R785, P30/f375, WO75 (Ta-J24/0), RP4, Early Paleocene.

14 ***Lithelius minor*** Jörgensen **gr., n.gr.** R786, P30/f375, WO75 (Tb-F23/0), RP4, Early Paleocene.

15 ***Lithelius minor*** Jörgensen **gr., n.gr.** R787, P30/f375, WO75 (Ta-M49/4), RP4, Early Paleocene.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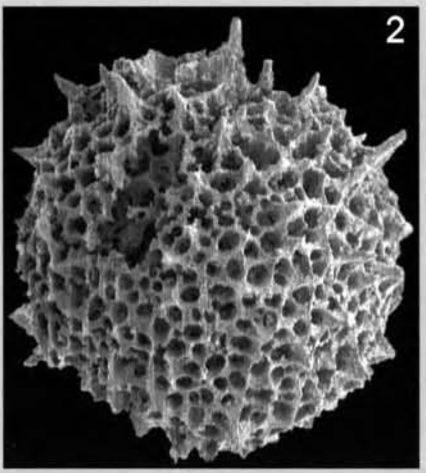
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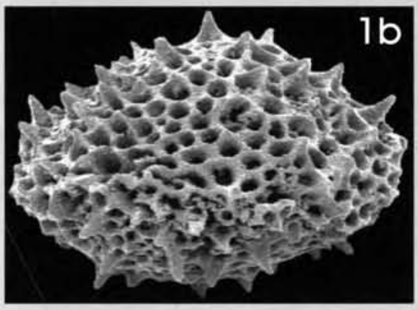
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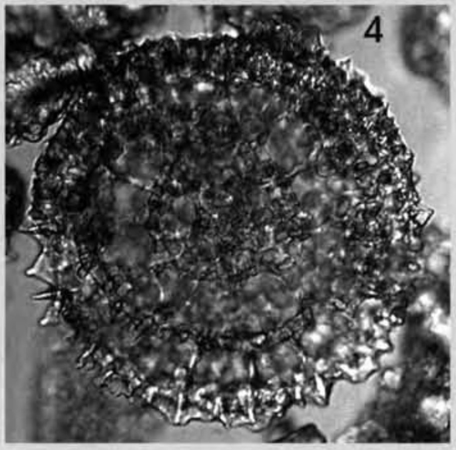
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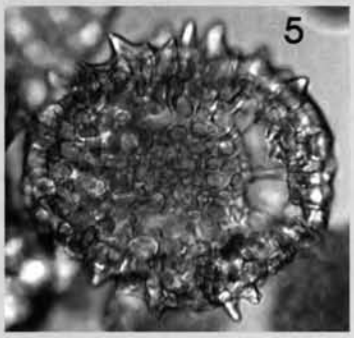
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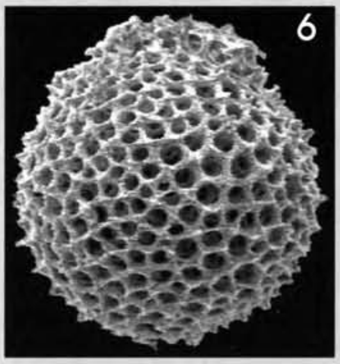
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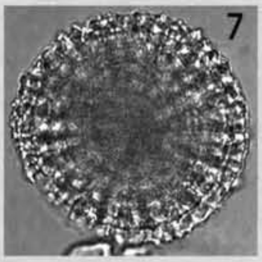
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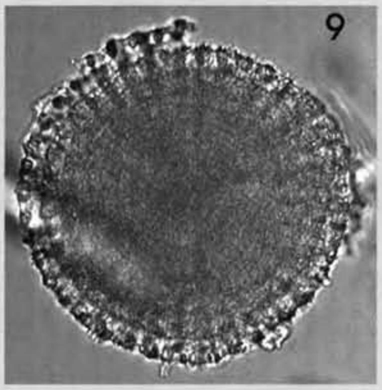
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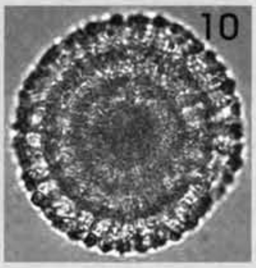
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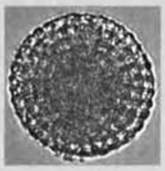
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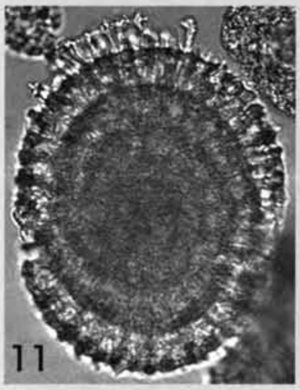
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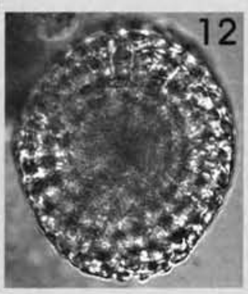
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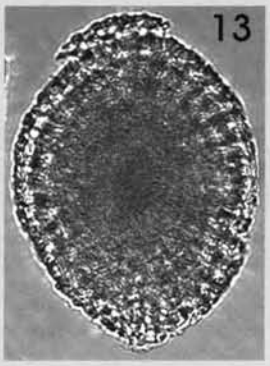
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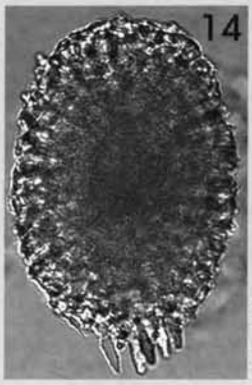
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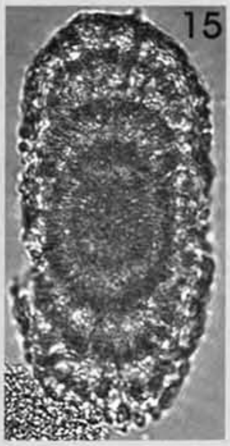
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Plate 7

Scale bars = 100 μm

Fig. 1 ***Lithelius*? aff. *minor*** Jörgensen. R788, P30/f370, WO62 (CH008-52), RP2, Early Paleocene.

2 ***Lithelius*? aff. *minor*** Jörgensen. R789, P30/f457, WO61 (Tb-G50/0), RP2, Early Paleocene.

3 ***Lithelius*? aff. *minor*** Jörgensen. R790, P30/f372, WO69 (Ta-O55/1), RP3, Early Paleocene.

4 ***Spongoprunum* cf. *markleyense*** Clark & Campbell. R791, P30/f370, WO62 (CH008-28), RP2, Early Paleocene.

5 ***Spongoprunum* cf. *markleyense*** Clark & Campbell. R792, P30/f370, WO62 (Tb-K39/0), RP2, Early Paleocene.

6 ***Spongoprunum* cf. *markleyense*** Clark & Campbell. R793, P30/f372, WO69 (Ta-D56/0), RP3, Early Paleocene.

7 ***Amphymenium concentricum*** (Lipman). R794, P30/f363, WO28 (Ta-L29/1), RK9, Maastrichtian.

8 ***Amphymenium* cf. *splendiarmatum*** Clark & Campbell. R795, P30/f372, WO69 (CH008-50), RP3, Early Paleocene.

9 ***Amphymenium* cf. *splendiarmatum*** Clark & Campbell. R796, P30/f372, WO69 (Tb-V37/0), RP3, Early Paleocene.

10 ***Amphymenium* cf. *splendiarmatum*** Clark & Campbell. R797, P30/f373, WO72 (Ta-M33/0), RP3, Early Paleocene.

11 ***Prunobrachium kennetti*** Pessagno. R96, P30/f364, WO31 (Sb-10), RK9, Maastrichtian.

12 ***Prunopyle* sp.** R798, P30/f374, WO74 (Ta-Q45/1), RP4, Early Paleocene.

13 ***Prunopyle* sp.** R799, P30/f461, WO25 (Td-O53/4), RP5, Early Paleocene.

14 ***Spongurus spongiosus*** (Lipman). R800, P30/f363, WO28 (Sa-19), RK9, Maastrichtian.

15 ***Spongurus* cf. *bilobatus*** Clark & Campbell. R801, P30/f375, WO75 (Sa-30), RP4, Early Paleocene.

16 ***Spongurus* cf. *bilobatus*** Clark & Campbell. R802, P30/f368, WO56 (Tc-L27/3), RP1, Early Paleocene.

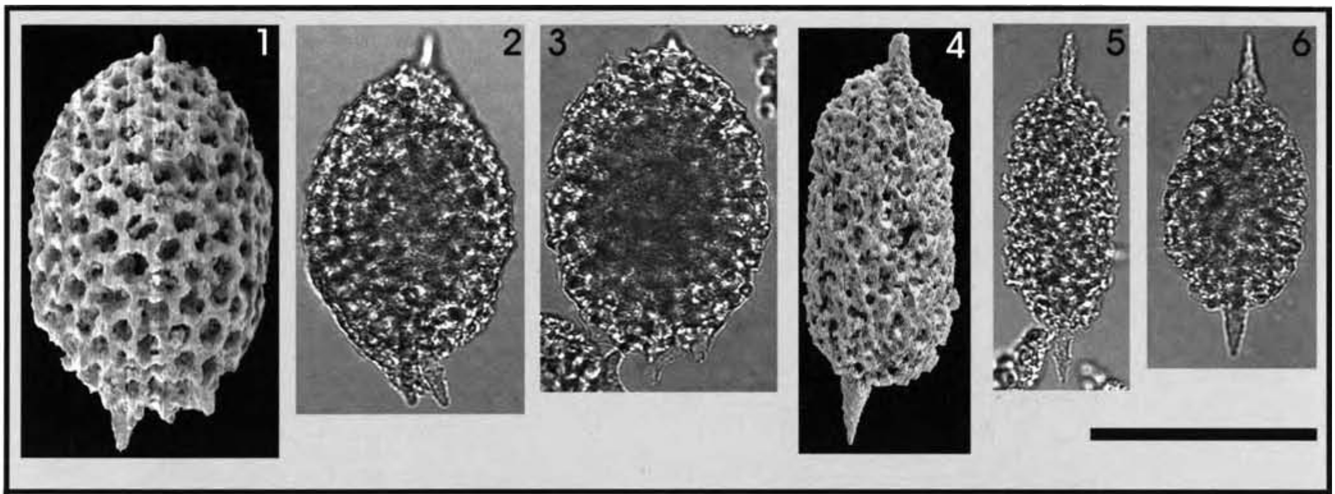
17 ***Spongurus* cf. *bilobatus*** Clark & Campbell. R803, P30/f375, WO75 (Ta-Y30/3), RP4, Early Paleocene.

18 ***Spongurus* cf. *bilobatus*** Clark & Campbell. R804, P30/f375, WO75 (Tb-R46/0), RP4, Early Paleocene.

19 ***Spongurus* aff. *prolixum*** (Sanfilippo & Riedel). R805, P30/f368, WO56 (Sa-104), RP1, Early Paleocene

20 ***Spongurus* aff. *prolixum*** (Sanfilippo & Riedel). R806, P30/f370, WO62 (CH008-29), RP2, Early Paleocene.

21 ***Spongurus* aff. *prolixum*** (Sanfilippo & Riedel). R807, P30/f457, WO61 (Tb-H38/0), RP2, Early Paleocene.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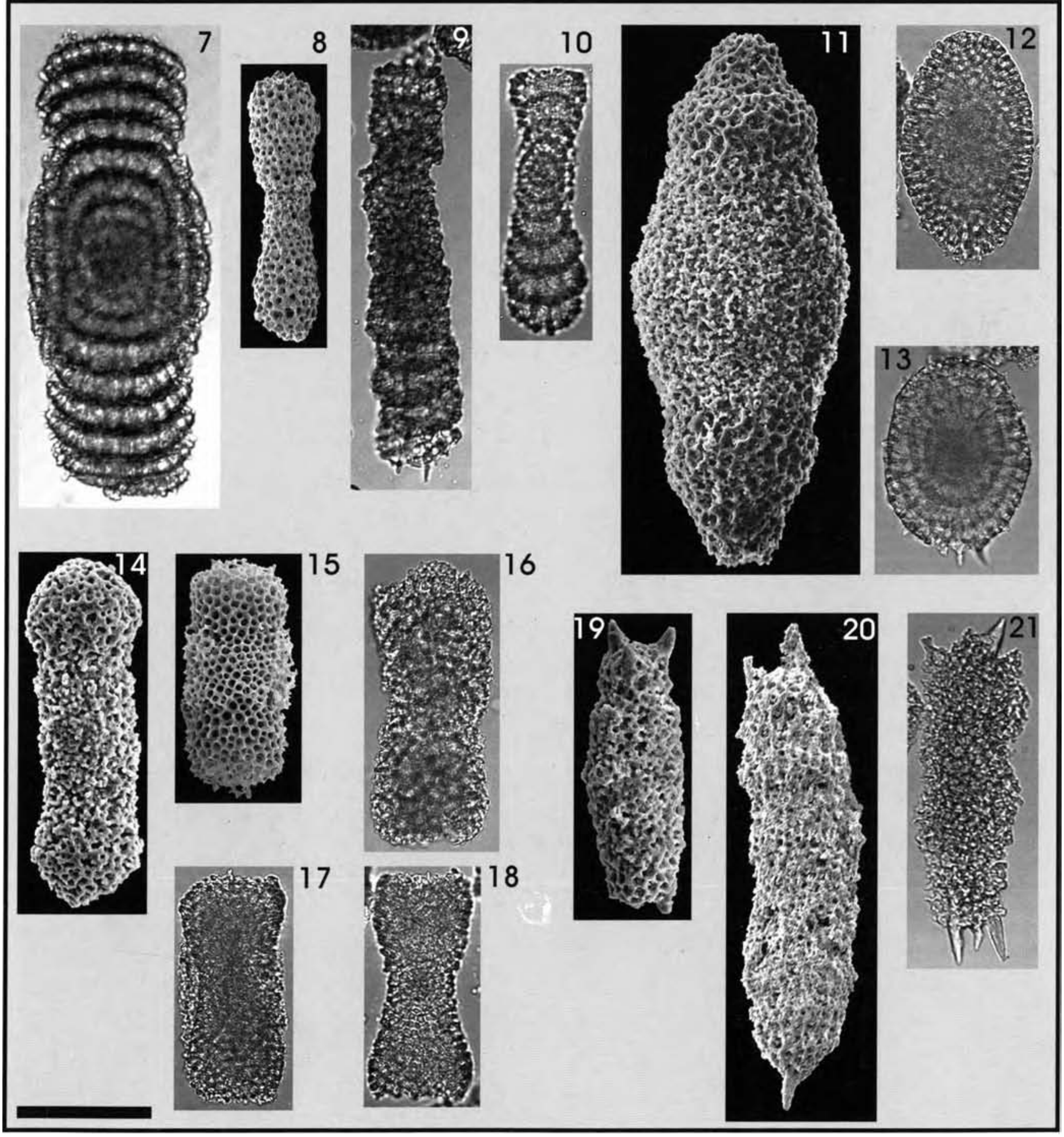
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Plate 8

Scale bar = 100 µm

Fig. 1 ***Phaseliforma laxa*** Pessagno. R93, P30/f375, WO75 (Sa-26), RP4, Early Paleocene.

2 ***Phaseliforma subcarinata*** Pessagno. R808, P30/f374, WO74 (Sa-20), RP4, Early Paleocene.

3 ***Phaseliforma subcarinata*** Pessagno. R809, P30/f375, WO75 (Tb-W38/0), RP4, Early Paleocene.

4 ***Phaseliforma subcarinata*** Pessagno. R92, P30/f374, WO74 (Sa-19), RP4, Early Paleocene.

5 ***Phaseliforma subcarinata*** Pessagno. R810, P30/f375, WO75 (Sa-25), RP4, Early Paleocene.

6 ***Patulibracchium*** **sp**. R811, P30/f455, WO04 (Sa-5), RK9, Maastrichtian.

7 ***Patulibracchium*** **sp**. R812, P30/f365, WO37 (Tb-J42/1), RK9, Maastrichtian.

8 ***Patulibracchium*** **sp**. R813, P30/f464, WH03 (Ta-G36/0), RP1, Early Paleocene.

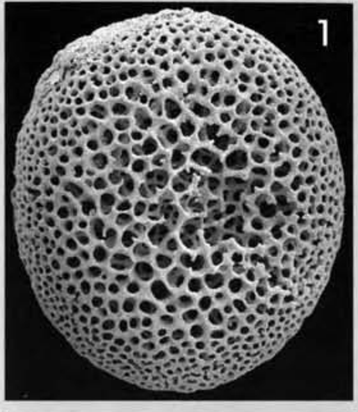
9 ***Patulibracchium*? sp**. R814, P30/f464, WH03 (Ta-H53/1), RP1, Early Paleocene.

10 ***Amphibrachium*** **aff.** ***sansalvadorensis*** Pessagno. R815 P30/f372, WO69 (CH008-56), RP3, Early Paleocene.

11 ***Amphibrachium*** **aff.** ***sansalvadorensis*** Pessagno. R816, P30/f457, WO61 (Ta-W49/1), RP2, Early Paleocene.

12 ***Patulibracchium*? sp**. R817, P30/f370, WO62 (CH008-30), RP2, Early Paleocene.

13 ***Patulibracchium*** **sp**. R818, P30/f372, WO69 (CH008-54), RP3, Early Paleocene.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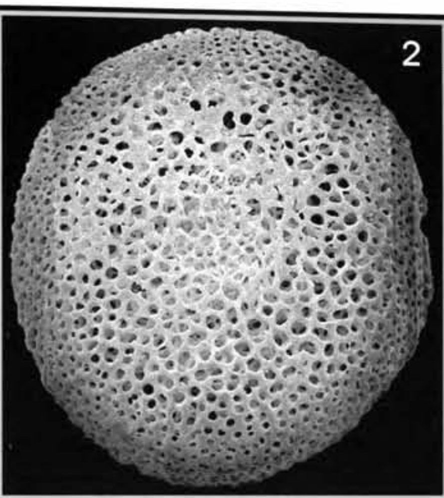
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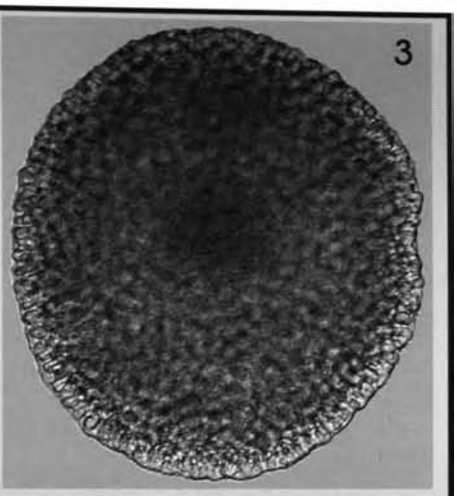
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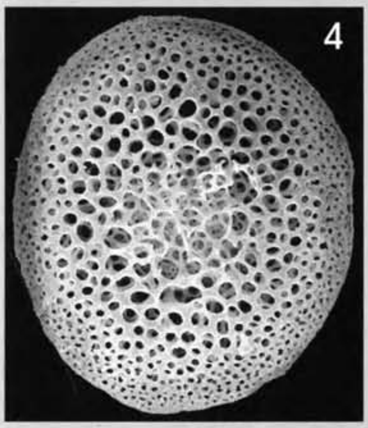
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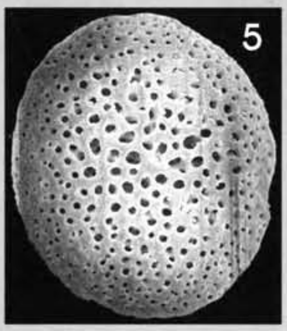
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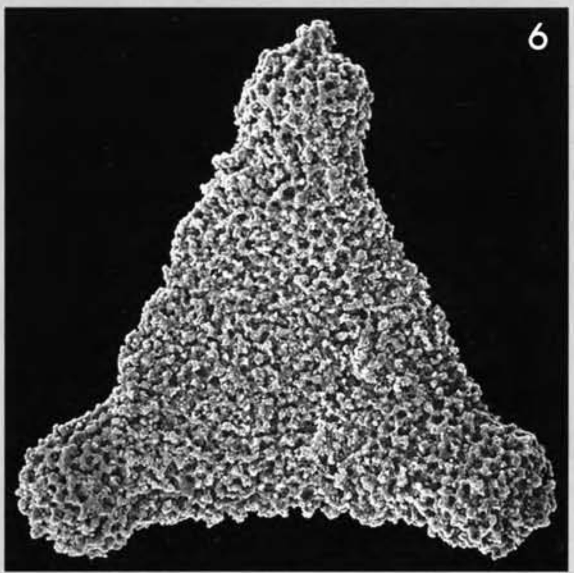
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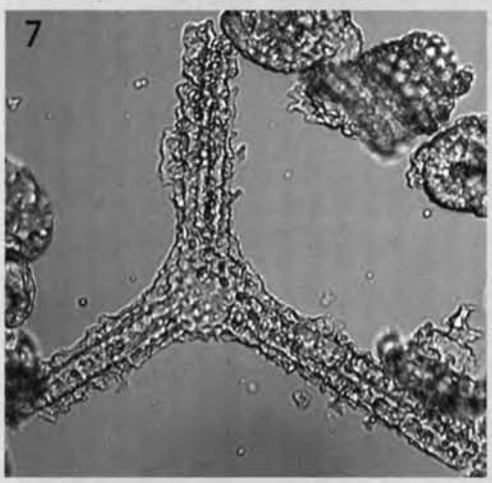
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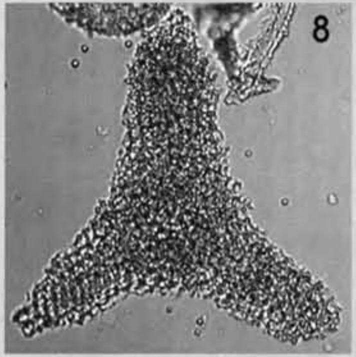
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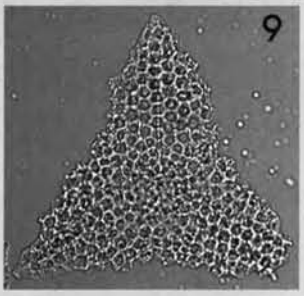
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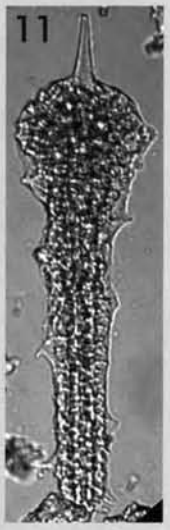
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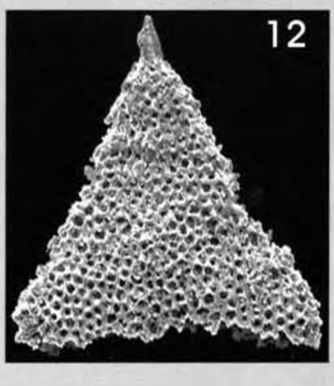
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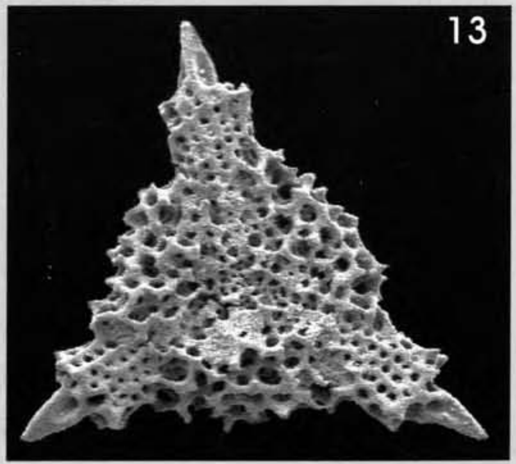
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Plate 9

Scale bar = 100 µm

Fig. 1 ***Orbiculiforma renillaeformis* s.l.** (Campbell & Clark) R819, P30/f372, WO69 (Sa-12), RP3, Early Paleocene.

2 ***Orbiculiforma renillaeformis* s.l.** (Campbell & Clark)R820, P30/f375, WO75 (Sa-34), RP4, Early Paleocene.

3 ***Orbiculiforma renillaeformis* s.l.** (Campbell & Clark) R821, P30/f374, WO74 (Sa-25), RP4, Early Paleocene (= Orbiculiforma australis Pessagno, 1975).

4 ***Orbiculiforma renillaeformis* s.s.** (Campbell & Clark) R822, P30/f372, WO69 (CH008-53), RP3, Early Paleocene.

5 ***Orbiculiforma renillaeformis* s.s.** (Campbell & Clark) R70, P30/f374, WO74 (Sa-26), RP4, Early Paleocene.

6 ***Orbiculiforma renillaeformis*** *s.s.* (Campbell & Clark) (Tb-R28/3), RP2, Early Paleocene.

7 ***Orbiculiforma renillaeformis* s.s.** (Campbell & Clark) R35, P30/f372, WO69 (Ta-H39/4), RP3, Early Paleocene.

8 ***Spongotripus* sp.** R823, P30/f455, WO04 (Sa-6), RK9, Maastrichtian.

9 ***Spongotripus*** sp. R824, P30/f371, WO65 (Sb-40), RP2, Early Paleocene.

10 ***Spongotripus* sp.** R825, P30/f375, WO75 (Sa-31), RP4, Early Paleocene.

11 ***Spongotrochus antiquus*** (Campbell & Clark). R95, P30/f368, WO56 (Sa-26), RP1, Early Paleocene.

12 ***Spongotrochus antiquus*** (Campbell & Clark). R826, P30/f363, WO28 (Ta-L35/4), RK9, Maastrichtian.

13 ***Spongotrochus antiquus*** (Campbell & Clark). R827, P30/f372, WO69 (Ta-H42/3), RP3, Early Paleocene.

14 ***Spongotrochus antiquus*** (Campbell & Clark). R828, P30/f368, WO56 (Tc-X34/0), RP1, Early Paleocene.

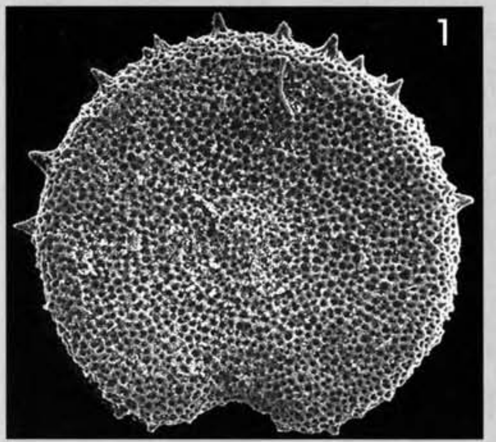
15 ***Spongotrochus*** cf. ***polygonatus*** (Campbell & Clark). R829, P30/f372, WO69 (Tb-S56/2), RP3, Early Paleocene.

16 ***Spongotrochus*** cf. ***polygonatus*** (Campbell & Clark). R830, P30/f363, WO28 (Sa-22), RK9, Maastrichtian.

17 ***Spongotrochus*** cf. ***polygonatus*** (Campbell & Clark). R 831, P30/f363, WO28 (Sa-21), RK9, Maastrichtian.

18 ***Spongotrochus*** cf. ***glacialis*** Popofsky. R832, P30/f372, WO69 (CH008-59), RP3, Early Paleocene.

19 ***Spongotrochus*** cf. ***glacialis*** Popofsky. R833, P30/f608, WO58 (Ta-O48/3), RP2, Early Paleocene.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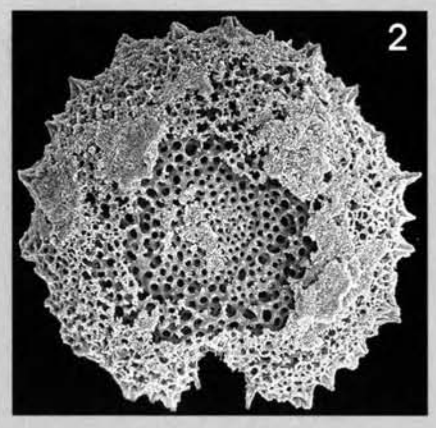
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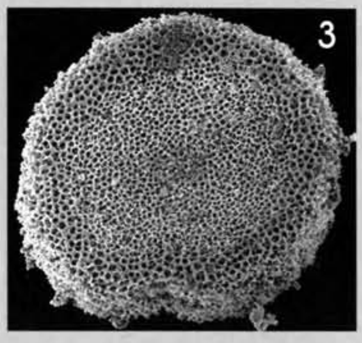
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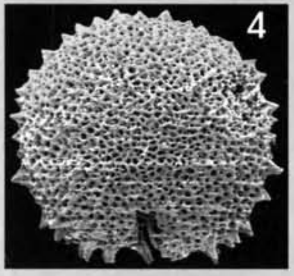
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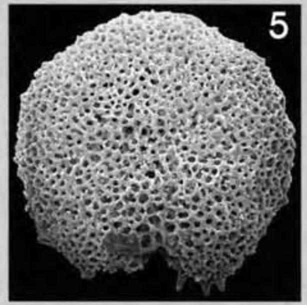
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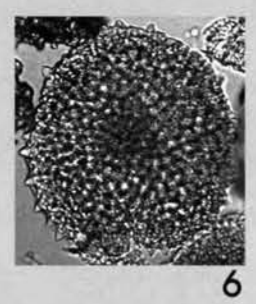
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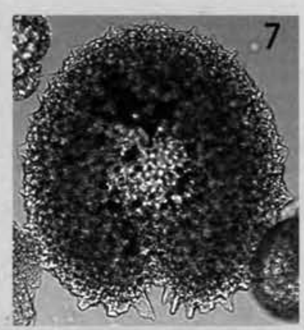
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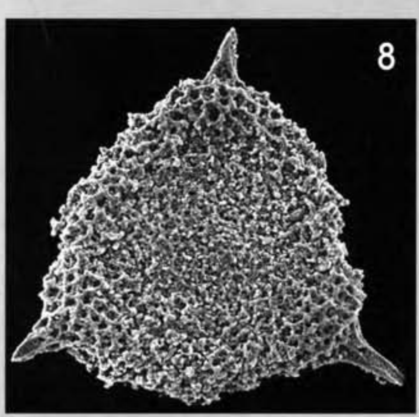
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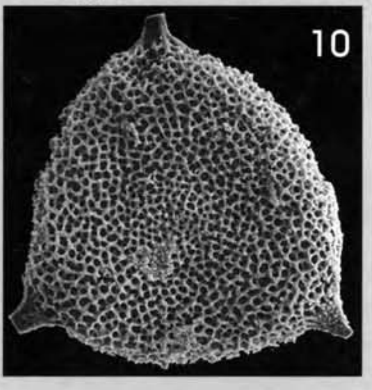
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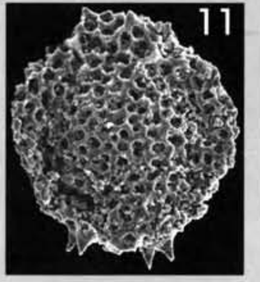
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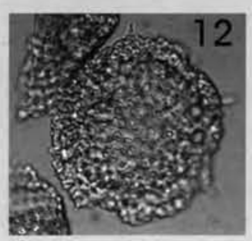
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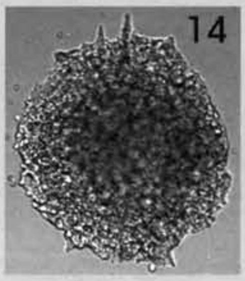
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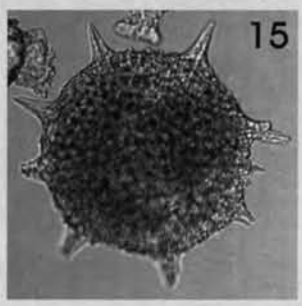
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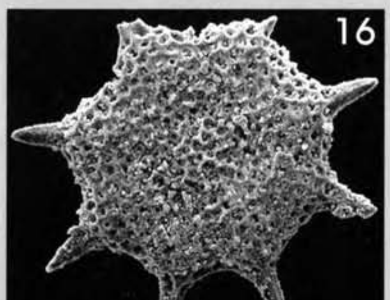
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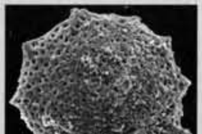
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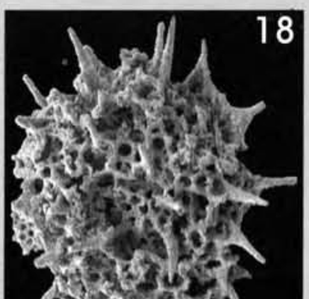
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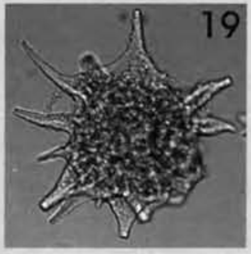
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Plate 10

Scale bars = 100 µm

Fig. 1 ***Spongodiscus* sp.** R834, P30/f374, WO74 (Sa-23), RP4, Early Paleocene.

2 ***Spongodiscus* sp.** R835, P30/f372, WO69 (Sa-11), RP3, Early Paleocene.

3 ***Spongodiscus* sp.** R836, P30/f375, WO75 (Ta-R38/1), RP4, Early Paleocene.

4 ***Spongodiscus alveatus*** (Sanfilippo & Riedel). R837, P30/f374, WO74 (Sa-25), RP4, Early Paleocene.

5 ***Spongodiscus alveatus*** (Sanfilippo & Riedel). R838, P30/f375, WO75 (Ta-R52/2), RP4, Early Paleocene.

6 ***Spongodiscus rhabdostylus*** (Ehrenberg). R839, P30/f375, WO75 (Sa-32), RP4, Early Paleocene.

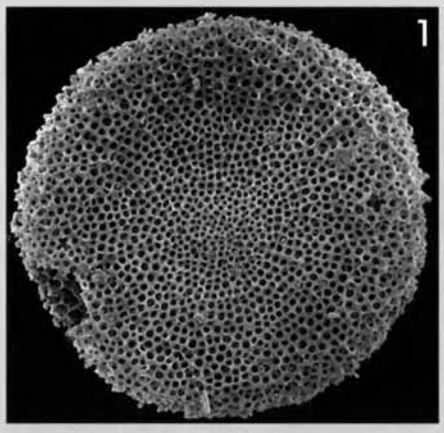
7 ***Spongodiscus rhabdostylus*** (Ehrenberg). R840, P30/f375, WO75 (Ta-N45/0), RP4, Early Paleocene.

8 ***Spongodiscus rhabdostylus*** (Ehrenberg). R 841, P30/f375, WO75 (Tb-F24/1), RP4, Early Paleocene.

9 ***Spongopyle insolita* Kozlova**. R842, P30/f375, WO75 (Tb-T33/3), RP4, Early Paleocene.

10 ***Flustrella cretacea*** (Campbell & Clark). R843, P30/f372, WO69 (Ta-F42/2), RP3, Early Paleocene.

11 ***Flustrella ruesti*** (Campbell & Clark). R844, P30/f368, WO56 (Tc-B39/4), RP1, Early Paleocene.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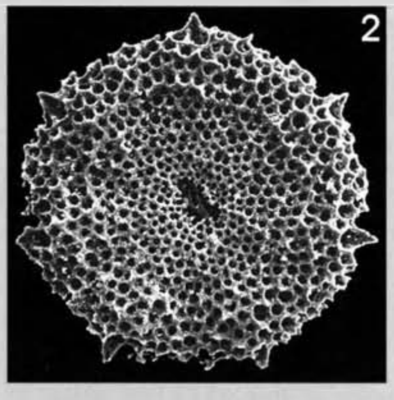
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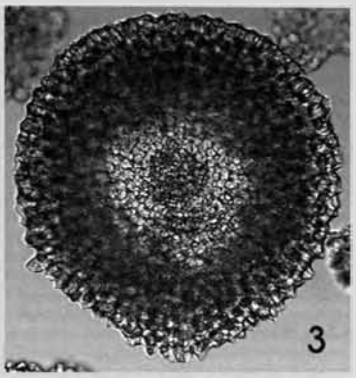
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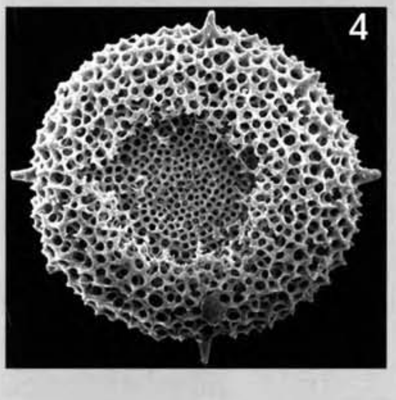
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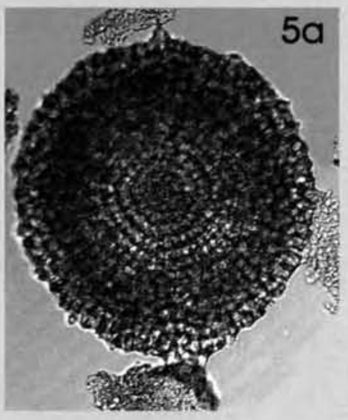
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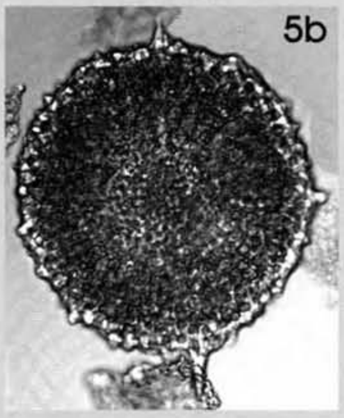
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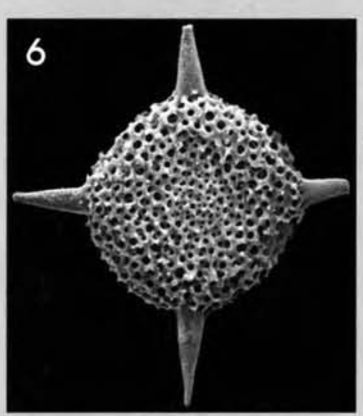
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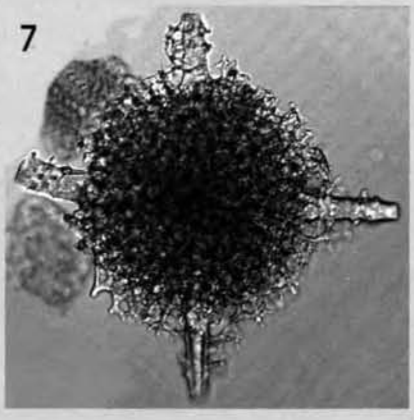
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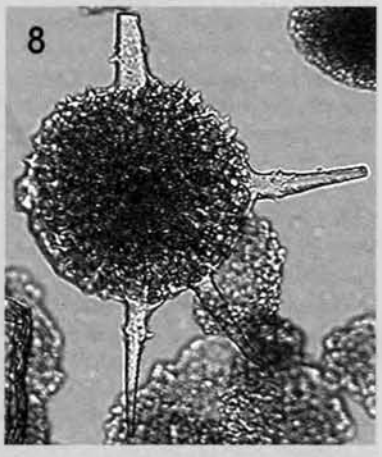
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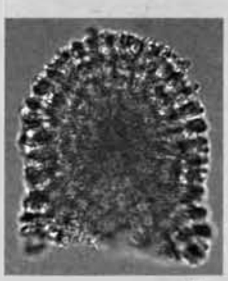
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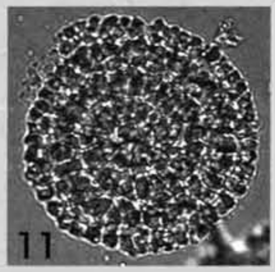
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Plate 11

Scale bar = 100 µm

Fig. 1 ***Tholodiscus densus*** (Kozlova). R845, P30/f801, WO24 (CH008-6), RP4, Early Paleocene.

2 ***Tholodiscus densus*** (Kozlova). R846, P30/f363, WO28 (Td-L41/0), RK9, Maastrichtian.

3 ***Tholodiscus densus*** (Kozlova). R847, P30/f368, WO56 (Tc-J23/3), RP1, Early Paleocene.

4 ***Tholodiscus*** **cf.** ***ocellatus*** (Ehrenberg). R848, P30/f363, WO28 (Tc-R50/3), RK9. Maastrichtian.

5 ***Tholodiscus*** **cf.** ***ocellatus*** (Ehrenberg). R849, P30/f375, WO75 (Ta-F55/2), RP4, Early Paleocene.

6 ***Tholodiscus*** **cf.** ***ocellatus*** (Ehrenberg). R850, P30/f375, WO75 (Tb-G46/4), RP4, Early Paleocene.

7 ***Tholodiscus*** **cf.** ***ocellatus*** (Ehrenberg). R851, P30/f375, WO75 (Tb-E49/1), RP4, Early Paleocene.

8 ***Tholodiscus*** **cf.** ***ocellatus*** (Ehrenberg). R852, P30/f375, WO75 (Ta-V54/2), RP4, Early Paleocene.

9 ***Tholodiscus*** **cf.** ***targaeformis*** Clark & Campbell. R853, P30/f375, WO75 (Tb-H22/4), RP4, Early Paleocene.

10 ***Tholodiscus*** **cf.** ***targaeformis*** Clark & Campbell. R854, P30/f460, WO23 (Tb-Q32/3), RP4, Early Paleocene.

11 ***Stylodictya*** **cf.** ***sexispinata*** Clark & Campbell. R855, P30/f374, WO74 (Tb-R33/0), RP4, Early Paleocene.


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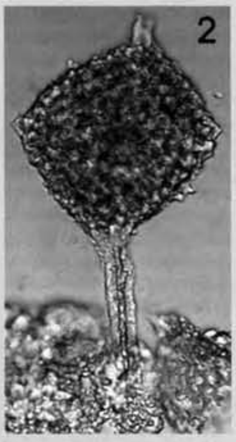
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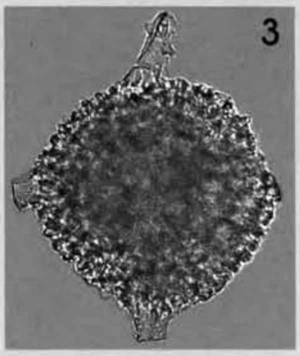
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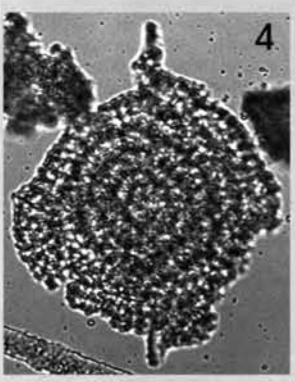
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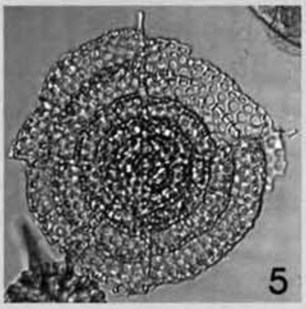
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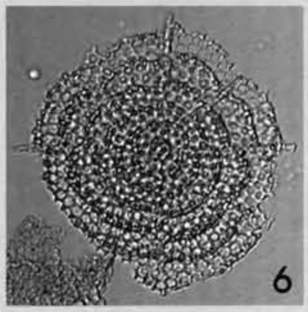
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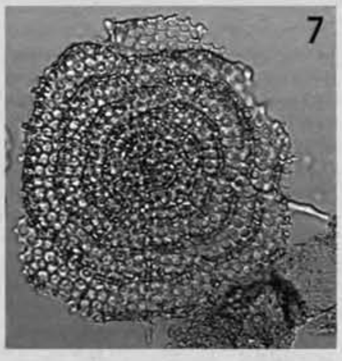
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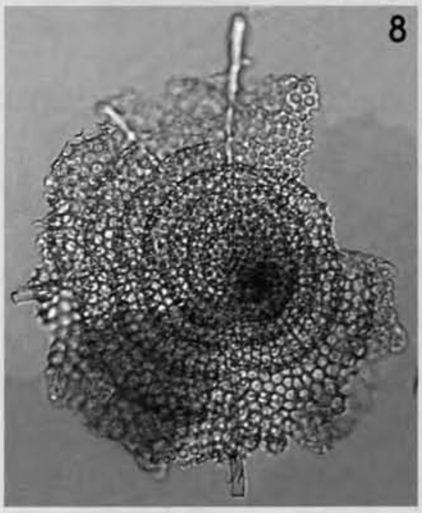
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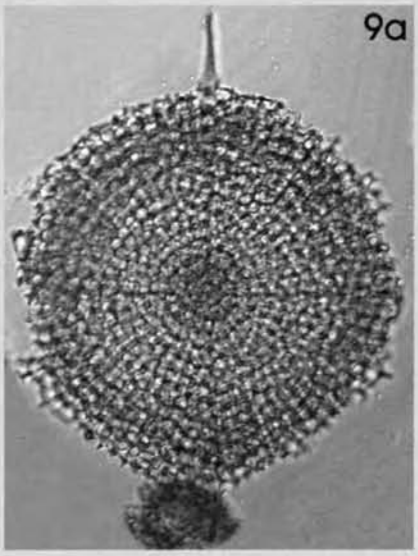
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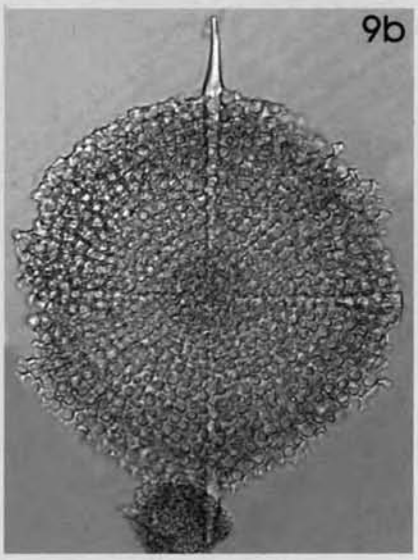
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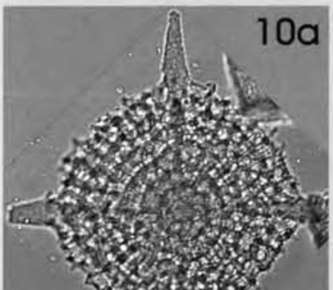
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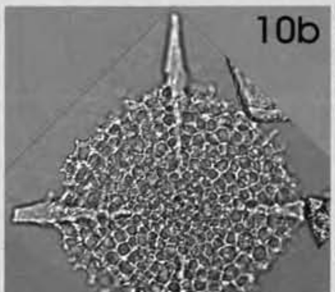
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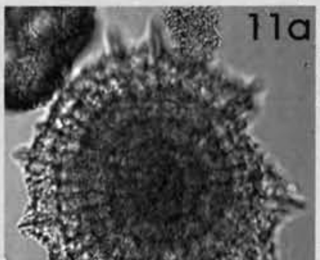
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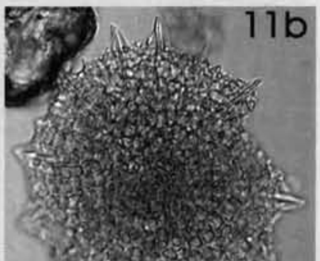
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Plate 12

Scale bars = 100 μm

Fig. 1 ***Lithomelissa*? *hoplites*** Foreman. R856, P30/f455, WO04 (Sa-32), RK9, Maastrichtian.

2 ***Lithomelissa*? *hoplites*** Foreman. R857, P30/f372, WO69 (Sa-110), RP3, Early Paleocene.

3 ***Lithomelissa*? *hoplites*** Foreman. R32, P30/f369, WO60 (Tb-T29/1), RP2, Early Paleocene.

4 ***Lithomelissa*? *polycyrtis*?** (Campbell & Clark). R858, P30/f372, WO69 (Sa106), RP3, Early Paleocene.

5 ***Lithomelissa*? *aitai* n.sp.** Holotype. R98, P30/f368, WO56 (Sa-105), RP1, Early Paleocene.

6 ***Lithomelissa*? *aitai* n.sp**. Paratype. R859, P30/f608, WO58 (Tb-R49/4), RP2, Early Paleocene.

7 ***Lithomelissa*? *aitai* n.sp**. Paratype. R860, P30/f459, WO19 (Ta-Y52/3), RP4, Early Paleocene.

8 ***Lithomelissa*? *aitai* n.sp.** R861, P30/f375, WO75 (Ta-K41/1), RP4, Early Paleocene.

9 ***Lithomelissa* cf. *heros*** Campbell & Clark. R862, P30/f368, WO56 (Sa-100), RP1, Early Paleocene.

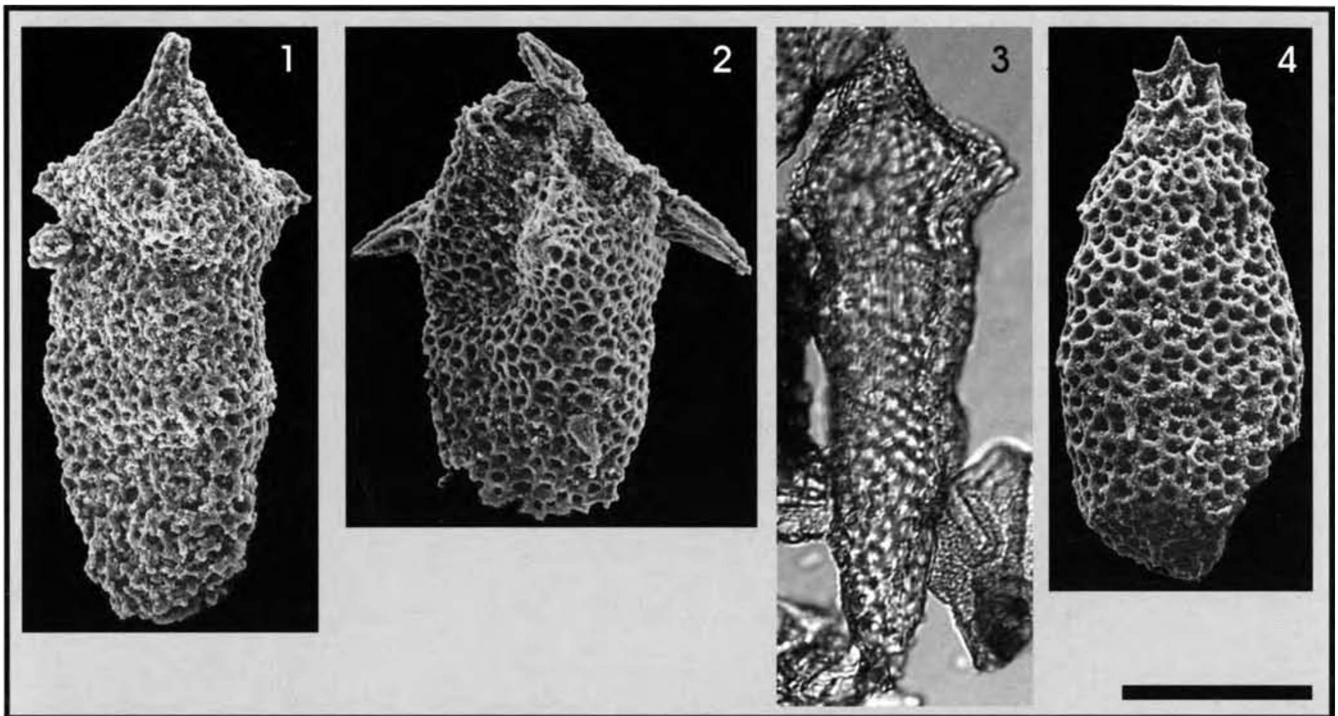
10 ***Lithomelissa* cf. *heros*** Campbell & Clark. R99, P30/f375, WO75 (Ta-R36/1), RP4, Early Paleocene.

11 ***Lithomelissa* cf. *heros*** Campbell & Clark. R863, P30/f374, WO74 (Ta-Z52/3), RP4, Early Paleocene.

12 ***Lithomelissa*? *polycyrtis*?** (Campbell & Clark). R864, P30/f608, WO58 (Tb-S50/0), RP2, Early Paleocene.

13 ***Lithomelissa gelasinus*** O'Connor. R865, P30/f460, WO23 (Tc-Q49/0), RP4, Early Paleocene.

14 ***Lithomelissa gelasinus*** O'Connor. R866, P30/f460, WO23 (Tc-Q45/2), RP4, Early Paleocene.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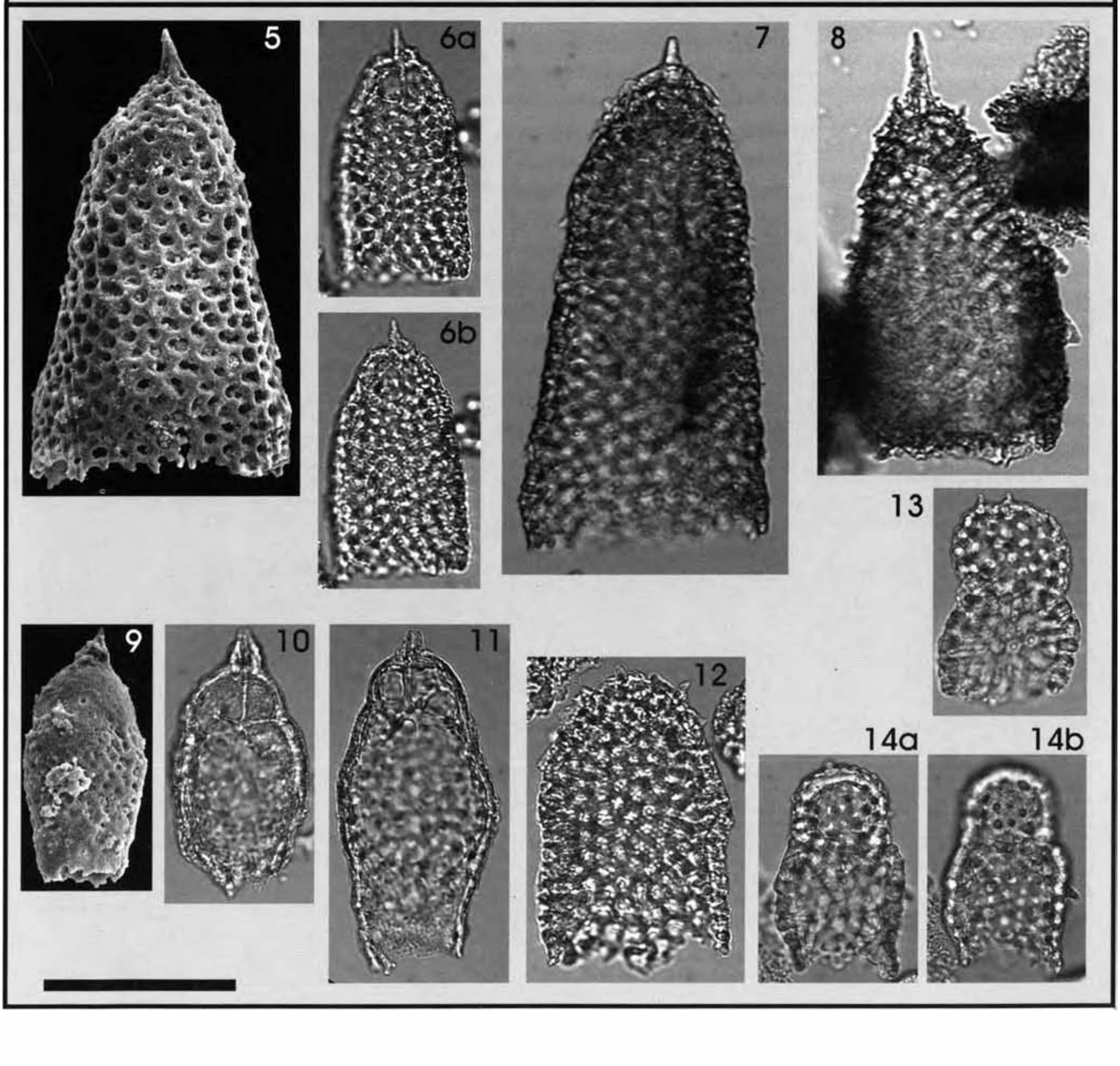
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Plate 13

Scale bars = 100 μm

Fig. 1 ***Phormostichoartus? strongi* n.sp.** Holotype. R867, P30/f363, WO28 (Sa-75), RK9, Maastrichtian.

2 ***Phormostichoartus? strongi* n.sp.** Paratype. R868, P30/f608, WO58 (Tb-N47/2), RP2, Early Paleocene.

3 ***Phormostichoartus? strongi* n.sp.** Paratype. R869, P30/f374, WO74 (Ta-K28/2), RP4, Early Paleocene.

4 ***Phormostichoartus? strongi* n.sp.** Paratype. R870, P30/f459, WO19 (Tc-N33/1), RP4, Early Paleocene.

5 ***Phormostichoartus? strongi* n.sp.** Paratype. R871, P30/f460, WO23 (Tb-H45/3), RP4, Early Paleocene.

6 ***Artostrobus pusillus*** (Ehrenberg). R872, P30/f460, WO23 (Tc-K28/2), RP4, Early Paleocene.

7 ***Artostrobus pusillus*** (Ehrenberg). R873, P30/f460, WO23 (Tc-T29/4), RP4, Early Paleocene.

8 ***Theocampe apicata*?** Foreman. R874, P30/f374, WO74 (Sa-55), RP4, Early Paleocene.

9 ***Theocampe* cf. *vanderhoofi*** Campbell & Clark. R875, P30/f364, WO31 (Sb-33), RK9, Maastrichtian.

10 ***Theocampe* cf. *vanderhoofi*** Campbell & Clark. R71, P30/f368, WO56 (Sa-61), RP1, Early Paleocene.

11 ***Theocampe* cf. *vanderhoofi*** Campbell & Clark. R876, P30/f371, WO65 (Sb-67), RP2, Early Paleocene.

12 ***Theocampe* cf. *vanderhoofi*** Campbell & Clark. R877, P30/f374, WO74 (Ta-Z53/0), RP4, Early Paleocene.

13 ***Botryostrobus? parsonsae* n.sp.** Holotype. R97, P30/f368, WO56 (Sa-54), RP1, Early Paleocene.

14 ***Botryostrobus? parsonsae* n.sp.** Paratype. R878, P30/f375, WO75 (Sa-72), RP4, Early Paleocene.

15 ***Botryostrobus? parsonsae* n.sp.** Paratype. R879, P30/f375, WO75 (Ta-L37/3), RP4, Early Paleocene.

16 ***Botryostrobus? parsonsae*? n.sp.** R880, P30/f375, WO75 (Sa-73), RP4, Early Paleocene.

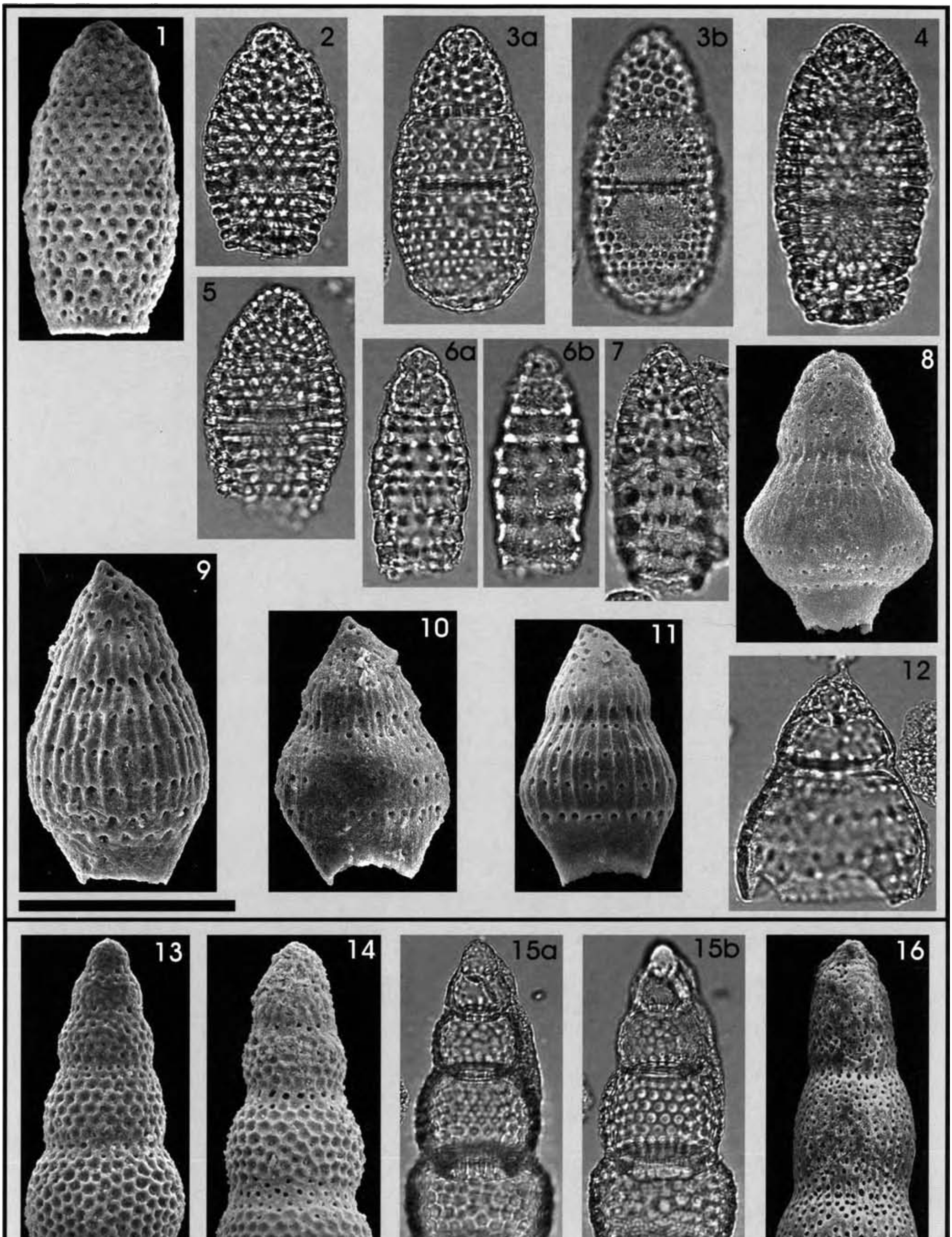
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Plate 14

Scale bar = 100 µm

Fig. 1 ***Siphocampe altamontensis*** (Campbell & Clark). R72, P30/f363, WO28 (Sa-73), RK9, Maastrichtian.

2 ***Siphocampe altamontensis*** (Campbell & Clark). R881, P30/f363, WO28 (Sa-74), RK9, Maastrichtian.

3 ***Siphocampe altamontensis*** (Campbell & Clark). R882, P30/f374, WO74 (Ta-H24/4), RP4, Early Paleocene.

4 ***Siphocampe argyris*** (Foreman). R883, P30/f460, WO23 (Ta-D26/0), RP4, Early Paleocene.

5 ***Siphocampe* cf. *altamontensis*** (Campbell & Clark). R73, P30/f375, WO75 (Sa-62), RP4, Early Paleocene.

6 ***Siphocampe* cf. *altamontensis*** (Campbell & Clark). R884, P30/f373, WO72 (Ta-W38/4), RP3, Early Paleocene.

7 ***Myllocercion acineton*** Foreman **var.** R885, P30/f368, WO56 (Sa-55), RP1, Early Paleocene.

8 ***Myllocercion acineton*** Foreman **var.** R886, P30/f375, WO75 (Ta-H57/4), RP4, Early Paleocene.

9 ***Myllocercion acineton*** Foreman. R77, P30/f368, WO56 (Sa-55), RP1, Early Paleocene.

10 ***Myllocercion acineton*** Foreman. 887, P30/f374, WO74 (Ta-L46/0), RP4, Early Paleocene.

11 ***Myllocercion acineton*** Foreman. R888, P30/f374, WO74 (Tb-F38/3), RP4, Early Paleocene.

12 ***Myllocercion* aff. *echtus*** (Empson-Morin). R100, P30/f375, WO75 (Sa-101), RP4, Early Paleocene.

13 ***Myllocercion* aff. *echtus*** (Empson-Morin). R889, P30/f374, WO74 (Tb-Y44/0), RP4, Early Paleocene.

14 ***Theocapsomma erdnussa*** (Empson-Morin). R890, P30/f375, WO75 (Sa-76), RP4, Early Paleocene.

15 ***Theocapsomma erdnussa*** (Empson-Morin). R74, P30/f375, WO75 (Sa-79), RP4, Early Paleocene.

16 ***Theocapsomma erdnussa*** (Empson-Morin). R891, P30/f375, WO75 (Sa-78), RP4, Early Paleocene.

17 ***Theocapsomma erdnussa*** (Empson-Morin). R892, P30/f369, WO60 (Ta-R44/3), RP2, Early Paleocene.

18 ***Theocapsomma erdnussa*** (Empson-Morin). R893, P30/f375, WO75 (Tb-N45/4), RP4, Early Paleocene.

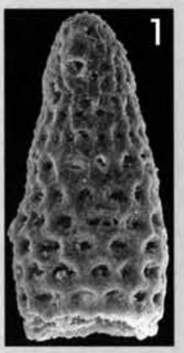
19 ***Theocapsomma erdnussa*** (Empson-Morin). R894, P30/f459, WO19 (Ta-M34/3), RP4, Early Paleocene.

20 ***Theocapsomma erdnussa*** (Empson-Morin). R75, P30/f368, WO56 (Sa-73), RP1, Early Paleocene.

21 ***Theocapsomma erdnussa*** (Empson-Morin).. R895, P30/f372, WO69 (Ta-S37/4), RP3, Early Paleocene.

22 ***Theocapsomma erdnussa*?** (Empson-Morin). R896, P30/f368, WO56 (Sa-79), RP1, Early Paleocene.

23 ***Theocapsomma erdnussa*?** (Empson-Morin). R897, P30/f368, WO56 (Td-N35/0), Rp1, Early Paleocene.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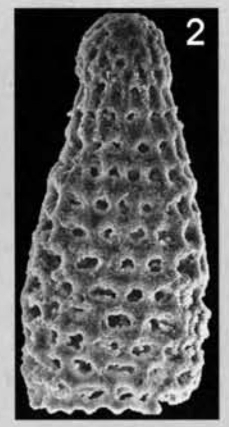
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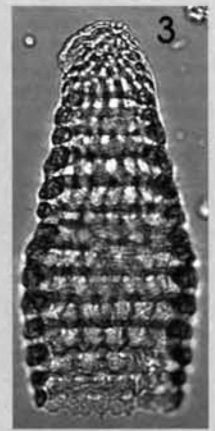
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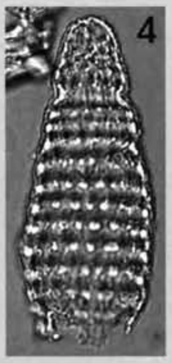
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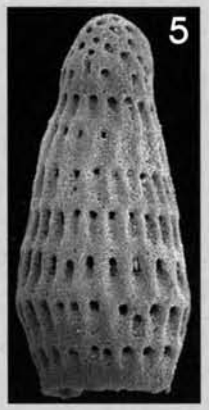
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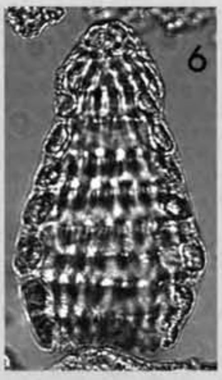
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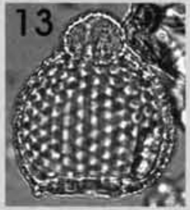
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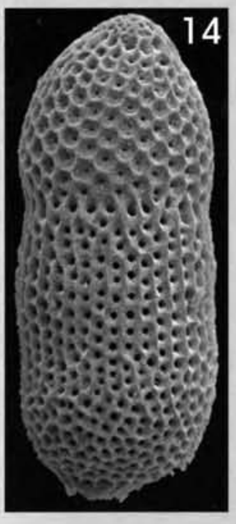
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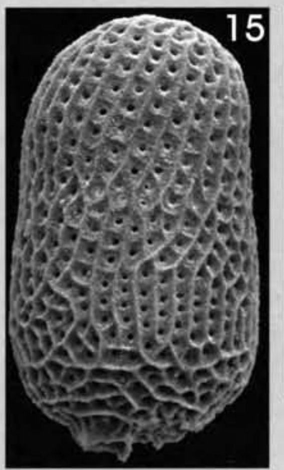
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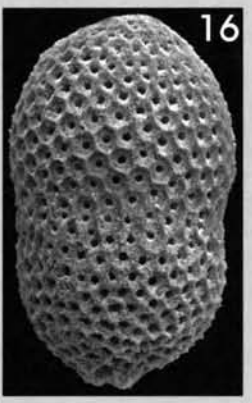
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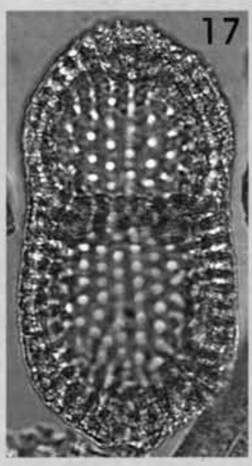
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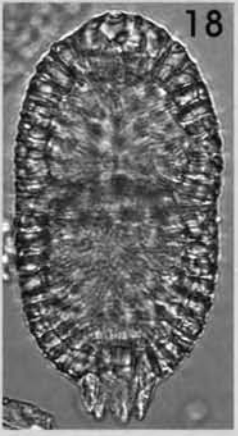
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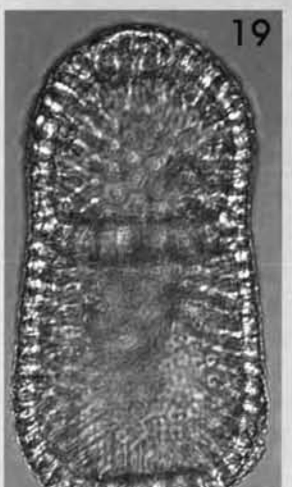
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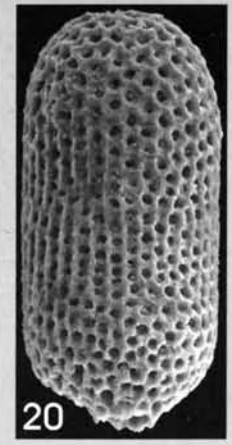
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Plate 15

Scale bars = 100 μm except for Figs. 6b and 8b where scale bar = 50 μm

1 ***Theocapsommma amphora*** (Campbell & Clark). R898, P30/f375, WO75 (Sa-85), RP4, Early Paleocene.

2 ***Theocapsommma amphora*** (Campbell & Clark). R899, P30/f375, WO75 (Ta-F28/0), RP4, Ep.

3 ***Theocapsommma* sp.** R900, P30/f461, WO25 (Tb-T40/2), RP5, Early Paleocene.

4 ***Cryptocarpium*? cf. *ornatum*** (Ehrenberg). R901, P30/f374, WO74 (Ta-Q41/0), RP4, Early Paleocene.

5 ***Amphipyndax stocki*** (Campbell & Clark) **gr., n.gr.** R79, P30/f375, WO75 (Sa-43), RP4, Early Paleocene.

6 ***Amphipyndax stocki*** (Campbell & Clark) **gr., n.gr.** R902, P30/f375, WO75 (Ta-S52/4), RP4, Early Paleocene.

7 ***Amphipyndax stocki*** (Campbell & Clark) **gr., n.gr.** R903, P30/f363, WO28 (Sa-26), RK9, Maastrichtian.

8 ***Amphipyndax stocki*** (Campbell & Clark) **gr., n.gr.** R904, P30/f375, WO75 (Ta-G33/3), RP4, Early Paleocene.

9 ***Amphipyndax stocki*** (Campbell & Clark) **gr., n.gr.** P30/f375, WO75 (Sa-42), RP4, Early Paleocene.

10 ***Amphipyndax stocki*** (Campbell & Clark) **gr., n.gr.** P30/f375, WO75 (Sa-41), RP4, Early Paleocene.

11 ***Amphipyndax stocki*** (Campbell & Clark) **gr., n.gr.** P30/f375, WO75 (Sa-39), RP4, Early Paleocene.

12 ***Amphipyndax* aff. *conicus*** Nakaseko & Nishimura. R905, P30/f455, WO04 (Sa-23), RK9, Maastrichtian.

13 ***Amphipyndax* aff. *conicus*** Nakaseko & Nishimura. R906, P30/f368, WO56 (Tc-T27/1), RP1, Early Paleocene.

14 ***Amphipyndax* aff. *conicus*** Nakaseko & Nishimura. R907, P30/f369, WO60 (Ta-W52/0), RP2, Early Paleocene.

15 ***Amphipternis alamedaensis*** (Campbell & Clark). R78, P30/f364, WO31 (Ta-26), RK9, Maastrichtian.

16 ***Amphipternis alamedaensis*** (Campbell & Clark). R908, P30/f372, WO69 (Tb-X42/1, RP3, Early Paleocene.

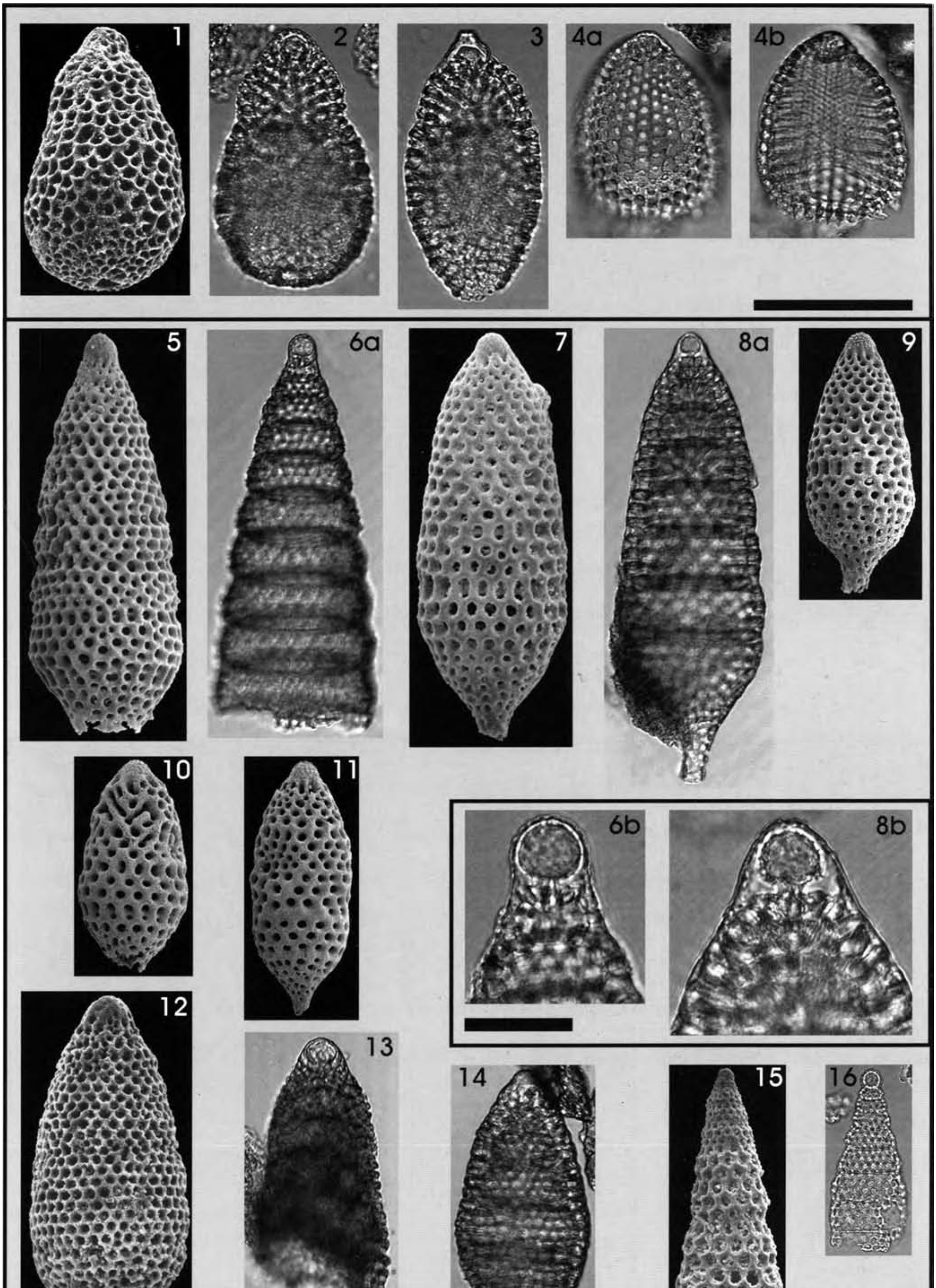
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Plate 16

Scale bars = 100 µm

Fig. 1 ***Archaeodictyomitra* cf. *lamellicostata*** (Foreman). R909, P30/f375, WO75 (Sa-60), RP4, Early Paleocene.

2 ***Archaeodictyomitra* cf. *lamellicostata*** (Foreman). R910, P30/f375, WO75 (Sa-55), RP4, Early Paleocene.

3 ***Archaeodictyomitra* cf. *lamellicostata*** (Foreman). R84, P30/f375, WO75 (Sa-58), RP4, Early Paleocene.

4 ***Archaeodictyomitra* cf. *lamellicostata*** (Foreman). R911, P30/f375, WO75 (Tb-C28/4), RP4, Early Paleocene.

5 ***Archaeodictyomitra* cf. *lamellicostata*** (Foreman). R912, P30/f375, WO75 (Ta-R34/0), RP4, Early Paleocene.

6 ***Dictyomitra multicostata*** Zittel. R913, P30/f363, WO28 (Sa-43), RK9, Maastrichtian.

7 ***Dictyomitra multicostata*** Zittel. R914, P30/f375, WO75 (Sa-52), RP4, Early Paleocene.

8 ***Dictyomitra multicostata*** Zittel. R83, P30/f375, WO75 (Sa-55), RP4, Early Paleocene.

9 ***Dictyomitra multicostata*** Zittel. R915, P30/f375, WO75 (Ta-P48/3), RP4, Early Paleocene.

10 ***Dictyomitra multicostata*** Zittel. R916, P30/f375, WO75 (Tb-O52/3), RP4, Early Paleocene.

11 ***Dictyomitra andersoni*** (Campbell & Clark). R917, P30/f364, WO31 (Sa-117), RK9, Maastrichtian.

12 ***Dictyomitra andersoni*** (Campbell & Clark). R918, P30/f375, WO75 (Sa-53), RP4, Early Paleocene.

13 ***Dictyomitra andersoni*** (Campbell & Clark). R82, P30/f375, WO75 (Sa-51), RP4, Early Paleocene.

14 ***Dictyomitra andersoni*** (Campbell & Clark). R919, P30/f375, WO75 (Ta-F53/0), RP4, Early Paleocene.

15 ***Dictyomitra andersoni*** (Campbell & Clark). R920, P30/f372, WO69 (Ta-F29/0), RP3, Early Paleocene.

16 ***Dictyomitra andersoni*** (Campbell & Clark). R921, P30/f375, WO75 (Tb-Q52/0), RP4, Early Paleocene.

17 ***Dictyomitra* aff. *rhadina*** Foreman. R922, P30/f363, WO28 (Sa-58), RK9, Maastrichtian.

18 ***Dictyomitra* aff. *rhadina*** Foreman. R923, P30/f368, WO56 (Tb-P46/0), RP1, Early Paleocene.

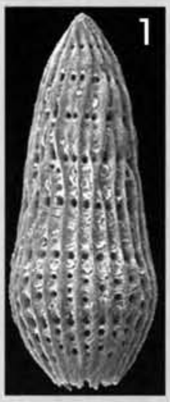
19 ***Dictyomitra* aff. *rhadina*** Foreman. R924, P30/f369, WO60 (Tb-C24/2), RP2, Early Paleocene.

20 ***Dictyomitra* aff. *rhadina*** Foreman. R925, P30/f370, WO62 (Ta-R38/4), RP2, Early Paleocene.

21 ***Dictyomitra* sp.** R926, P30/f368, WO56 (Sa-42), RP1, Early Paleocene.

22 ***Dictyomitra* sp.** R927, P30/f363, WO28 (Sa-58), RK9, Maastrichtian.

23 ***Dictyomitra* sp.** R928, P30/f368, WO56 (Sa-116), RP1, Early Paleocene.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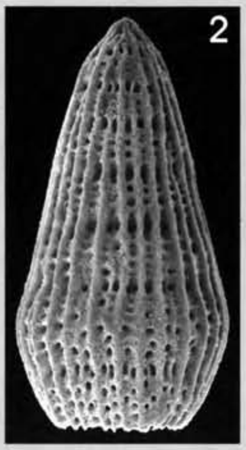
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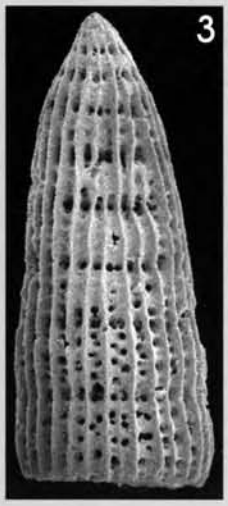
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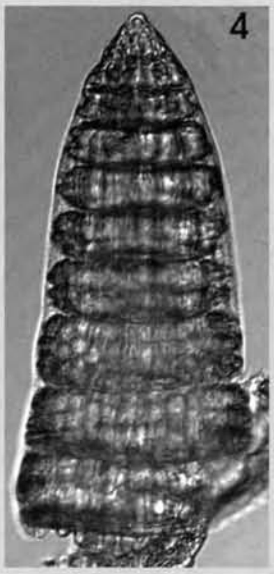
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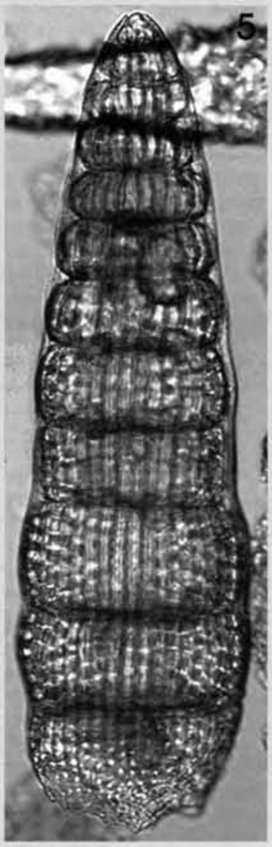
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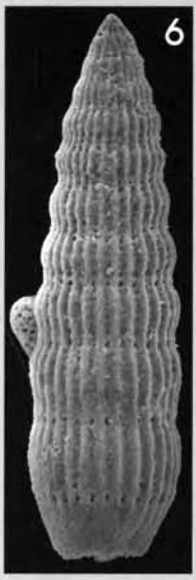
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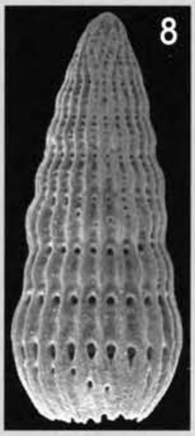
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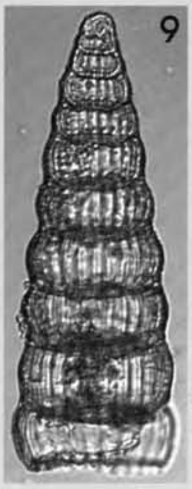
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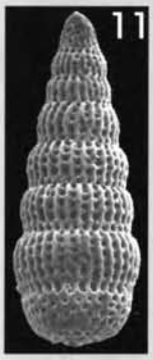
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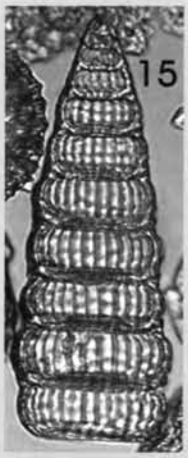
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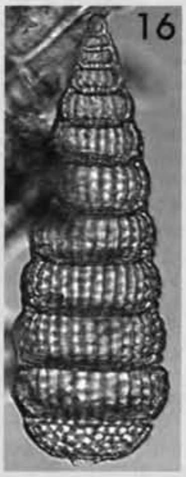
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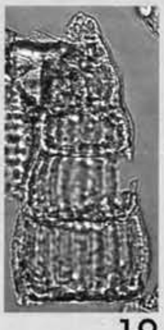
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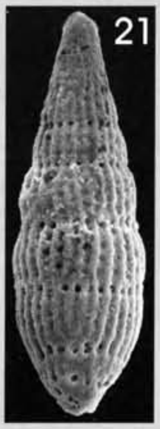
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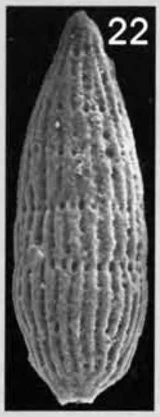
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Plate 17

Scale bars = 100 µm

Fig. 1 ***Mita regina*** (Campbell & Clark). R929, P30/f363, WO28 (Sa-50), RK9, Maastrichtian.

2 ***Mita regina*** (Campbell & Clark). R930, P30/f368, WO56 (Sa-113), RP1, Early Paleocene.

3 ***Mita regina*** (Campbell & Clark). R931, P30/f375, WO75 (Tb-Y53/4), RP4, Early Paleocene.

4 ***Mita regina*** (Campbell & Clark). R932, P30/f459, WO19 (Ta-O34/4), RP4, Early Paleocene.

5 ***Bathropyramis sanjoaquinensis s.l.*** Campbell & Clark R933, P30/f371, WO65 (Sb-61), RP2, Early Paleocene.

6 ***Mita* cf. *regina*** (Campbell & Clark). R101, P30/f375, WO75 (Sa-54), RP4, Early Paleocene.

7 ***Mita* cf. *regina*** (Campbell & Clark). R934, P30/f374, WO74 (Ta-H42/0), RP4, Early Paleocene.

8 ***Mita* cf. *regina*** (Campbell & Clark). R935, P30/f459, WO19 (Tb-W43/4), RP4, Early Paleocene.

9 ***Mita* cf. *regina*** (Campbell & Clark). R936, P30/f375, WO75 (Ta-T29/2), RP4, Early Paleocene.

10 ***Mita regina*** (Campbell & Clark). R937, P30/f374, WO74 (Ta-G25/4), RP4, Early Paleocene.

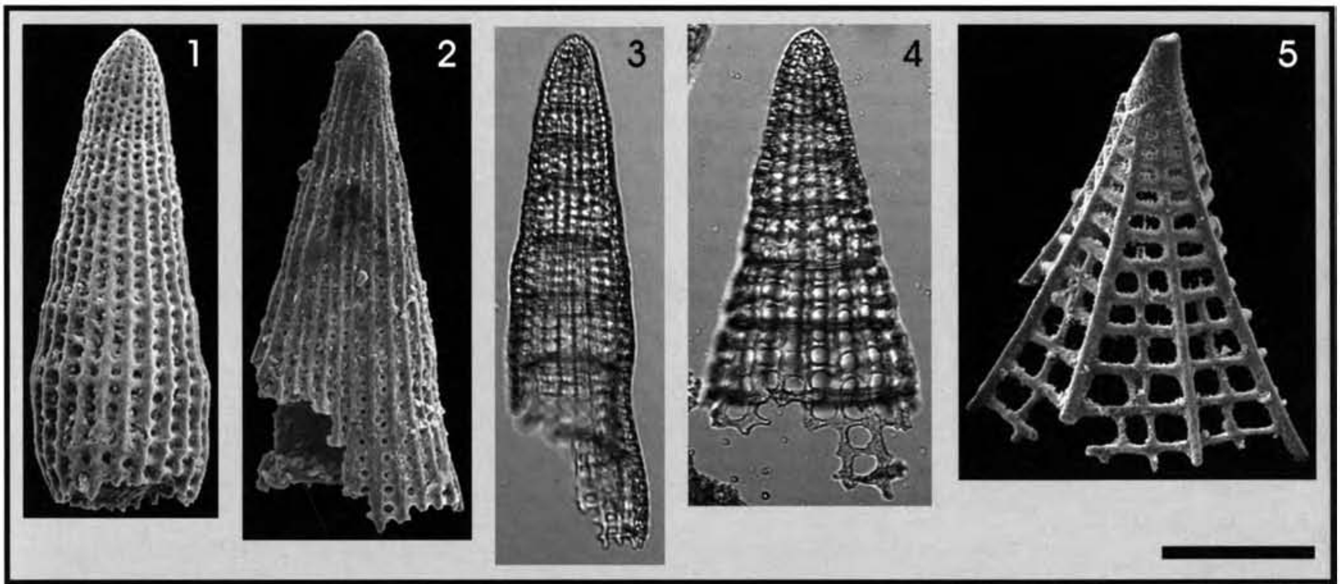
11 ***Bathropyramis sanjoaquinensis s.l.*** Campbell & Clark R938, P30/f370, WO62 (Tb-R30/3), RP2, Early Paleocene.

12 ***Bathropyramis sanjoaquinensis s.l.*** Campbell & Clark R939, P30/f375, WO75 (Ta-T30/3), RP4, Early Paleocene.

13 ***Cornutella californica*** Campbell & Clark. R80, P30/f368, WO56 (Sa-99), RP1, Early Paleocene.

14 ***Cornutella californica*** Campbell & Clark. R940, P30/f459, WO19 (Tb-K40/2), RP4, Early Paleocene.

15 ***Cornutella californica*** Campbell & Clark. R941, P30/f460, WO23 (Ta-G43/3), RP4, Early Paleocene.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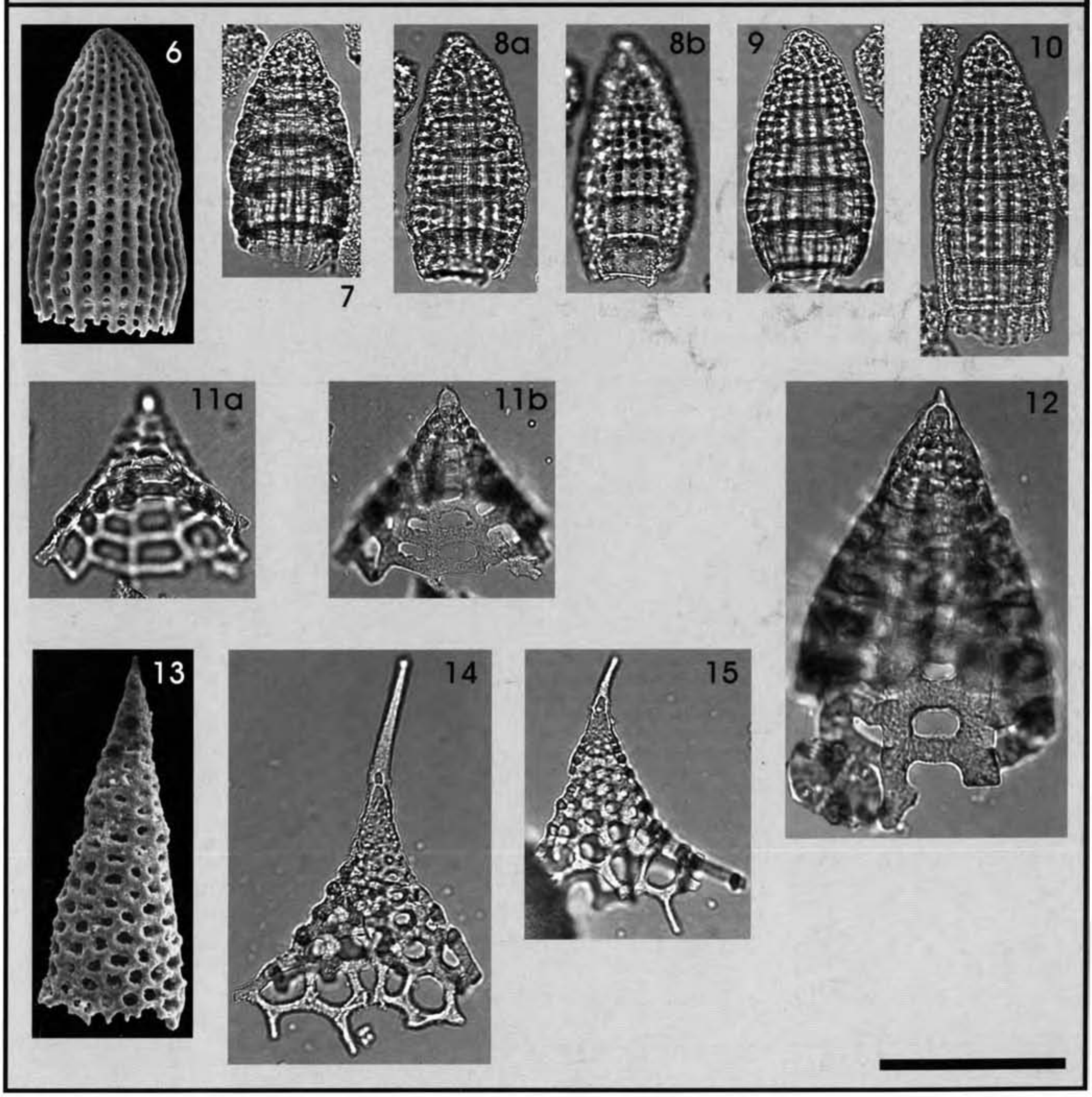
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Plate 18

Scale bars = 100 μm

Fig. 1 *Neosciadiocapsa jenkinsi* Pessagno. R942, P30/f372, WO69 (Sa-117), RP3, Early Paleocene.

2 *Neosciadiocapsa jenkinsi* Pessagno. R943, P30/f370, WO62 (Ta-G35/1), RP2, Early Paleocene.

3 ***Eusyringium*? *woodsidensis* n.sp.** Paratype. R944, P30/f372, WO69 (Sa-40), RP3, Early Paleocene.

4 ***Eusyringium*? *woodsidensis* n.sp.** Holotype. R104, P30/f375, WO75 (Sa-83), RP4, Early Paleocene.

5 ***Eusyringium*? *woodsidensis* n.sp.** Paratype. R945, P30/f372, WO69 (Tb-Y43/2), RP3, Early Paleocene.

6 ***Eusyringium*? *woodsidensis* n.sp.** Paratype. R946, P30/f375, WO75 (Ta-Q34/4), RP4, Early Paleocene.

7 ***Eusyringium*? *woodsidensis* n.sp.** Paratype. R947, P30/f375, WO75 (Tb-L30/2), RP4, Early Paleocene.

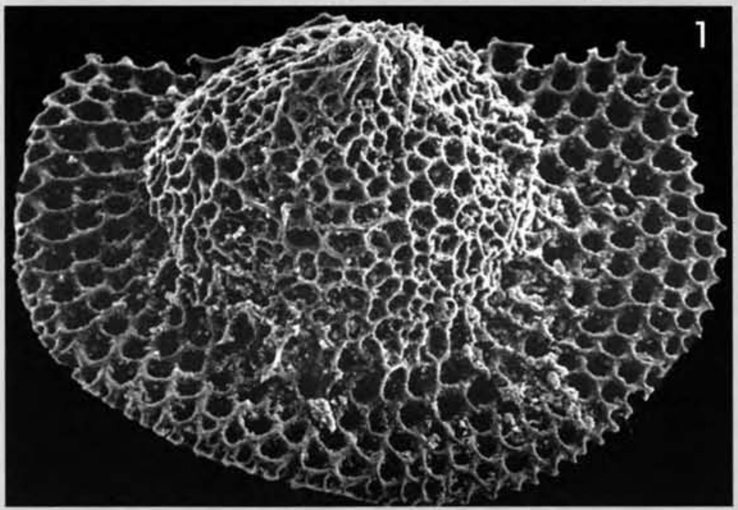
8 ***Lithocampe wharanui* n.sp.** Paratype. R948, P30/f363, WO28 (Sa-94), RK9, Maastrichtian.

9 ***Lithocampe wharanui* n.sp.** Paratype. R105, P30/f368, WO56 (Sa-47), RP1, Early Paleocene.

10 ***Lithocampe wharanui* n.sp.** Holotype. R949, P30/f368, WO56 (Tc-K36/0), RP1, Early Paleocene.

11 ***Lithocampe* aff. *subligata*** Stöhr. R106, P30/f375, WO75 (Sa-64), RP4, Early Paleocene.

12 ***Lithocampe* aff. *subligata*** Stöhr. R950, P30/f375, WO75 (Tb-N53/4), RP4, Early Paleocene.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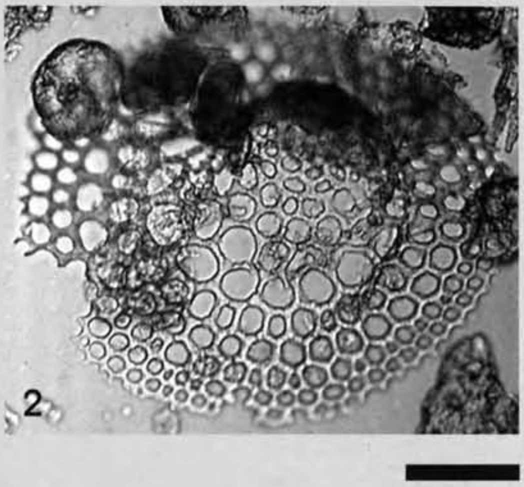
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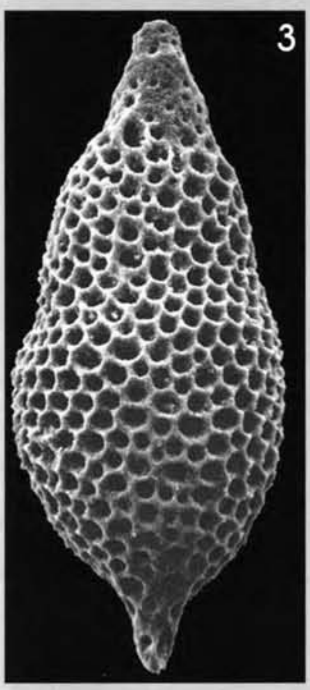
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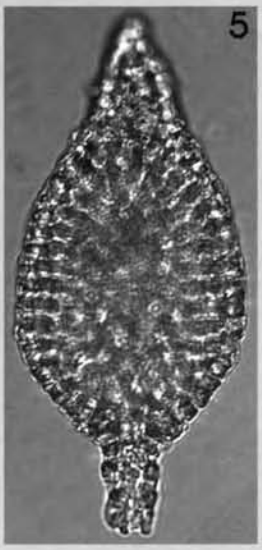
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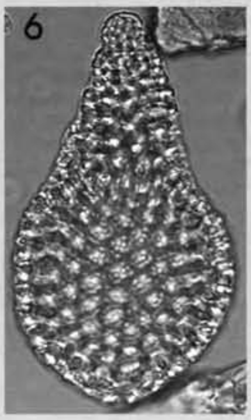
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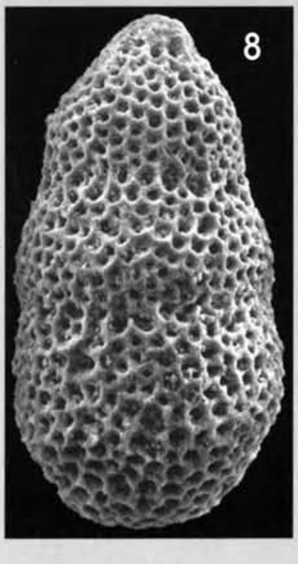
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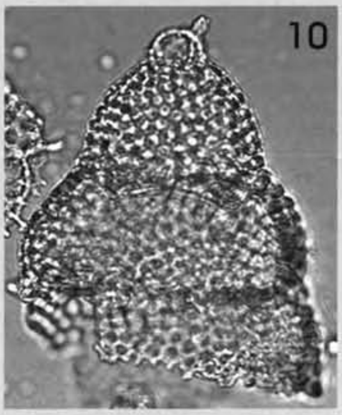
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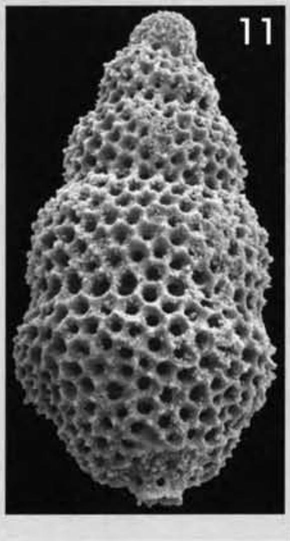
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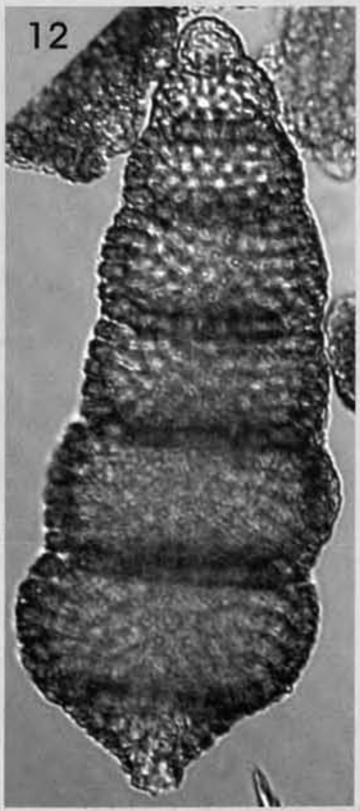
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Plate 19

Scale bar = 100 µm, except for Fig. 12b where scale bar = 50 µm

Fig. 1 ***Stichomitra grandis*** (Campbell & Clark). R951, P30/f365, WO37 (Sa-27), RK9, Maastrichtian.

2 ***Stichomitra grandis*** (Campbell & Clark). R86, P30/f372, WO69 (Sa-83), RP3, Early Paleocene.

3 ***Stichomitra grandis*** (Campbell & Clark). R952, P30/f608, WO58 (Ta-M31/3), RP2, Early Paleocene.

4 ***Stichomitra grandis*** (Campbell & Clark). R953, P30/f375, WO75 (Tb-B26/3), RP4, Early Paleocene.

5 ***Stichomitra grandis*?** (Campbell & Clark). R954, P30/f375, WO75 (Sa-69), RP4, Early Paleocene.

6 ***Stichomitra grandis*?** (Campbell & Clark). R955, P30/f375, WO75 (Ta-R45/0), RP4, Early Paleocene.

7 ***Stichomitra carnegiense*** (Campbell & Clark). R956, P30/f363, WO28 (Sa-66), RK9, Maastrichtian.

8 ***Stichomitra carnegiense*** (Campbell & Clark). R107, P30/f374, WO74 (Sa-36), RP4, Early Paleocene.

9 ***Stichomitra carnegiense*** (Campbell & Clark). R957, P30/f374, WO74 (Sa-35), RP4, Early Paleocene.

10 ***Stichomitra carnegiense*** (Campbell & Clark). R958, P30/f369, WO60 (Ta-C52/0), RP2, Early Paleocene.

11 ***Stichomitra carnegiense*** (Campbell & Clark). R959, P30/f375, WO75 (Tb-Z36/4), RP4, Early Paleocene.

12 ***Stichomitra carnegiense*** (Campbell & Clark). R960, P30/f375, WO75 (Ta-A49/4), RP4, Early Paleocene.

13 ***Stichomitra* cf. *carnegiense*** (Campbell & Clark). R961, P30/f372, WO69 (Sa-80), RP3, Early Paleocene.

14 ***Stichomitra* cf. *carnegiense*** (Campbell & Clark). R962, P30/f375, WO75 (Sa-65), RP4, Early Paleocene.

15 ***Stichomitra* cf. *carnegiense*** (Campbell & Clark). R963, P30/f375, WO75 (Ta-C53/1), RP4, Early Paleocene.

16 ***Stichomitra* cf. *carnegiense*** (Campbell & Clark). R964, P30/f459, WO19 (Ta-H38/4), RP4, Early Paleocene.

17 ***Stichomitra* cf. *carnegiense*** (Campbell & Clark). R965, P30/f372, WO69 (Sa-79), RP3, Early Paleocene.

18 ***Stichomitra* cf. *carnegiense*** (Campbell & Clark). R966, P30/f459, WO19 (Tb-C22/4), RP4, Early Paleocene.

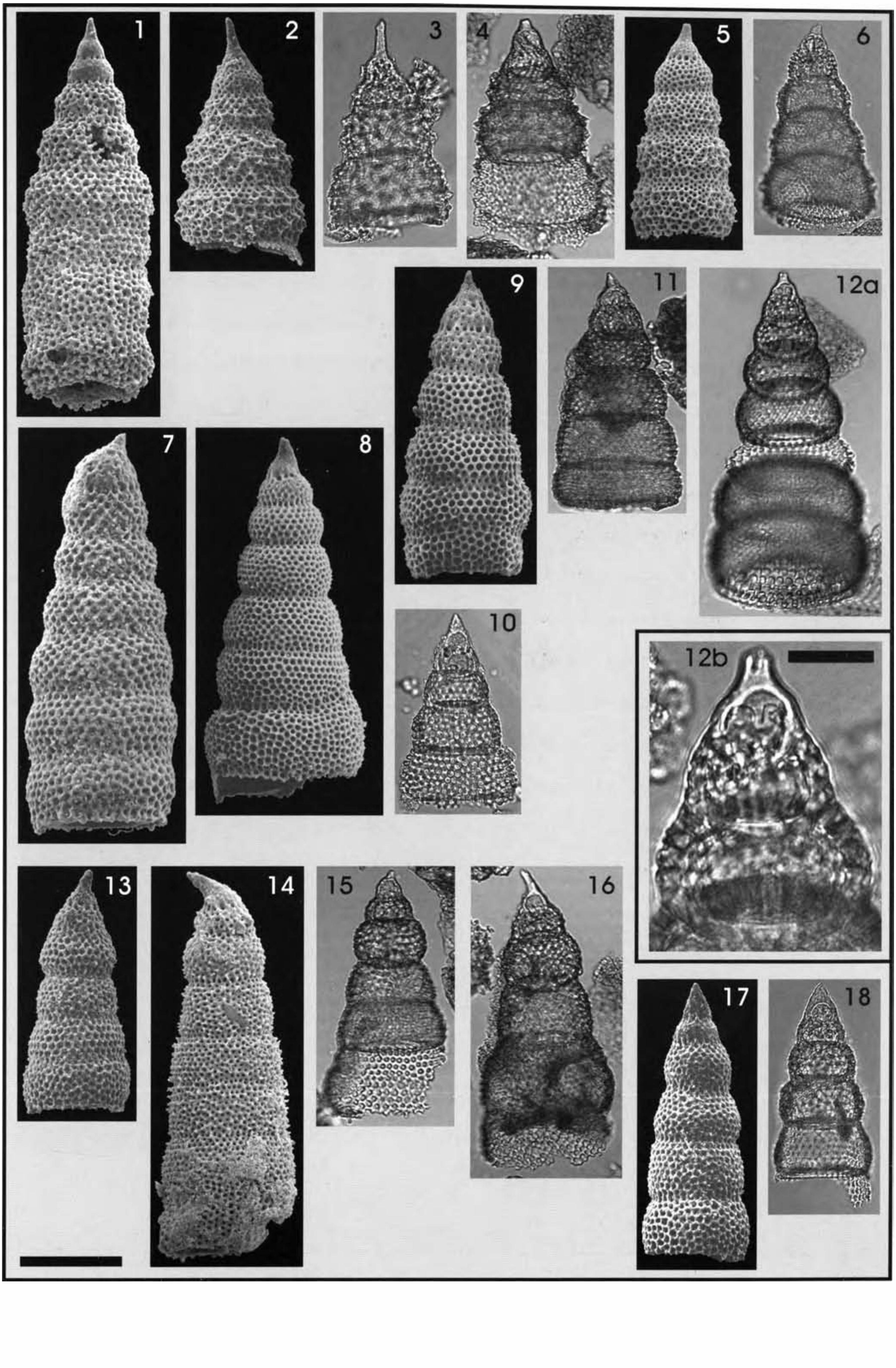
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Plate 20

Scale bar = 100 µm

Fig. 1 ***Cyrtocapsa livermorensis*** (Campbell & Clark). R967, P30/f368, WO56 (Sa-50), RP1, Early Paleocene.

2 ***Cyrtocapsa livermorensis*** (Campbell & Clark). R88, P30/f375, WO75 (Sa-49), RP4, Early Paleocene.

3 ***Cyrtocapsa livermorensis*** (Campbell & Clark). R968, P30/f372, WO69 (Ta-F29/0), RP3, Early Paleocene.

4 ***Cyrtocapsa livermorensis*** (Campbell & Clark). R969, P30/f375, WO75 (Ta-Y31/4), RP4, Early Paleocene.

5 ***Cyrtocapsa livermorensis*** (Campbell & Clark). R970, P30/f375, WO75 (Ta-G27/4), RP4, Early Paleocene.

6 ***Stichomitra bertrandi*** Cayeux. R87, P30/f363, WO28 (Sa-42), RK9, Maastrichtian.

7 ***Stichomitra bertrandi*** Cayeux. R971, P30/f368, WO56 (Sb-32), RP1, Early Paleocene.

8 ***Stichomitra bertrandi*** Cayeux. R972, P30/f374, WO74 (Tb-G40/0), RP4, Early Paleocene.

9 ***Stichomitra bertrandi*** Cayeux. R973, P30/f374, WO74 (Tb-F34/4), RP4, Early Paleocene.

10 ***Cyrtocapsa campi*** Campbell & Clark. R89, P30/f368, WO56 (Sa-53), RP1, Early Paleocene.

11 ***Cyrtocapsa campi*** Campbell & Clark. R974, P30/f372, WO69 (Ta-R50/4), RP3, Early Paleocene.

12 ***Cyrtocapsa campi*** Campbell & Clark. R975, P30/f375, WO75 (Ta-W29/0), RP4, Early Paleocene.

13 ***Cyrtocapsa campi*** Campbell & Clark. R976, P30/f459, WO19 (Tc-C46/1), RP4, Early Paleocene.

14 ***Lithostrobus wero*** (Hollis). R22, P30/f372, WO69 (Sa-62), RP3, Early Paleocene.

15 ***Lithostrobus wero*** (Hollis). R25, P30/f371, WO65 (Tb-S50/1), RP2, Early Paleocene.

16 ***Lithostrobus wero*** (Hollis). R26, P30/f372, WO69 (Ta-T28/1), RP3, Early Paleocene.

17 ***Lithostrobus wero*** (Hollis). R27, P30/f375, WO75 (Ta-K40/1), RP4; Early Paleocene.

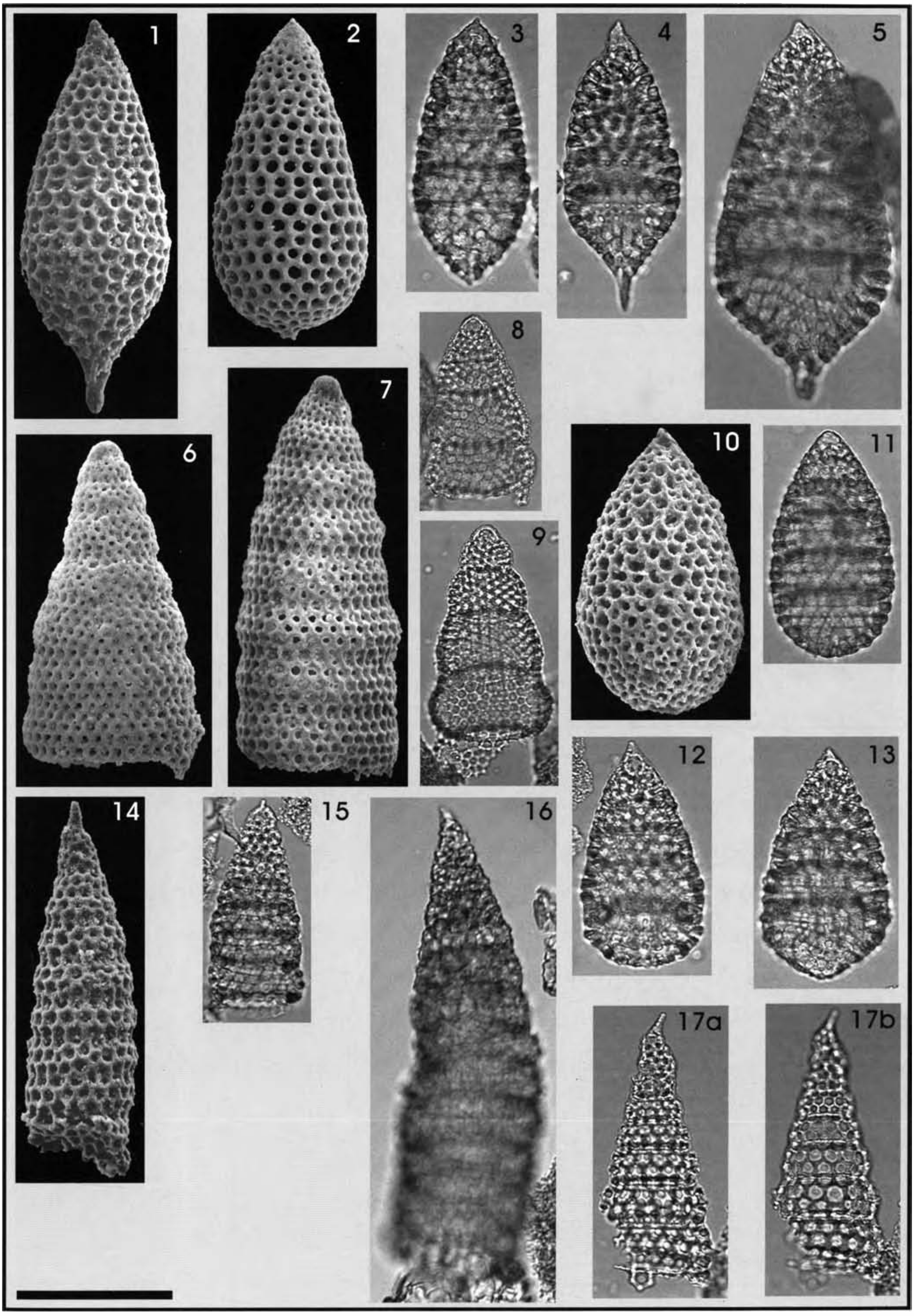
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Plate 21

Scale bar = 100 µm

Fig. 1 ***Buryella granulata*** (Petrushevskaya). R28, P30/f372, WO69 (Sa-64), RP3, Early Paleocene.

2 ***Buryella granulata*** (Petrushevskaya). R977, P30/f372, WO69 (Ta-N42/2), RP3, Early Paleocene.

3 ***Buryella granulata*** (Petrushevskaya). R978, P30/f373, WO72 (Ta-V33/1), RP3, Early Paleocene.

4 ***Buryella granulata*** (Petrushevskaya). R29, P30/f373, WO72 (Ta-X27/4), RP3, Early Paleocene.

5 ***Buryella granulata*** (Petrushevskaya). R979, P30/f373, WO72 (Ta-X28/3), RP3, Early Paleocene.

6 ***Buryella foremanae*** Petrushevskaya. R30, P30/f375, WO75 (Sa-97), RP4, Early Paleocene.

7 ***Buryella foremanae*** Petrushevskaya. R980, P30/f375, WO75 (Sa-91), RP4, Early Paleocene.

8 ***Buryella foremanae*** Petrushevskaya. R981, P30/f375, WO75 (Tb-U23/1), RP4, Early Paleocene.

9 ***Buryella foremanae*** Petrushevskaya. R982, P30/f460, WO23 (Tc-M40/3), RP4, Early Paleocene.

10 ***Buryella dumitricai*** Petrushevskaya. R31, P30/f375, WO75 (Sa-93), RP4, Early Paleocene.

11 ***Buryella dumitricai*** Petrushevskaya. R983, P30/f375, WO75 (Sa-96), RP4, Early Paleocene.

12 ***Buryella dumitricai*** Petrushevskaya. R984, P30/f375, WO75 (Ta-V57/0), RP4, Early Paleocene.

13 ***Buryella dumitricai*** Petrushevskaya. R985, P30/f460, WO23 (Ta-C23/0), RP4, Early Paleocene.

14 ***Buryella kaikoura*** **n.sp.** Holotype. R986, P30/f461, WO25 (Sa-25), RP5, Early Paleocene.

15 ***Buryella kaikoura*** **n.sp.** Paratype. R987, P30/f461, WO25 (Ta-L34/4), RP5, Early Paleocene.

16 ***Buryella tetradica*** Foreman. R988, P30/f461, WO25 (Sa-19), RP5, Early Paleocene.

17 ***Buryella tetradica*** Foreman. R989, P30/f461, WO25 (Sa-21), RP5, Early Paleocene.

18 ***Buryella tetradica*** Foreman. R990, P30/f461, WO25 (Sa-20), RP5, Early Paleocene.

19 ***Buryella tetradica*** Foreman. R991, P30/f461, WO25 (Ta-C43/0), RP5, Early Paleocene.

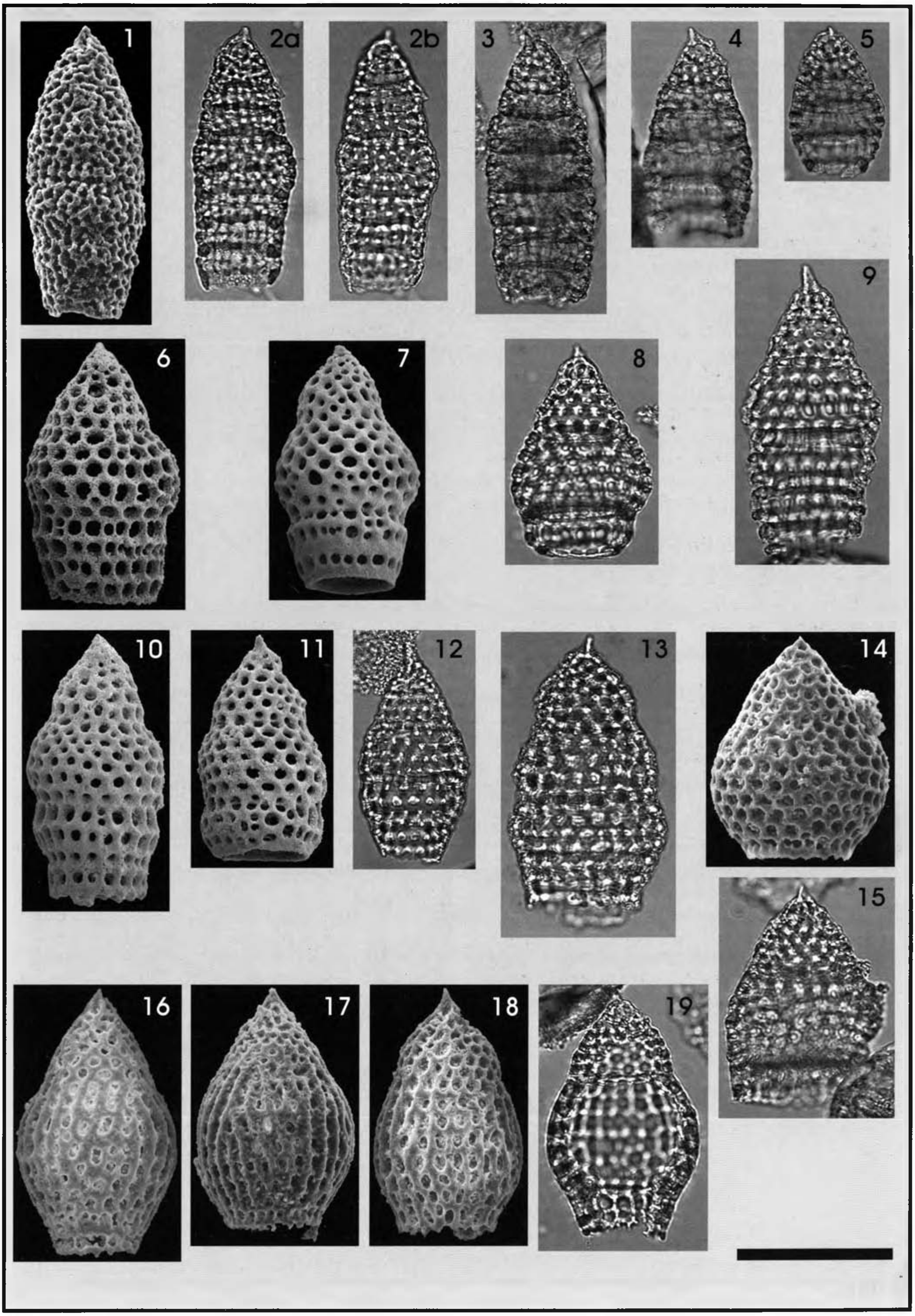
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Plate 22

Scale bars = 100 µ

Fig. 1 ***Clathrocyclas australis*** **n.sp.** Holotype. R992, P30/f374, WO74 (Sa-49), RP4, Early Paleocene.

2 ***Clathrocyclas australis*** **n.sp.** Paratype. R993, P30/f374, WO74 (Sa-48), RP4, Early Paleocene.

3 ***Clathrocyclas australis*** **n.sp.** Paratype. R994, P30/f375, WO75 (Ta-O33/0), RP4, Early Paleocene.

4 ***Clathrocyclas australis*** **n.sp.** Paratype. R995, P30/f460, WO23 (Ta-V48/0), RP4, Early Paleocene.

5 ***Dictyophimus*** **aff.** ***archipilium*** Petrushevskaya. R996, P30/f372, WO69 (Sa-111), RP3, Early Paleocene.

6 ***Dictyophimus*** **aff.** ***archipilium*** Petrushevskaya. R997, P30/f460, WO23 (Ta-H32/3), RP4, Early Paleocene.

7 ***Dictyophimus*** **aff.** ***archipilium*** Petrushevskaya. R998, P30/f460, WO23 (Tb-R30/3), RP4, Early Paleocene.

8 ***Clathrocyclas*** **sp.** R999, P30/f460, WO23 (Tb-R30/3), RP4, Early Paleocene.

9 ***Dictyophimus*** **sp.** DSDP 208-31-3, 101 (Ta-N32/0), RP4, Early Paleocene.

10 ***Dictyophimus*** **aff.** ***pocillum*** Ehrenberg. Chancet Rocks, CH29 (Ta-F36/3), RP5, Early Paleocene.

11 ***Dictyophimus*** **aff.** ***pocillum*** Ehrenberg. Chancet Rocks, CH27 (Tc-F34/2), RP5, Early Paleocene.

12 **Eucyrtidiidae gen.** ***et*** **sp. indet.** R1000, P30/f374, WO74 (Sa-63), RP4, Early Paleocene.

13 ***Dorcadospyris*** **aff.** ***confluens*** (Ehrenberg). R1001, P30/f374, WO74 (Sa-43), RP4, Early Paleocene.

14 ***Dorcadospyris*** **aff.** ***confluens*** (Ehrenberg). R1002, P30/f460, WO23 (Tb-R44/0), RP4, Early Paleocene.

15 ***Dorcadospyris*** **aff.** ***confluens*** (Ehrenberg). R1003, P30/f460, WO23 (Tc-H28/2), RP4, Early Paleocene.

16 ***Dorcadospyris*** **aff.** ***confluens*** (Ehrenberg). R1004, P30/f460, WO23 (Ta-R44/1), RP4, Early Paleocene.

17 **Eucyrtidiidae gen. et sp. indet.** R1005, P30/f460, WO23 (Tc-N42/4), RP4, Early Paleocene.


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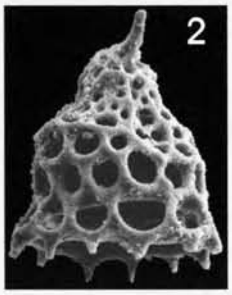
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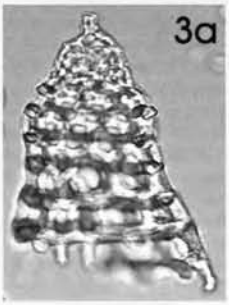
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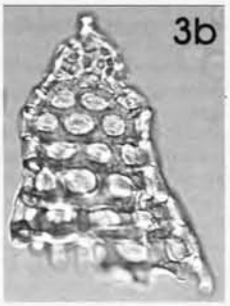
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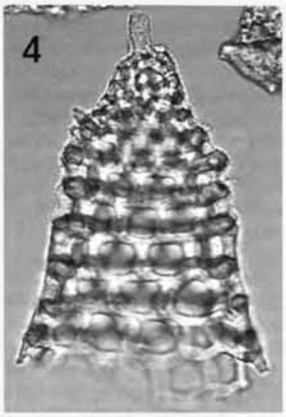
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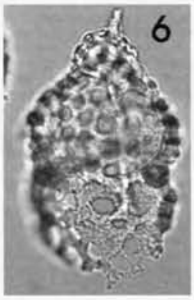
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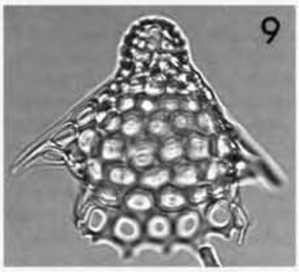
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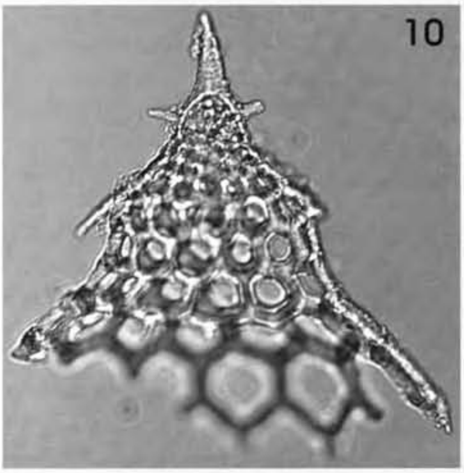
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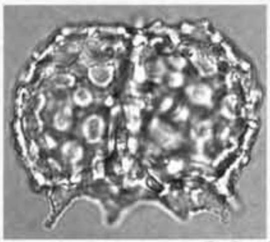
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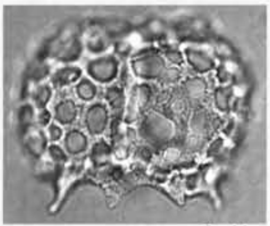
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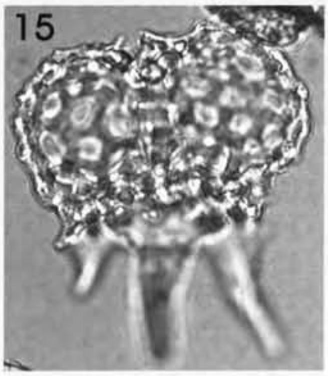
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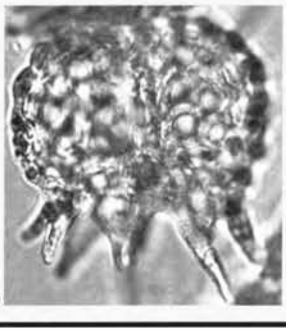
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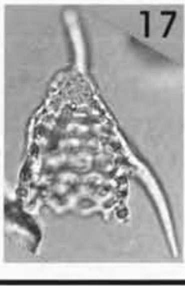
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INDEXES

GENERAL INDEX

TAXONOMIC INDEX

Northern Kaikoura (eastern Marlborough) coast, with the Cretaceous -Tertiary boundary section at Wharanui Point in the foreground. The near-vertical sequence youngs seaward, and the boundary is at the base of the metre-thick dark-grey porcellanite (location of hammer head in lower photo).