LATEST CRETACEOUS TO EARLIEST PALEOGENE MOLLUSCAN FAUNAS OF NEW ZEALAND: CHANGES IN COMPOSITION AS A CONSEQUENCE OF THE BREAK-UP OF GONDWANA AND EXTINCTION

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Frontispiece B. During the collecting phase of this study large blocks of the Wangaloa Formation had to dragged along the beach at Mitchells Rocks and winched up and over a break in the cliff face shown in the background. After several unsuccessful attempts, this particular block finally made its way into the back of the vehicle. Leading the way is Dr. R. Ewan Fordyce, followed by Mr. Stuart Munro and Mr. Andrew Grebneff. Grid reference: H46/c.768337.

This dissertation is dedicated to paleontologists
who have sought to better understand the
origin and evolution of the
biosphere

ABSTRACT

Uppermost Cretaceous (Campanian?-Maastrichtian) to lowermost Paleogene (Paleocene) rocks of New Zealand contain an exceptional record of Bivalvia, Gastropoda and Scaphopoda. The composition of these faunas is closely linked with the separation of New Zealand from the East Antarctic-Australian sector of Gondwana, development of open oceanic conditions by Early Campanian time (c. 80-85 Ma), and Cretaceous-Tertiary boundary extinctions. This work aims to: 1) document the changes in paleobiogeographic elements (endemic, paleoaustral, Indo-Pacific/Tethyan, and cosmopolitan) of molluscs across the K-T interval; 2) provide a quantitative analysis of the Weddellian Biotic Province hypothesis of Zinsmeister (1979), which has resulted in a refined biogeographic model for the Gondwana Realm; and 3) examine the extent and effect of the terminal Cretaceous extinction event on the Mollusca of New Zealand.

This study recognises 329 species of latest Cretaceous to earliest Paleogene molluscs from New Zealand. Of these, 118 new species are described in the systematic catalogue together with comments on their inferred feeding habits. Previously established species are refigured and where justified, redescribed and taxonomically updated. Of 329 species, 159 are of latest Cretaceous age (Piripauan to Haumurian stages) and 170 are Paleocene ("Wangaloan" or Teurian). A total of 79 bivalve, 47 gastropod and 2 scaphopod genera/subgenera are recognised in the Late Cretaceous record, with 35 bivalve, 76 gastropod and 3 scaphopod comparable taxa from the Paleocene. New genera/subgenera proposed in the systematics section are *Brookula* (*Paleobrookula* n. subgen.) (Skeneidae), *Kaiparomphalus* n. gen. (Trochidae), *Saulopsis* n. gen. (Tudiclidae), *Wangaluta* n. gen. (Volutidae), *Wangacteon* n. gen. (Acteonidae), and *Kaurueon* n. gen. (Acteonidae). Thirty-four new combinations are proposed. *Zelandiella* Finlay, 1926, is synonymised with *Austrocominella* von Ihering, 1907. *Conchothyra* *marshalli* (Trechmann, 1917) is considered as distinct from *C*. *parasitica* Hutton, 1877. The following species-group synonymies are proposed: *Bittiscala* *communis* Finlay and Marwick, 1937, with *B*. *simplex* (Marshall, 1917); *Conchothyra* *expedita* Finlay and Marwick, 1937, with *C*. *australis* (Marshall, 1916); *Euspira* *lateaperta* (Marwick, 1924) with *Euspira* *fyfei* (Marwick, 1924); and *Campylacrum* *debile* Finlay and Marwick, 1937, with *C*. *sanum* Finlay and Marwick, 1937.

Though the biostratigraphic resolution of uppermost Cretaceous and Paleocene New Zealand rocks has improved recently, problems still exist in correlating some macrofossil localities because of rarity of index microfossils, facies faunas, and incomplete knowledge of stratigraphic ranges of some taxa. Thus, Piripauan (Campanian? Maastrichtian?) and Haumurian (Maastrichtian) stages are virtually inseparable in the field and laboratory. At Wangaloa, southeastern Otago, a K-T boundary section appears to be present c.10 m below the shell beds. Reintroduction of the abandoned Wangaloan Stage may be appropriate, pending further microfossil work, as the relationship of this stage to the very long (c. 8 m. y.) Teurian Stage could be established. Molluscan faunas at Wangaloa and elsewhere in South Island can be correlated to the lower part of the dinoflagellate Palaeocystodinium golzowense Zone, indicating a late Early Paleocene age. A macrofossil zone, Zeacolpus (Leptocolpus) semiconcavus Assemblage-zone, is proposed for widespread molluscan-rich Paleocene faunas of South Island.

Compared to other Austral sequences, New Zealand has an excellent record of latest Cretaceous to earliest Paleogene molluscs. Dramatic compositional changes across this interval ultimately reflect the break-up of Gondwana and environmental perturbations on shallow shelf faunas. Endemism in New Zealand latest Cretaceous molluscs was weak (c. 8% of genera/subgenera), but increased substantially (c. 32%) by Paleocene time, partially reflecting the geographic and genetic isolation of "greater New Zealand" at this time. The paleoaustral component, including endemics herein, was also relatively weak (c. 21%) during the Cretaceous but marked (c. 60%) by the Paleocene. The Indo-Pacific/Tethyan and cosmopolitan components decreased from c. 48% to c. 26% and c. 26% to c. 12% across the interval, respectively. Few cosmopolitan Late Cretaceous species and endemic genera/subgenera of this age have been recorded. Most Late Cretaceous taxa are endemic species of cosmopolitan or wide-ranging genera/subgenera (c. 92%). The Paleocene fauna is entirely endemic at species-level, apart from possible records of Cucullaea (Cucullona) inarata Finlay and Marwick, 1937, from the Paleocene of southeastern Australia and Taieria allani Finlay and Marwick, 1937, from the Paleocene of Chatham Islands.

High similarity coefficient values (≤0.76; Simple, Dice and Simple Matching) of latest Cretaceous and Paleocene molluscan genera/subgenera from New Zealand, Chatham Islands, Australia, New Caledonia, Antarctic Peninsula and southern South America, indicate strong faunal links between these areas during the latest Cretaceous. Such links corroborate the Weddellian Province hypothesis. The marked homogeneity of these widespread faunas probably reflects large shelf area, a low sea-surface temperature gradient, and favourable oceanic circulation including perhaps a trans-Antarctic seaway during the latest Cretaceous. Sea-surface temperatures across the K-T boundary were probably subtropical to at least warm temperate in New Zealand. The New Zealand Subprovince of the Austral Province (Kauffman, 1973) should be abandoned because of the low endemic component of New Zealand molluscs during the Late Cretaceous. For the Paleocene only New Zealand and southeastern Australia have significantly similar faunas (Simpson similarity indices: 0.36-bivalves, 0.91-gastropods). In the Paleocene, the Weddellian Province probably was reduced to the New Zealand-southeastern Australia and possibly Chatham Islands region along the newly opened Tasman Sea.

New Zealand data are consistent with the idea that gradual environmental changes resulting from the final fragmentation of Gondwana, coupled with a probable bolide impact(s) in lower latitudes, caused mass extinction and suppressed biomass productivity, but was followed by faunal rebound during the Early Paleocene. In this study the latest Maastrichtian-earliest Danian time interval could not be resolved enough to identify any low diversity "disaster fauna" above the K-T boundary. The magnitude, however, of the extinction can be gauged along with the extent of the inferred initial radiation phase. In total, about 39% and 36% of bivalve genera/subgenera and gastropods became extinct at the end of the Cretaceous in New Zealand. All New Zealand species recorded in uppermost Cretaceous rocks became extinct sometime during the late Maastrichtian and earliest Danian. The extinction at genus-level was not as severe as in other areas including North Africa, Atlantic Coastal Plain, and northern Europe. The extinction particularly affected infaunal and ' suspension feeders (c. 89%), fewer epifaunal herbivores and browsers (c. 65%), and negligible carnivores and deposit feeders. Data support the idea that the K-T event was selective against suspension feeders and that there was diminished productivity of phytoplankton at the base of the food chain.

About 50% of latest Cretaceous molluscs, including Lazarus taxa, crossed the K-T boundary. Most survivors were seemingly eurybathyal with recorded species in a spectrum of shelf settings. Approximately half of Paleocene survivors were infaunal suspension feeders, but few were epifaunal. Most gastropod survivors were carnivores and deposit feeders. Significantly, Paleocene survivors and presumed new taxa became extinct during the Paleocene (c. 27%). Gamma (total) species diversity changed little across the K-T boundary indicating that diversity quickly recovered in the first few million years after the extinction. Bivalve diversity decreased substantially over the K-T interval, whereas gastropod diversity climbed. This "flip-flop" in diversity indicates that gastropods outpaced bivalves during the early Tertiary and could help explain the veritable burst of radiation in inferred "bloom" families (e. g. Naticidae, Turridae, Acteonidae). The "Wangaloan" fauna probably characterises rapid evolution in isolation and an initial phase of radiation reflecting high speciation in which many new groups filled the ecological vacuum left by the extinction, followed by a further less severe extinction pulse in late Danian time.

' epifaunal

ACKNOWLEDGMENTS

During the 1986-87 expedition to Seymour Island, Antarctica, I met a young Kiwi vertebrate paleontologist, Dr. R. Ewan Fordyce, who in passing commented that there were many significant molluscan projects in New Zealand and that I might consider doing my Ph. D. at University of Otago. After completing my M. S. at Purdue University, where I studied under Dr. William J. Zinsmeister, I considered Ewan Fordyce's offer and contacted him to see if there would be available support for my Ph. D. research. He wrote straight away and included forms for the Otago Postgraduate and New Zealand University Grants Committee Postgraduate Scholarship awards. He also stated that I would have to be quick, as the forms were due in a few days! A few months after completing my forms, etc., I received a letter just before Christmas of 1988 from the University of Otago stating that I had been awarded the N. Z. University Grants Committee Postgraduate Scholarship. What a Christmas present! On June 26, 1989, I embarked on a rewarding study of the Paleocene Mollusca of New Zealand, which had not been studied in any detail since the important monograph by Finlay and Marwick (1937). The focus of my research expanded after a few years to include the Late Cretaceous faunas as well, which have had little attention since Woods (1917) and Wilckens (1922), and changes across the K-T boundary in New Zealand and elsewhere in the southern hemisphere. A few noteworthy papers on various species have appeared since the monographs by Finlay and Marwick, Woods and Wilckens. I would like to express my appreciation to Ewan for inviting me to work in New Zealand and for his support and enthusiasm throughout the course of this investigation.

My mentor, Bill Zinsmeister of Purdue University, basically changed my life by extending to me, as a young naïve student, rare and exciting opportunities of travels and research in Antarctica, South America, México, and Great Britain, which ultimately led to work in New Zealand. It is a vast understatement to say that my first ever trip overseas (I had hardly ever set foot outside Indiana soil!) to Antarctica via South America and icebreaker across the Drake Passage made quite an impression! I appreciate his encouragement and support over the years more than he could ever know. Thanks, too, to his dear wife, Virginia.

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INTRODUCTION

The Upper Mesozoic and Cenozoic rocks of New Zealand (Figure 1) contain an exceptional record of fossil marine macroinvertebrates. Latest Cretaceous to earliest Paleogene molluscan faunas of New Zealand are no exception with representative taxa spanning most of the length of the country from Northland, North Island to southeastern Otago, South Island (Figure 2). These faunas represent an important part of what we know about the latest Cretaceous-early Paleogene molluscan composition of the southern circum-Pacific and provide a unique opportunity to study in detail faunal changes resulting from the final fragmentation of Gondwana during the Late Cretaceous. Furthermore, the composition of presumed Campanian (Upper Cretaceous) to Danian (Paleocene) shelf faunas of New Zealand is intimately associated with its inferred separation from the East Antarctic-Australian sector of Gondwana and development of open oceanic conditions by about Early Campanian time (c. 80-85 Ma) (see discussion below).

The Cretaceous-Tertiary (K-T) boundary, which falls within this interval, marks one of the greatest extinction events in the history of the Earth. The extent of this supposed mass extinction in New Zealand is considered in detail in a separate chapter herein on the K-T boundary. The K-T boundary, which marks the disappearance of many groups of animals and plants, is currently the subject of many international research programmes and is of interest to researchers and the general public across the globe.

Mollusc species-level diversity during this interval in New Zealand is moderately high compared to documented coeval faunas elsewhere with 329 recorded taxa; 159 are from the latest Cretaceous and 170 from the Paleocene (see Tables 1-3). Of these 329 taxa, 118 (c. 36%) are proposed herein as new species. The relatively complete record of fossil molluscs during this time allows a detailed qualitative and quantitative analysis of the changes in composition across the K-T boundary and provides important clues about the paleobiogeographic history of the Gondwana Realm.

The aim of this thesis is fourfold:

1) to provide a complete taxonomic review and revision of the latest Cretaceous and earliest Paleogene molluscan faunas of New Zealand, faunas which have not been studied in any detail for well over half a century;

2) to present a photographic catalogue and lists of fossil localities for all recorded species;

3) to examine survivorship versus extinction patterns and assess the extent of the supposed mass extinction for New Zealand molluscs across the K-T boundary; and

4) to qualitatively and quantitatively analyse the paleobiogeographic history and evolution of invertebrate faunas of New Zealand and others around the southern circum-Pacific, using information from this and other studies.

Accomplishing these tasks has resulted in a better understanding of the effects on faunas resulting from the final break-up of Gondwana and the concomitant dispersal of the southern continental "fragments". This study also provides significant new data on the composition of the Late Cretaceous-early Paleogene Austral biota and gives new insight into the role New Zealand has played in the distribution and origin of extant molluscs in the Gondwana Realm.

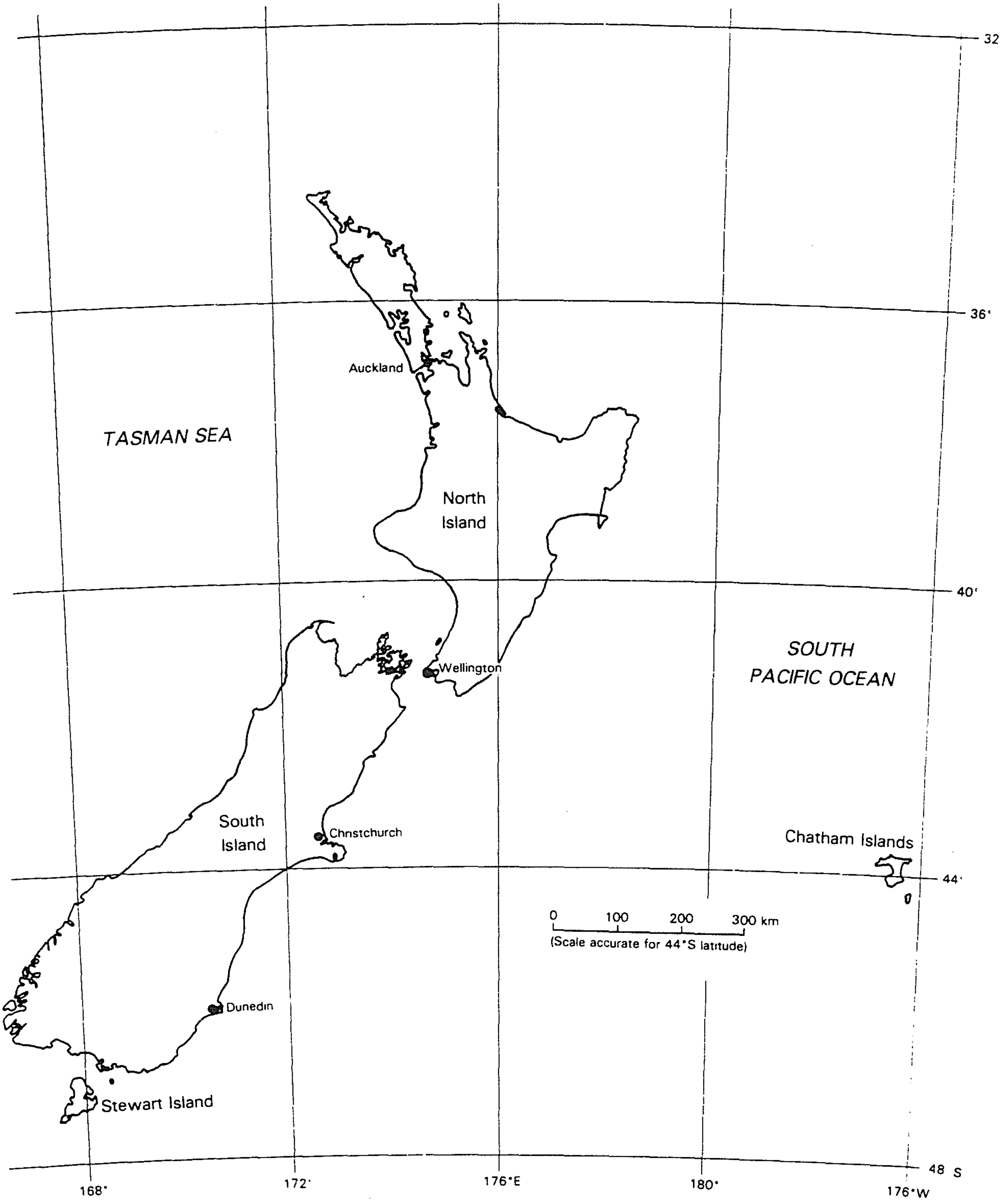


Figure 1. Location of New Zealand and Chatham Islands, South Pacific. Map based on the 1968 1:5,000,000 Geological Map of the World, Australia and Oceania, Sheet 13 (from Campbell et al., 1993).

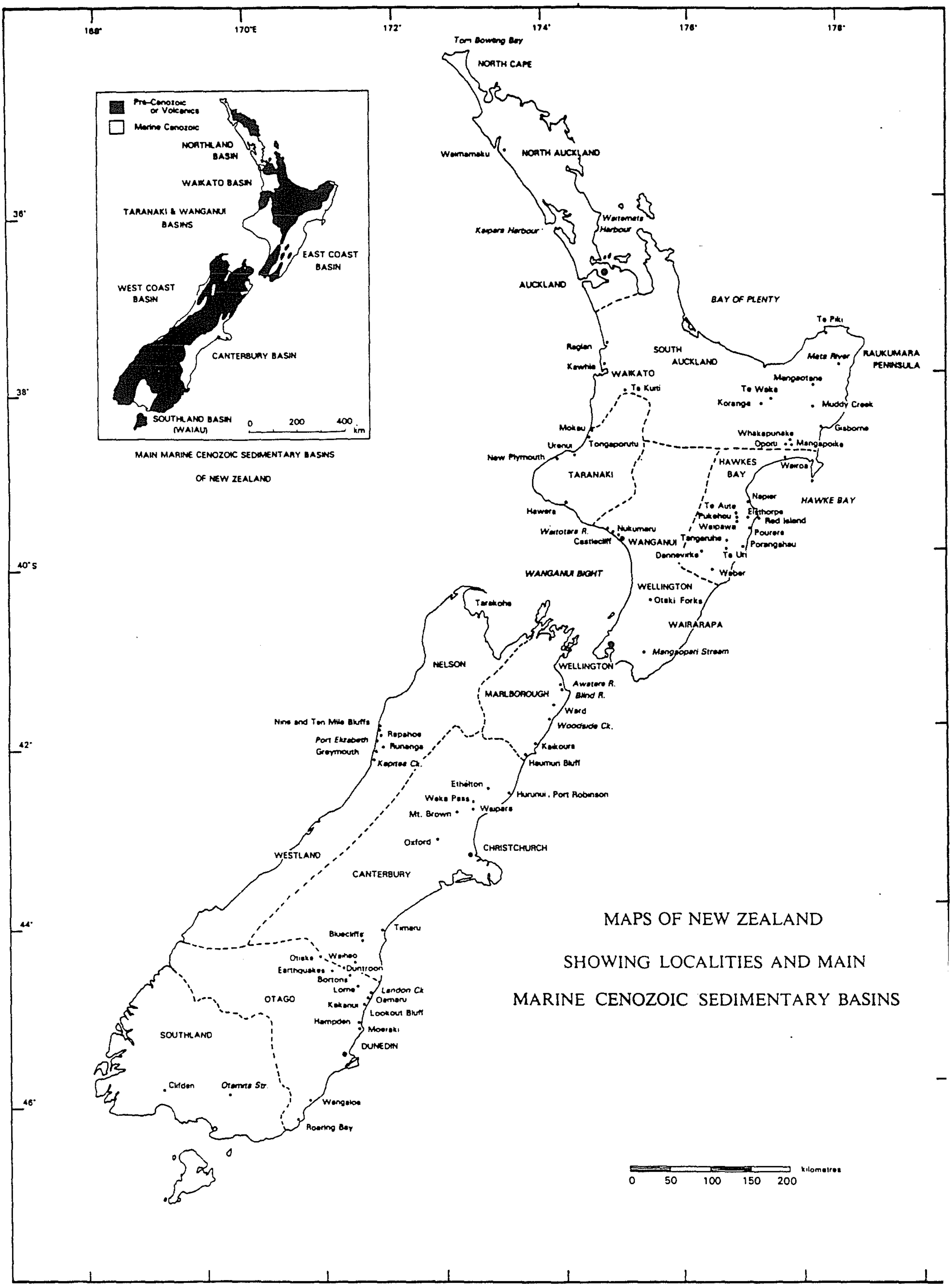


Figure 2. Maps of New Zealand showing localities and main sedimentary basins. Boundaries of provinces are indicated (from Hornibrook *et al.*, 1989).

Table 1: List of bivalve, gastropod, and scaphopod taxa in the latest Cretaceous (Campanian? - Maastrichtian) of New Zealand with inferred life habits. *DF*, deposit feeder; *SF*, suspension feeder; *IB*, infaunal burrower; *B*, burrower; *NSI*, nonsiphonate infaunal; *ES*, epifaunal sessile; *SY*, symbiotic on *Inoceramus*; *EB*, epifaunal byssate; *BY*, byssate; *FS*, free swimming; *SI*, siphonate infaunal; *I*, infaunal; *C*, carnivore; *EG*, epifaunal grazer; *E*, epifaunal; *BR*, browser; *EP*, ectoparasite; *EM*, epifaunal mobile; *ESC*, epifaunal scavanger; *BO*, borer.

BIVALVIA

Nuculidae	**Life Habits**
Nucula s.l. *teopuensis* n. sp	DF-IB
Nucula s.l. *kaiparaensis* n.sp	DF-IB
Linucula bullensis n. sp	DF-IB
Leionucula suboblonga (Wilckens, 1905)	DF-IB
Nuculanidae	
Nuculana austrodiscordia n.sp	DF-IB
Nuculana antichthona n. sp	DF-IB
Nuculana? amuriensis Woods, 1917	DF-IB
Jupiteria palaiozelandica n. sp	DF-IB
Jupiteria? notolissa n. sp	DF-IB
Saccella? primaeva n. sp	DF-IB
Saccella s.l. sp. of Woods, 1917	DF-IB
Pseudoportlandia? n. sp. A	DF-IB
Pseudoportlandia? n. sp. B	DF-IB
Portlandia ? sp.	DF-IB
Malletiidae	
Tindaria? veta n. sp	DF-IB
Neilo (Neiloides) cymbula (Woods, 1917)	DF-IB
Australoneilo zealandica n. sp	DF-IB
Solemyidae	
Solemya suroradiata n. sp	SF-SI-B
Arcidae	
Barbatia mackayi Woods, 1917	SF-B-E
Cucullaeidae	
Cucullaea cf. *C. antarctica* Wilckens, 1905	SF-NSI
Cucullaea (Cucullastis) zealandica (Woods, 1917)	SF-NSI
Cucullaea sp. of Woods, 1917	SF-NSI
Austrocucullaea n. sp. cf. *A. oliveroi* Zinsmeister and Macellari, 1988	SF-NSI
Indogrammatodon hectori (Woods, 1917)	SF-NSI
Nordenskjoeldia woodsi Wilckens, 1920	SF-NSI
Limopsidae	
Limopsis s.s. *griffini* n. sp	SF-NSI
Glycymerididae	
Glycymerita selwynensis (Woods, 1917)	SF-NSI
Mytilidae	
Lycettia cf. *L. foaensis* Freneix, 1980	SF-EB
Lycettia lanceolata (Sowerby, 1823)	SF-EB
Septifer? eurycrenulata n. sp.	SF-EB
Modiolus cf. *M. typicus* Forbes, 1846	SF-EB
Inoperna sp. aff. *I. flagellifera* (Forbes, 1846)	SF-EB
Pinnidae	
Pinna sp.	SF-NSI-BY
Inoceramidae	
Inoceramus sp.	SF-EB
Inoceramus australis Woods, 1917	SF-EB
Inoceramus pacificus Woods, 1917	SF-EB
Inoceramus matotorus Wellman, 1959	SF-EB
Isognomonidae	
Isognomon sp.	SF-EB
Entoliidae	
Entolium membranaceum (Nilsson, 1827)	SF-FS
Pectinidae	
Aequipecten sp.	SF-FS-EB
Camptonectes selwynensis (Finlay, 1927)	SF-FS-EB
Camptonectes n. sp.? cf. *virgatus* (Nilsson, 1827)	SF-FS-EB
Camptonectes n. sp.	SF-FS-EB
Mixtipecten amuriensis (Woods, 1917)	SF-FS-EB
Chlamys (Lyriochlamys) conwayensis n. sp	SF-FS-EB
Neithea grangei (Murdoch, 1924)	SF-FS-EB
Pectinidae gen. et sp. indet.	SF-FS-EB
Anomiidae	
Anomia n. sp.?	SF-EB
Limidae	
Limea (Pseudolimea) woodsi (Suter, 1921)	SF-EB
Limatula sp. indet.	SF-EB

Seymourtula cf. *S. antarctica* (Wilckens, 1910) .... SF-EB

Acesta s.s. *warreni* n. sp .... SF-EB

Acesta (Plicacesta) n. sp.? .... SF-EB

Ostreidae

Planospirites sp. .... SF-ES

Pseudoperna lapillicola (Marwick, 1926) .... SF-ES

Crassostrea sp. .... SF-ES

Trigoniidae

Pterotrigonia s.s. *pseudocaudata* (Hector, 1886) .... SF-NSI

Pterotrigonia s.s. *waitangiensis* Fleming, 1987 .... SF-NSI

Pterotrigonia s.s. n. sp. aff. *waitangiensis* Fleming, *1987* .... SF-NSI

Pterotrigonia (Ptilotrigonia) ultima Fleming, 1987 .... SF-NSI

Pacitrigonia hanetiana (d'Orbigny, 1842) *hectoria* Fleming, *1987* .... SF-NSI

Pacitrigonia hanetiana (d'Orbigny, 1842) *woodsi* Fleming, 1987 .... SF-NSI

Pacitrigonia sylvesteri Marwick, 1932 .... SF-NSI

Oistotrigonia piripauana Fleming, 1987 .... SF-NSI

Oistotrigonia ongleyi Fleming, 1987 .... SF-NSI

Oistotrigonia waiparensis (Woods, 1917) .... SF-NSI

Iotrigonia leda Fleming, 1987 .... SF-NSI

Iotrigonia lenseni Fleming, 1987 .... SF-NSI

Eselaevitrigonia? n. sp? .... SF-NSI

Trigonia n. sp. aff. *marwicki* Fleming, 1987 .... SF-NSI

Lucinidae

Myrtea canterburiensis (Woods, 1917) .... SF-SI

Myrtea cretacea n. sp. .... SF-SI

Thyasiridae

Thyasira (Conchocele) bullpointensis n. sp. .... SF-SI

Astartidae

Astarte n. sp. .... SF-NSI

Eriphyla s.s. *meridiana* Woods, 1917 .... SF-NSI

?*Dozyia lenticularis* (Goldfuss, 1840) .... SF-NSI

Crassatellidae

Anthonya elongata Woods, 1917 .... SF-NSI

Cardiidae

Cardium (Bucardium?) sp. .... SF-NSI

Austrocardium acherontis Freneix & Grant-Mackie, 1978 .... SF-NSI

Granocardium (Ethmocardium) woodsi (Marwick, 1944) .... SF-NSI

Granocardium (Ethmocardium) sp. indet .... SF-NSI

Cardium sp. 2 of Woods, 1917 .... SF-NSI

Schedocardia? waiparana Freneix & Grant-Mackie, 1978 .... SF-NSI

Lahillia aotearoa n. sp. .... SF-NSI

Mactridae

Cymbophora mackayi n. sp. .... SF-SI

Raeta? n. sp. .... SF-SI

Zenatia cretacea (Woods, 1917) .... SF-SI

? Tellinidae

Aenona n. sp.? .... DF-SI

Donacidae

?*Notodonax* sp. of Maxwell in Feldmann, 1984 .... SF-SI

Psammobiidae

Gari s.l. *barronshillensis* n. sp. .... SF-SI

Tancrediidae

Trancredia sura n. sp. .... SF-SI

Veneridae

Aphrodina (Tikia) thomsoni (Woods, 1917) .... SF-SI

Aphrodina (Tikia) wilckensi (Woods, 1917) .... SF-SI

Costacallista? n. sp. .... SF-SI

Cyclorismina woodsi Marwick, 1927 .... SF-SI

Myidae

Mya sp. of Warren and Speden, 1978 .... SF-SI

Corbulidae

Surobula cf. *S. nucleus* (Wilckens, 1910) .... SF-SI

Corbulidae gen. indet. n. sp. .... SF-SI

Hiatellidae

Cyrtodaria n. sp. .... SF-SI

Panopea clausa Wilckens, 1910 .... SF-SI

Panopea malvernensis Woods, 1917 .... SF-SI

Pholadidae

Clavipholas birchhollowensis n. sp .... SF-SI-BO

Pholadidea (Hatasia) wiffenae Crampton, 1990 .... SF-SI-BO

Teredinidae

Teredo sp. .... SF-SI-BO

Thraciidae

Thracia haasti Woods, 1917 .... SF-SI

Cuspidariidae

Cuspidaria surocretacica n. sp. .... C-I

GASTROPODA

Pleurotomariidae

Perotrochus maoriensis (Wilckens, 1922) .... EG-C?

Chelotia woodsi (Wilckens, 1922) .... EG-C?

Lottiidae

Patelloida? n. sp. .... EG

Nacellidae

Cellana? n. sp. .... EG

Patellidae

Patella? amuritica Wilckens, 1922 .... EG

Skeneidae

Brookula (Paleobrookula) marshalli n. subgen. n. sp. .... E-BR

Trochidae

Amberleya whangaroaensis n. sp. .... E-BR

Calliomphalus s.l. *hickmanae* n. sp. .... E-BR

Kaiparomphalus austrinus n. gen. n. sp. .... E-BR

Chrysostoma selwynensis Trechmann, 1917 .... E-BR

Calliostoma decapitatum Wilckens, 1922 .... E-BR-C?

Trochidae gen. indet. n. sp. .... E-BR

Turbinidae

"Angaria"? sp. .... E-BR

Turbo sp. of Crampton and Moore, 1990 .... E-BR

Neritopsidae

Damesia? n. sp .... E-BR

Neritopsis (Hayamiella?) sp. .... E-BR

Protodolium speighti (Trechmann, 1917) .... E-BR

Zygopleuridae

Zygopleura? obliquestriata (Trueman, 1924) .... E-BR?-DF?

aff. *Loxonema* n. sp. .... E-BR?-DF?

Potamididae

Bittiscala inaequicostata (Wilckens, 1922) .... E?B

Procerithiidae

Bathraspira zealandica n. sp. .... ESC

Rhabdocolpus? minutus n. sp. .... ESC

?Fossaridae

Procancellaria parkiana Wilckens, 1922 .... E?B

Turritellidae

Costacolpus solitaria (Wilckens, 1922) .... DF?E?

Aporrhaidae

Perissoptera waiparaensis (Hector, 1886) .... DF-E/I?

Struthioptera haastiana (Wilckens, 1922) .... DF-E/I?

Struthioptera novoseelandica (Wilckens, 1922) .... DF-E/I?

Arrhoges (Latiala) suteri (Trechmann, 1917) .... DF-E/I?

Struthiolariidae

Conchothyra parasitica Hutton, 1877 .... DF-E/I?

Conchothyra marshalli (Trechmann, 1917) .... DF-E/I?

Vanikoridae

Vanikoro? n. sp. .... EB?

Calyptraeidae

Sigapatella? solitaria (Wilckens, 1922) .... SF-EB?

Crepidula hochstetteriana Wilckens, 1922 .... SF-EB?

Capulidae

cf. *Capulus? sulcatus* (Wilckens, 1910) .... SY?-SF-E

Gigantocapulus n. sp. .... SY-E

Trichotropidae

Trichotropis (Cerithioderma) waimaramaensis n. sp. .... DF?-E

Naticidae

Euspira selwyniana (Wilckens, 1922) .... C-I/E?

Eunaticina? omapereensis n. sp. .... C-I/E?

Amauropsona? n. sp.	C-I/E?
Naticidae gen. et sp. indet.	C-I/E?
Epitoniidae	
Acirsa (Notacirsa?) pacifica (Wilckens, 1922)	C-EM-EP
Opalia cramptoni n. sp.	C-EM-EP
Fasciolariidae	
"Cryptorhytis" vulnerata Wilckens, 1922	C-EM
Melongenidae	
Sycostoma notiale n. sp.	C-EM
Tudiclidae	
Saulopsis? n. gen. n. sp.	C-EM
Pseudoperissolax? similis (Wilckens, 1922)	C-EM
Perissitys? sp.	C-EM
Acteonidae	
Tornatellaea evansi n. sp.	C-I
Ringiculidae	
Eriptycha punamutica Wilckens, 1922	C-I
Ringicula s.s. *zigzagia* n. sp.	C-I
?Hydatinidae	
n. gen? aff. *Aplustrum selwynensis* Trechmann, 1917	C-I?
Cylichnidae	
Cylichnania thomsoniana (Wilckens, 1922)	C-I?
Pyramidellidae	
Odostomia? paleozelandica n. sp.	EP
SCAPHOPODA	
Antalis grantmackiei n. sp.	DF?-C?-I
Dentalium (Laevidentalium) morganianum (Wilckens, 1922)	DF?-C?-I

Table 2: List of bivalve, gastropod and scaphopod taxa in the Paleocene (Danian - Thanetian) of New Zealand with inferred life habits. See Table 1 for acronyms used.

BIVALVIA

Nuculidae	**Life Habits**
Linucula austrobullata n. sp.	DF-IB
Varinucula? n. sp	DF-IB
Leionucula palaioanaxea Stilwell, 1993	DF-IB
Leionucula cf. *L. palaioanaxea* Stilwell, 1993	DF-IB
Nuculanidae	
Jupiteria maxwelli n. sp.	DF-IB
Jupiteria n. sp.?	DF-IB
Sareptidae	
Ledina taioma (Finlay & Marwick, 1937)	DF-IB
Malletiidae	
Neilo n. sp.	DF-IB
Spineilo elongata (Marshall, 1917)	DF-IB
Cucullaeidae	
Cucullaea (Cucullona) inarata Finlay and Marwick, 1937	SF-NSI
Cucullaea (Cucullona?) dunrobinensis n. sp.	SF-NSI
Cucullaea (Cucullastis) barbara Finlay and Marwick, 1937	SF-NSI
Limopsidae	
Limopsis (Limopsista) microps Finlay and Marwick, 1937	SF-NSI
Glycymerididae	
Glycymerita s.s. *concava* (Marshall, 1917)	SF-NSI
Mytilidae	
Septifer? *alata* n. sp.	SF-ESB
Pteriidae	
Electroma (Pterelectroma) intecta Finlay and Marwick, 1937	SF-EB
Isognomonidae	
Isognomon s.s. *wellmani* Crampton, 1988	SF-EB
Pectinidae	
Chlamys s.l. *raupoensis* n. sp.	SF-FS-EB
Anomiidae	
Anomia sp.	SF-FS-EB
Gryphaeidae	
Pycnodonte (Notostrea?) sp.	SF-ES
Ostreidae	
Ostrea n. sp.?	SF-ES
Lucinidae	
Pteromyrtea obesa Finlay and Marwick, 1937	SF-SI
Pteromyrtea modica n. sp.	SF-SI
Miltha agilis Finlay and Marwick, 1937	SF-SI
Myrtea microlirata (Finlay and Marwick, 1937)	SF-SI
Thyasiridae	
Thyasira? sp.	SF-SI
Thyasira (Conchocele) n. sp.	SF-SI
Kelliidae	
Kellia? paleocenica n. sp.	SF-ES?
Carditidae	
Purpurocardia fyfei (Finlay and Marwick, 1937)	SF-NSI
Cardiidae	
Nemocardium (Pratulum) modicum Marwick, 1944	SF-NSI
Lahillia neozelanica Marshall & Murdoch, 1923	SF-NSI
Mactridae	
Maorimactra perialla n. sp.	SF-SI
Mactra s.l. *praeobtusa* (Finlay and Marwick, 1937)	SF-SI
Psammobiidae	
Gari tokomairiroensis n. sp.	SF-SI
Veneridae	
Aphrodina (Tikia) lepra n. sp.	SF-SI
Marwickia parthiana (Marwick, 1927)	SF-SI
Dosinia (Kereia?) n. sp.	SF-SI
Dosinia (Dosinobia) ongleyi (Marwick, 1927)	SF-SI
Hiatellidae	
Panopea n. sp? aff. *P. worthingtoni* Hutton, 1873	SF-SI

GASTROPODA

Trochidae	
Conominolia conica (Marshall, 1917)	E-BR
Turbinidae	
Bolma (Ormastralium) eoaustralicus n. sp.	E-BR

Potamididae

Bittiscala simplex (Marshall, 1917) .... E?BR

Turritellidae

Colposigma mesalia Finlay and Marwick, 1937 .... DF?-E?

Spirocolpus globulus n. sp. .... DF?-E?

Zeacolpus (Leptocolpus) semiconcavus (Suter, 1911) .... DF?-E

Aporrhaidae

Drepanocheilus (Tulochilus) bensoni Finlay and Marwick, 1937 .... DF-E/I?

n. gen.? n. sp. aff. *Hemichenopus* .... DF-E/I?

Struthioptera osiris Finlay and Marwick, 1937 .... DF-E/I?

Struthiolariidae

Conchothyra australis (Marshall, 1916) .... DF-E/I?

Perissodonta minor (Marshall, 1917) .... DF-E/I?

Perissodonta mita n. sp. .... DF-E/I?

Calyptraeidae

Sigapatella (Spirogalerus) lamellaria (Finlay and Marwick, 1937) .... SF-EB?

Naticidae

Globisinum spirale (Marshall, 1917) .... C-I/E?

Globisinum suratulum n. sp. .... C-I/E?

Magnatica (Spelaenacca) firma (Marwick, 1924) .... C-I/E?

Magnatica (Spelaenacca) procera Finlay and Marwick, 1937 .... C-I/E?

Magnatica (Spelaenacca) kakanuiensis n. sp. .... C-I/E?

Taniella (Pristinacca) seniscula (Marwick, 1924) .... C-I/E?

Amauropsona major (Marshall, 1917) .... C-I/E?

Amauropsis teres (Marwick, 1924) .... C-I/E?

Euspira fyfei Marwick, 1924 .... C-I/E?

Polinices s.s. *parki* Finlay and Marwick, 1937 .... C-I/E?

Polinices (Polinella) finlayi (Marwick, 1924) .... C-I/E?

Polinices (Polinella) hypsaspeira n. sp. .... C-I/E?

Eunaticina? auriforme (Marwick, 1924) .... C-I/E?

Eunaticina nota n. sp. .... C-I/E?

Cassidae

Galeodea s.s. *n. sp?* aff. *modesta* (Suter, 1917) .... C-IE

Taieria allani Finlay and Marwick, 1937 .... C-IE

Ficidae

Priscoficus obtusa (Marshall, 1917) .... C-I/E?

Priscoficus minuta n. sp. .... C-I/E?

Eulimidae

Melanella lautoides Finlay and Marwick, 1937 .... EP

Melanella? n. sp. .... EP

Niso putata Finlay and Marwick, 1937 .... EP

Epitoniidae

Acirsa (Notacirsa) pavicostata (Marshall, 1917) .... C-EM-EP

Acirsa (Notacirsa) dieffenbachi n. sp. .... C-EM-EP

Acirsa (Plesioacirsa) otagoensis n. sp. .... C-EM-EP

Acirsa (Plesioacirsa) sp. .... C-EM-EP

Amaea s.s. *casca* n. sp. .... C-EM-EP

Buccinidae

Austrofusus s.s. *ayressi* n. sp. .... C-EM

Austrofusus (Nassicola) sublurida (Marshall, 1917) .... C-EM

Austrofusus (Nassicola?) n. sp.? .... C-EM

Buccinulum adelum n. sp. .... C-EM

Buccinulum paleogenicum n. sp. .... C-EM

Penion proavitus (Finlay and Marwick, 1937) .... C-EM

Aeneator dyskritos n. sp. .... C-EM

Pseudofax ordinarius (Marshall, 1917) .... C-EM

Austrocominella cancellaria (Finlay and Marwick, 1937) .... C-EM

Austrocominella imitatrix (Finlay and Marwick, 1937) .... C-EM

Tudiclidae

Saulopsis n. gen. *zelandicus* (Marshall, 1917) .... C-EM

"Pyropsis" zinsmeisteri Stilwell, 1993 .... C-EM

Tudiclana simulator Finlay and Marwick, 1937 .... C-EM

Turbinellidae

Columbarium vulneratum (Finlay and Marwick, 1937) .... C-EM

Columbarium n. sp.? .... C-EM

Exilia vixcostata (Finlay and Marwick, 1937) .... C-EM

Fyfea lirata Finlay and Marwick, 1937 .... C-EM

Fyfea tuberculata Finlay and Marwick, 1937 .... C-EM

Microfulgur longirostris (Marshall, 1917) .... C-EM

Muricidae

Uttleya? sp. .... C-EM

Volutomitridae

Volutomitra n. sp. .... C-EM

Volutidae

Wangaluta henaconstricta n. gen. n. sp. .... C-EM/I

Wangaluta? n. gen. *neozelanica* (Finlay and Marwick, 1937) .... C-EM/I

Alcithoe s.l. *wangaloaensis* n. sp. .... C-EM/I

Volutidae? gen. indet. n. sp. .... C-EM/I

Turridae

Austrotoma indiscreta Finlay and Marwick, 1937 .... C-EM

Marshallaria multicincta (Marshall, 1917) .... C-EM

Amuletum s.s. *mitchellsrocksensis* n. sp. .... C-EM

Campylacrum sanum Finlay and Marwick, 1937 .... C-EM

Cosmasyrinx (Tholitoma) dolorosa (Finlay and Marwick, 1937) .... C-EM

Hesperiturris gemmuliformis n. sp. .... C-EM

Zemacies immatura Finlay and Marwick, 1937 .... C-EM

Inquisitor boucheti n. sp. .... C-EM

aff. *Inquisitor* n. sp. .... C-EM

Eothesbia microtomoides Finlay and Marwick, 1937 .... C-EM

Tomopleura striata (Marshall, 1917) .... C-EM

Taioma tricarinata Finlay and Marwick, 1937 .... C-EM

Cancellariidae

Pristimerica dolioides Finlay and Marwick, 1937 .... C-EM

Cancellariidae gen. indet. n. sp. .... C-EM

Antepepta nasuta Finlay and Marwick, 1937 .... C-EM

Coptostomella pupa Finlay and Marwick, 1937 .... C-EM

Coptostomella campbelli n. sp. .... C-EM

Kapuatriton? n. sp. cf. *kaitarus* Beu & Maxwell, 1987 .... C-EM

Acteonidae

Acteon semispiralis Marshall, 1917 .... C-I

Acteon wangaloa Finlay and Marwick, 1937 .... C-I

Acteon austropunctatus n. sp. .... C-I

Wangacteon grebneffi Stilwell, 1993 .... C-I

Crenilabium paleocenicum n. sp. .... C-I

Crenilabium darraghi n. sp. .... C-I

Kaurueon insolitus n. gen. n. sp. .... C-I

Ongleya tholispira Finlay and Marwick, 1937 .... C-I

Ongleya n. sp. cf. *O. tholispira* Finlay and Marwick, 1937 .... C-I

Tornatellaea incompta Finlay and Marwick, 1937 .... C-I

Tornatellaea saucia Finlay and Marwick, 1937 .... C-I

Tornatellaea morbosa Finlay and Marwick, 1937 .... C-I

Ringiculidae

Superstes exquisitus n. sp. .... C-I

Superstes dentatus n. sp .... C-I

Cylichnidae

Cylichnania impar Finlay and Marwick, 1937 .... C-I?

Cylichnania daphneae n. sp. .... C-I?

Prisaphander cingulatus (Marshall, 1937) .... C-I?

Priscaphander elongatus n. sp. .... C-I?

Architectonicidae

Wangaloa plana (Marshall, 1917) .... C-I-EP?

Wangaloa depressa n. sp. .... C-I-EP?

Mathildidae

Eomathilda paxilla Finlay and Marwick, 1937 .... C-I-EP?

Gegania hendersoni Finlay and Marwick, 1937) .... C-I-EP?

Gegania subreticuloides n. sp. .... C-I-EP?

Pyramidellidae

Odostomia n. sp.? .... EP

Pyramidella? n. sp. .... EP-SF?-DF?

SCAPHOPODA

Dentaliidae

Fissidentalium waikaroensis n. sp. .... DF?-C?-I

Antalis multistricta (Finlay and Marwick, 1937) .... DF?-C?-I

Gadilidae

Gadila n. sp. .... DF?-C?-I

Table 3:

Tabulations: Latest Cretaceous Mollusca of New Zealand (Campanian? - Maastrichtian)

	Total genera	**New genera/subgenera**	**Total species**	**New species**
Bivalvia	79	0	105	34
Gastropoda	47	2	52	20
Scaphopoda	2	0	2	1
Totals	128	2	159	55

Tabulations: Paleocene Mollusca of New Zealand (Danian - Thanetian)

	Total genera	**New genera/subgenera**	**Total species**	**New species**
Bivalvia	35	0	60	14
Gastropoda	76	3	107	39
Scaphopoda	3	0	3	2
Totals	114	3	170	63

329 species total | **118 new species total**

PREVIOUS INVESTIGATIONS

The latest Cretaceous and earliest Paleogene molluscan faunas of New Zealand have received sporadic attention from the latter part of last century to the present day in terms of systematics, distribution, paleoecology and paleobiogeography. There follows a detailed summary of all previous work on these faunas.

Late Cretaceous molluscan faunas of New Zealand

The first Cretaceous fossils to be recorded in New Zealand were collected by J. H. Cockburn Hood in 1859 in a bed in the Waipara River, Canterbury (Fleming *in* Wilson, 1963, p. 25). These fossils, identified and described as saurian remains of *Plesiosaurus* by Owen (1861), were assigned a Jurassic age, but are now known to be Late Cretaceous. The first lists of Cretaceous molluscs are to be found in the Catalogue of the Colonial Museum (Anon., 1870, see pages 193, 195). These lists cite mostly genera apart from a few species assignments, including "*Aporhais* (*Conchithyra parasitica*. McCoy. ?)" (sic), which is the earliest published mention of the bizarre, heavily callused, endemic gastropod *Conchothyra parasitica* Hutton, 1877a. This gastropod also has the distinction of being the first Late Cretaceous mollusc of New Zealand to be described formally (**fide** Hutton, 1877a, pp. 37-38). (As a sidenote, this species was assigned to "*Conchothyra parasitica* (McCoy)" and "*Conchotyra parasitica*, McCoy" (**sic**; mis-spelling) by von Haast (1871, pp. 10 and 45 respectively) in his reports on the Cretaceous stratigraphy/biostratigraphy of the Waipara and Amuri districts, suggesting that as early as 1871 there were already discrepancies in the spelling of this taxon which have propagated through time.) Haast (1872) reported on the Cretaceous geology of the Malvern Hills, Canterbury area and included notes on the fossils. Hutton (1872, 1873) summarised the "...Younger Formations of New Zealand", including the Cretaceous. Hutton *in* Hutton and Ulrich (1875) provided the first comprehensive account of the Mesozoic-Cenozoic geology and paleontology of Otago, including descriptions of Cretaceous strata. Notes on the fossiliferous Cenozoic deposits of coastal Otago were given much earlier, however, by Forbes *in* Mantell (1850). Von Haast (1877) published a map and notes on the Cretaceous geology of the Shag Point District, North Otago. Hutton (1877a) published a report on the geology of the northeastern part of South Island. McKay (1877) in the same year provided a report on the Kaikoura Peninsula and Amuri (= Haumuri Bluff). Von Haast (1879) published a comprehensive account of the geology of the Canterbury and Westland, including a wealth of information on Cretaceous stratigraphy and paleontology. Little systematic work on Late Cretaceous molluscs was undertaken or published between the years 1878-1916 apart from Hutton's (1894) paper on *C. parasitica*, although several general papers on stratigraphy and faunal lists were published (e.g. Hector, 1879; McKay, 1881, 1884, 1887, 1897; Park, 1910; Marshall *et al.*, 1911; Marshall, 1912; Thomson, 1913). The most significant contribution to our knowledge of Cretaceous molluscs during this period was Hector's (1886) "Detailed Catalogue and Guide to the Geological Exhibits" of the Indian and Colonial Exhibition, London, 1886, in which 10 species of molluscs of this age were first figured, including Conchothyra parasitica (see Hector, 1886, Fig. 20, p. 58; Fig. 28, p. 64) (Figures 3-4, herein). It was to be more than three decades before the Late Cretaceous molluscs of New Zealand would receive monographic treatment.

Early in 1912 H. Woods of Cambridge University expressed to P. G. Morgan (Director, New Zealand Geological Survey) his interest in describing a representative collection of Cretaceous ammonites, belemnites and bivalves from New Zealand. These specimens were sent to Woods in three main lots in May, 1912; July, 1912; and 1913. At this time Survey geologist J. A. Thomson was given the monumental task of organising the unclassified fossil material of the Geological Survey, more than 40 tons, most of which was still packed in 700 whisky cases (Burton, 1965, p. 62). Some of this material was sent to various workers, including Woods, for systematic descriptions. Woods did not commence work on the New Zealand Cretaceous taxa until 1913, because he had to finish his long-term project on Cretaceous bivalves of England. He finished the monograph on New Zealand taxa near the end of 1914. Following a major disaster when the plates were lost in the wreck of the ship "Tongariro" off the coast of New Zealand and delays due to World War I, the memoir was published three years later (Woods, 1917). In the end the plates were reproduced from the original blocks that had to be sent from England to New Zealand. The original intention had been to have the letterpress printed in New Zealand and illustrations collotyped in England (Morgan in Woods, 1917). Woods described 45 species of Late Cretaceous bivalves from the

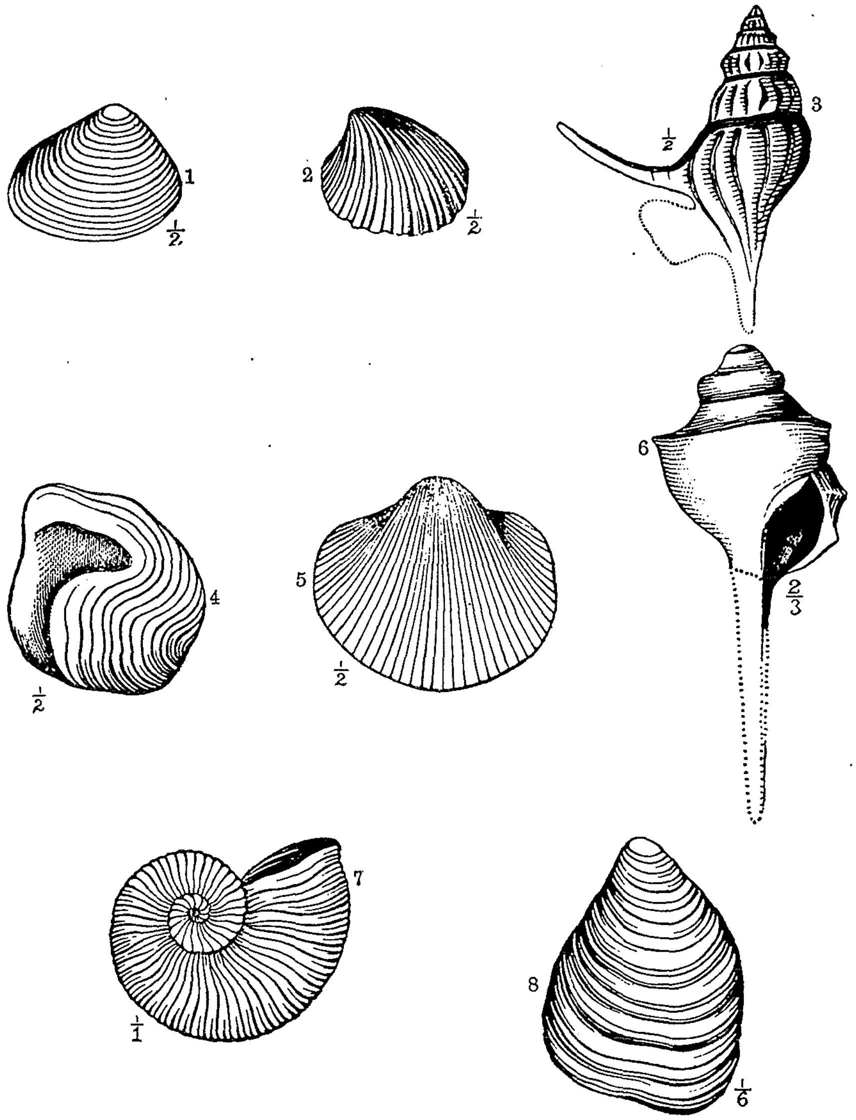


Fig. 20.

1. Astarte australis (Kakahu). 2. Hemicardium (Blackpoint, Waitaki). 3. Rostellaria waiparensis (Saurian beds, Waipara and Amuri Bluff). 4. Conchothyra parsisitica (McCoy). 5. Cardium brunneri (Brunnerton). 6. Tudicla biangulata. 7. Ammonites haumuriensis (Coverham and Amuri group, Amuri Bluff). 8. Inoceramus (Coverham and Wellington).

Figure 3. First illustrations of New Zealand latest Cretaceous molluscs. Figures 3, *Perissoptera waiparaensis* (Hector, 1886); 4, *Conchothyra parasitica* Hutton, 1877; 6, *Pseudoperissolax*? *similis* (Wilckens, 1922); 7, *Kossmaticeras* s. s. *haumuriensis* (Hector, 1886) (original woodcut drawings reproduced from Hector, 1886, Fig. 20).

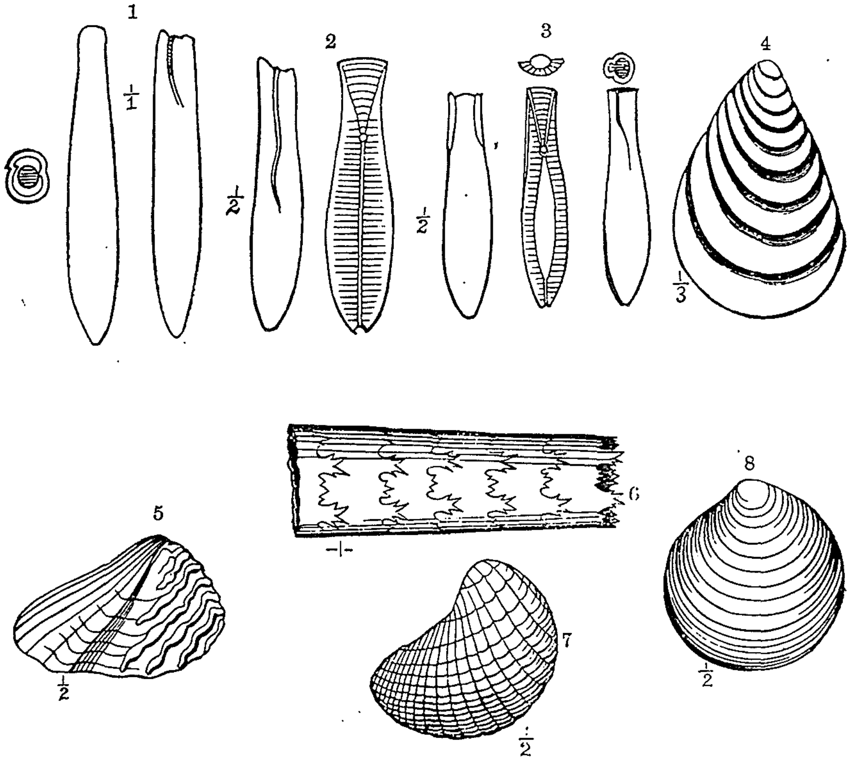


Fig. 28.

1. Belemnites australis, var. *a*. 2. Belemnites australis, var. *b*. 3. Belemnites australis, var. *d*. 4. Inoceramus haastii. 5. Trigonia sulcata. 6. Baculites anceps. 7. Trigonia pseudo-cundata. 8. Lucina americana.

Figure 4. First illustrations of New Zealand latest Cretaceous molluscs. Figures 1-3, *Dimitobelus lindsayi* (Hector, 1886); 4, *Inoceramus australis*? Woods, 1917; 5, *Pacitrigonia hanetiana* (d'Orbigny, 1842) *hectori* Fleming, 1987; 6, *Baculites rectus*? Marshall, 1926; 7, *Pterotrigonia* s. s. *pseudocaudata* (Hector, 1886); 8, *Eriphyla meridiana* Woods, 1917 (original woodcut drawings reproduced from Hector, 1886, Fig. 28).

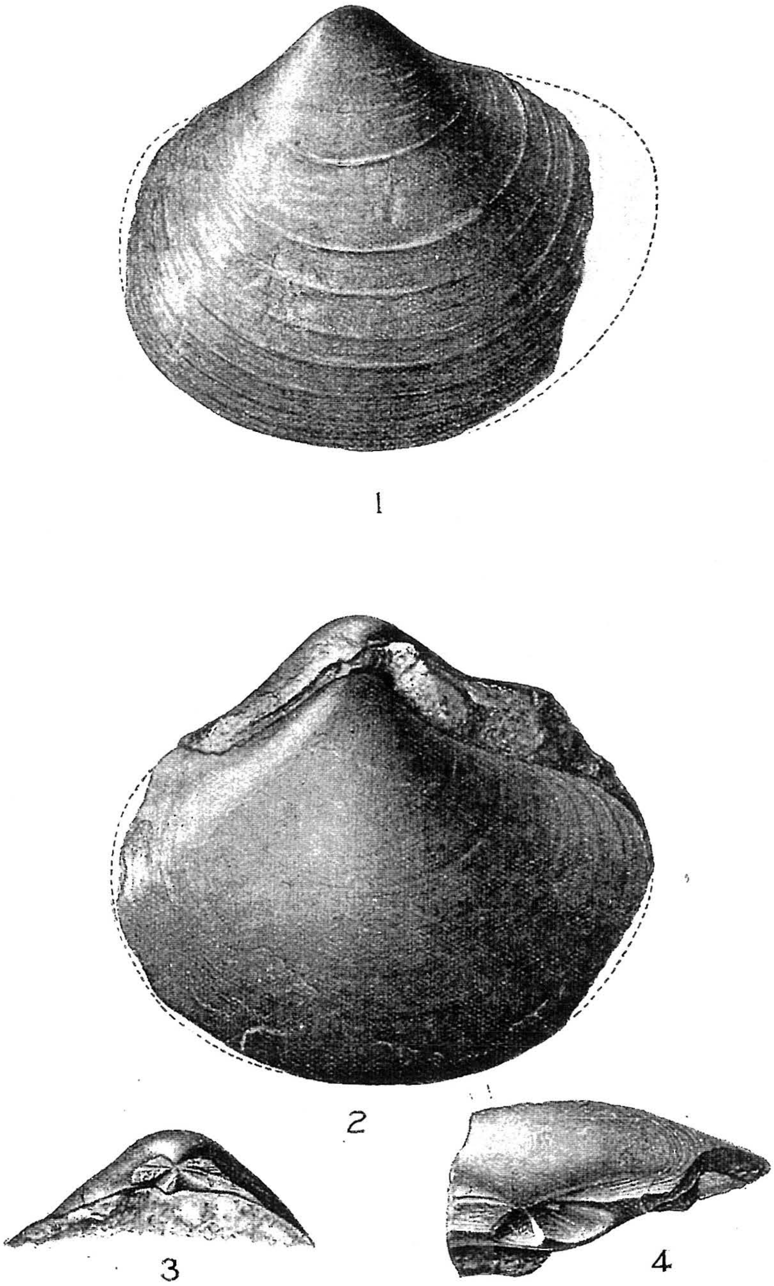


Figure 5. Specimens of Lahillia cf. luisa Wilckens, 1910 of Wilckens (1924) (= Lahillia aotearoa n. sp., this work) from Shag Point, Haumuri Bluff and Selwyn Rapids. Figures 1, TM 2569 (IGNS). Shag Point; 2, TM 2571 (IGNS). Shag Point; 3, TM 2570 (IGNS). Haumuri Bluff; 4, TM 2572 (IGNS). Selwyn Rapids.

northeastern part (Canterbury and Marlborough) of South Island and, of these, 20 species were described as new and formally named. The types and figured specimens from Woods' work are housed at the Institute of Geological and Nuclear Sciences, Lower Hutt (IGNS; formerly New Zealand Geological Survey).

Although English paleontologist C. T. Trechmann from Durham is known mainly for his work on New Zealand Permian, Triassic and Jurassic geology and paleontology, he made a significant collection of Late Cretaceous molluscs in 1914 at Selwyn Rapids, Waipara Gorge, Waimakiriri Gorge and near Wangaloa after attending a British Association for the Advancement of Science meeting in Australia. After his return to England, he published in 1917 descriptions of 13 species of molluscs, including one bivalve, one scaphopod and 11 gastropods. Six of these species were described as new. It was Trechmann's intention to describe fossils other than those already described by Woods (1917) and those already under investigation by P. Marshall of University of Otago (until 1916); Marshall was working on the "Wangaloan" fauna, considered then to be Cretaceous in age. Trechmann's collection of fossils, including all types, are housed in the Natural History Museum, London (BMNH).

Wilckens (1920a) reviewed the New Zealand Late Cretaceous bivalve fauna and proposed a new species, Nordenskjoeldia woodsi, based on Nemodon? sp. of Woods, 1917. Late Cretaceous New Zealand taxa were also mentioned by Wilckens (1920b) in his review of the Cretaceous. The species name of Limea (Pseudolimea) huttoni (Woods, 1917) [Lima (Limatula)] was found to be preoccupied; Suter (1921) renamed this species L. (P.)

woodsi. Gastropods did not receive monographic treatment until Wilckens (1922).

Fossils described by O. Wilckens of Bonn University (formerly of University of Strasburg, later relieved of his post there) were originally sent to H. Woods in 1912, but Woods recommended that they be sent to Wilckens who was considered to be the foremost authority on Cretaceous Gastropoda. These fossils were in Wilckens' possession by 1913, but World War I prevented him from working on the material until 1919. The monograph, which was finally published three years later, described 29 gastropod species, 23 of which were considered new. *Pleurotoma otagoensis* Wilckens, 1922 (most likely an aporrhaid), of Shag Point, North Otago and *Turritella solitaria* Wilckens, 1922 (later relegated to *Costacolpus* by Marwick, 1966) from Hapuka River, eastern Marlborough) were considered by Wilckens to be probably Upper Cretaceous, but the age is uncertain. Wilckens apparently overlooked the aporrhaid gastropod *Arrhoges* (*Latiala*) *suteri* (Trechmann, 1917) [*Alaria*] in his monograph.

Systematic treatment of Late Cretaceous bivalves, gastropods and scaphopods after 1922 remained infrequent until this work. Murdoch (1924) described a virtually unknown latest Cretaceous pectinid bivalve *Neithea grangei* [originally cited as *Chlamys grangei*] from Brighton, Otago, in a paper describing Tertiary fossils. The same year Trueman (1924) described the enigmatic gastropod *Zygopleura obliquestriata* from Tapuwaeroa Valley, Raukumara Peninsula. Wilckens (1924) also published a paper on the occurrence of *Lahillia* and other fossils in the Late

Cretaceous of New Zealand, many from Shag Point, North Otago (see Figure 5 herein; fossils from this region were also noted by Service (1934) and Marwick (1946)). In a list of fossils collected in association with Late Cretaceous ammonites, Marshall (1926) noted that 40 species of gastropods and some bivalves (no faunal lists provided) were present in rocks in Northland and stated that he had hopes of describing these taxa in the following year. This project never came to fruition. Till this present study the latest Cretaceous bivalves, gastropods and scaphopods of Northland remained undescribed.

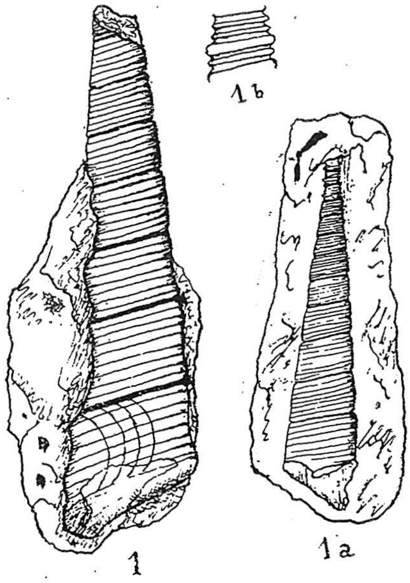
Finlay (1927) found the species name *Pecten* (*Camptonectes*) *hectori* Woods, 1917, to be preoccupied, and a new name *C. selwynensis* was designated. Speight (1927) also listed fossils from Canterbury. The next fossil to be described was the venerid bivalve *Cyclorismina woodsi* Marwick, 1927, followed by the trigoniid bivalve *Pacitrigonia sylvesteri* Marwick, 1932. In Marwick's (1944) review of New Zealand Recent and fossil Cardiidae, he described *Granocardium* (*Ethmocardium*) *woodsi* [*Cardium* sp. of Woods, 1917].

Wellman's (1959) widely cited paper on the divisions of the New Zealand Cretaceous contains a wealth of new information, including extensive faunal lists by J. Marwick and C. A. Fleming and the description by Wellman of the Haumurian (Maastrichtian) inoceramid bivalve *Inoceramus matotorus*. Fleming *in* Wilson (1963) provided lists of fossils present in the Waipara Subdivision. Speden *in* Nathan (1977) listed some poorly preserved fossils from Westland, which are the only reported Late Cretaceous macroinvertebrates from this area. The next significant works were published late the following decade; these include: Warren and Speden's (1978) classic work on the Piripauan and Haumurian stages including much biostratigraphic information, faunal lists and the first photographs of many taxa; Suggate *et al*.'s (1978) two volume work on the geology of New Zealand, including a review of the Late Cretaceous with figures and notes on various taxa; and Freneix and Grant-Mackie's (1978) paper on Late Cretaceous Cardiidae of New Zealand and New Caledonia, which included descriptions of *Austrocardium* *acherontis* and *Schedocardia*? *waiparana*. Speden *in* Wiffen (1980), Crampton (1988a) and Crampton and Moore (1990) provided extensive lists, paleoecological information and some photos of fossils from the Maungataniwha Sandstone of Hawke's Bay. Speden and Keyes (1981) illustrated key fossils earlier published by Suggate *et* *al*. (1978), but included catalogue numbers for specimens. Maxwell *in* Feldmann (1984) listed some poorly preserved molluscs from Cheviot. Crampton (1988c) provided notes on bivalve families Inoceramidae and Isognomonidae and in 1990 described beautifully preserved material of the pholadid bivalve *Pholadidea* (*Hatasia*) *wiffenae* from Hawke's Bay. The most recent works on the New Zealand Cretaceous fauna were that by Stilwell *in* Aitchison *et al*. (1993), who provided faunal lists and photographs of specimens from the Katiki Formation, collected along the Waianakarua River, North Otago, and Stilwell (1994a-b), who presented information on changes across the K-T boundary and a revision of the gastropod *Protodolium*, respectively.

Paleocene molluscan faunas of New Zealand

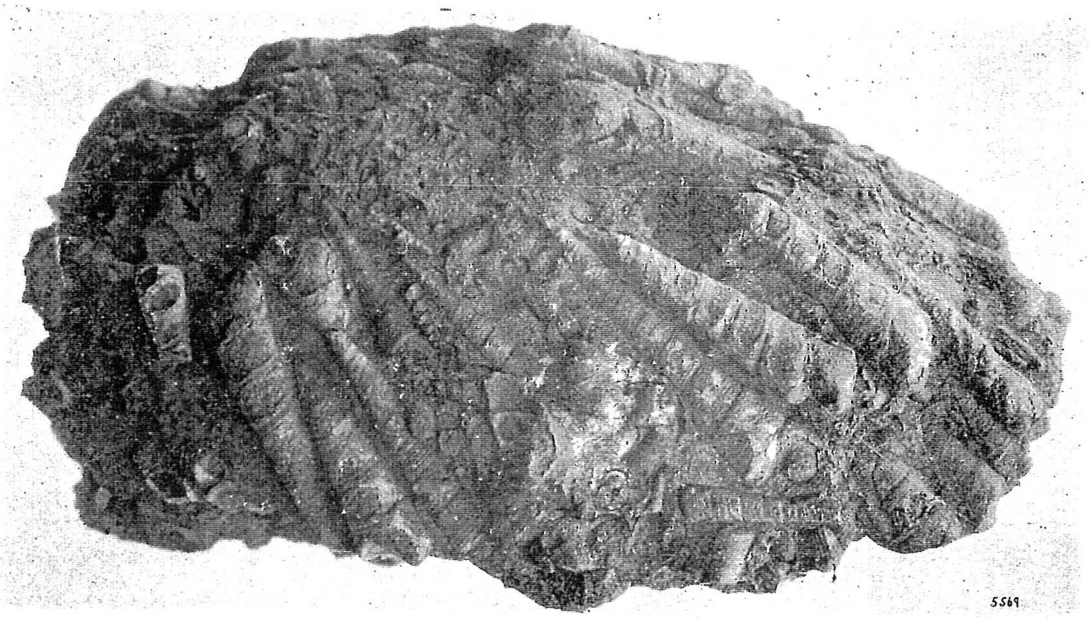
Work on the Paleocene molluscs of New Zealand began historically with a small collection of 14 specimens by former Otago Provincial Geologist J. Hector or by his assistant J. Buchanan in 1869 (possibly earlier, see comments below). Around 1860 The Otago Provincial Council tried unsuccessfully to get the Austrian geologist F. von Hochstetter to investigate finds in the late 1850s of gold-bearing deposits in Otago and conduct a geological survey of the province. The council was later successful when applying to Sir R. I. Murchison, Director of the Geological Survey of Great Britain. James Hector, a young Scotsman who was appointed to the post of Provincial Geologist, accepted the position in 1861 and arrived in Otago the following year in April to draw up a geological map of the entire province (Burton, 1965, p. 11). Fossils in the southeastern part of Otago in the Kaitangata-Wangaloa area were not collected for study until possibly as late as 1869. Speden (1965, pp. 1243-1247), in an historical note on the date of collection of fossils in southeastern Otago and Southland by J. Hector, disputed Hector's record of collecting fossils in this area south of the Clutha River in 1869 for the following reasons: 1) Hector was employed as Otago Provincial Geologist from 1862-1865, and in April of 1865, he moved to Wellington to take up the position of Colonial Geologist and Director of the Colonial Museum; 2) a date of 1865 was annotated on J. Buchanan's drawings of some fossils from southeastern South Island ("Tautuku"); 3) in Hector's personal copy of Hutton and Ulrich's (1875) book on the geology and goldfields of Otago, he wrote that fossils from Mataura Falls near the Catlin's River, southeastern Otago were "all got by Hector, in 1864" (p. 1244); evidence points to a collection of fossils by Buchanan (not Hector) between November and January 1869 between the Clutha and Mataura Rivers (fossils from Wangaloa were collected probably during these three months, but not by Hector). In 1992 I studied the original collection by Buchanan or Hector from Measly (also spelled Measley) Beach, Wangaloa, GS 280 (H46/f9500), at the Institute of Geological and Nuclear Sciences, Lower Hutt. [As an historical aside, the name Measly (also spelled Measley; Maori name "Waikaro" = mussel water) Beach is derived from an unfortunate circumstance. Ships from Sydney brought measles to New Zealand in 1835 and influenza in 1836. The Maoris along the East Coast were greatly affected by these diseases. About 1838 Tuhawaiki organised a Maori war party at Measly Beach to fight Rauparaha in the north. There were originally nine war canoes, but by the time the measles and influenza had run their course, there were not enough Maoris to man one canoe to ward off threats from Rauparaha. When Surveyor of the New Zealand Company F. Tuckett arrived in 1844 there were only six resident natives at Port Molyneux and surrounding areas (Wilson, 1912, p. 109; Waite, 1948, p. 11)]. Twelve specimens, consisting of small blocks of various numbers of specimens, are held in the IGNS collection. The most abundant mollusc at Wangaloa, Zeacolpus (Leptocolpus) semiconcavus (Suter, 1911), is curiously absent from the collection. Specimens collected include many individuals of Colposigma mesalia Finlay and Marwick, 1937; Campylacrum sanum Finlay and Marwick, 1937; Ledina *taioma* (Finlay and Marwick, 1937); ?*Limopsis* (*Limopsista*) *microps* Finlay and Marwick, 1937; *Marwickia parthiana* (Marwick, 1927); ?*Dosinia* (*Dosinobia*) *perplexa* (Marwick, 1927); ?*Panopea* n. sp.? aff. *P*. *worthingtoni* Hutton, 1873c; and *Antalis multistricta* (Finlay and Marwick, 1937). Although overlooked by most later workers, F. W. Hutton (*in* Hutton and Ulrich's 1875 classic work on the geology of Otago), was the first to provide a list of fossil molluscs from Wangaloa (see tables pp. 59-61 and Hutton, 1886). Hutton identified "*Dentalium laevis*, Hutton" (= *Antalis multistricta*); "*Natica zealandica*, Quoy" (= probably *Polinices* (*Polinella*) *finlayi* (Marwick, 1924b)); "*Turritella rosea*, Quoy" (= *Zeptocolpus* (*Leptocolpus*) *semiconcavus* (Suter, 1911)); "?*Chione vellicata*, Hutton" (= *Purpurocardia fyfei* (Finlay and Marwick, 1937); "*Cucullaea* sp." (either *Cucullaea* (*Cucullona*) *inarata* Finlay and Marwick, 1937 or *C*. (*Cucullastis*) *barbara* Finlay and Marwick, 1937); "*Pectunculus laticostatus*, Quoy" (= ?*Glycymerita concava* (Marshall, 1917)); and "*Pectunculus globosus*, Hutton" (= ?*Limopsis* (*Limopsista*) *microps* Finlay and Marwick, 1937). The significance of the dash in Hutton's table corresponding to "*Turritella bicincta*, Hutton" at Wangaloa is uncertain and may represent a typographical error (p. 60). Apparently, no further collections were made at Wangaloa until 1891 when Hector returned there and collected 373 specimens (Thomson, 1913, p. 84). Forty-two years after the first collection by Buchanan at Wangaloa, Suter (1911) was the first to describe a Paleocene mollusc from New Zealand, the turritellid gastropod *Zeacolpus* (*Leptocolpus*) *semiconcava* [*Turritella*] from Measly Beach (Figures

6-7 herein). Marshall (1916b, 1917) was the first to describe the Wangaloa molluscs in any detail. His 1916 paper consisted of descriptions of four new gastropod species, Conchothyra australis [Pugnellus] from Wangaloa and three species of Superstes [Avellana]. Only C. australis now is considered to be Paleocene in age (Note: Marshall thought that the close similarity of C. australis to C. parasitica indicated a Cretaceous age for the former). Suter in Marshall (1916a) provided the first extensive faunal list of 49 species from Wangaloa. The following year Marshall (1917) wrote a more substantial paper on fossils from Wangaloa, comprising descriptions of 25 taxa, 24 of which were considered to be new. About 1914 C. T. Trechmann made a collection of fossils from Wangaloa while on a visit to New Zealand, but figured only one species, C. australis [Pugnellus], in his paper mostly on Cretaceous gastropods of New Zealand (1917), because P. Marshall was already working on the fauna. The same year P. G. Morgan (1917), in a note on presumed Tertiary fossils, advocated an Eocene age for the fauna at Wangaloa. Notes on the fauna were also presented by Thomson (1917). Suter (1921) published extensive faunal lists of previous collections based on fossils from Wangaloa, namely those by J. Hector in 1891, J. Park in 1912 and M. Ongley in 1917. Below each list of fossils from the various collections, Suter gave Lyellian percentages (proportions of Recent taxa divided by the total number of taxa). Suter (ibid, p. 97; Finlay and Marwick, 1937, p. 4) also stated that R. B. Newton, lately of the British Museum, was sent a collection of fossils from Wangaloa and Castle Hill Shaft in 1919 for examination and eventually a report. No



Figs. 1, 1*a*. *Turritella semiconcava.*
Fig. 1*b*. Post-nuclear whorl.

Figure 6. First illustrations of Paleocene fossils, Zeacolpus (Leptocolpus) semiconcavus (Suter, 1911), of New Zealand. Figures 1, Holotype TM 4475 (IGNS), Wangaloa; 1a-b, Paratype TM 4476 (IGNS), Wangaloa.



Turritella semiconcava.

Figure 7. First photograph of Paleocene fossils of New Zealand by Suter (1911, Pl. 30). Block of Zeacolpus (Leptocolpus) semiconcavus specimens from Wangaloa showing some current alignment.

report was ever published by Newton due to pressures of other projects and the fossils were eventually returned to New Zealand (E. Marsden *in* Finlay and Marwick, 1937, p. iii). Brief mentions of the "Wangaloan" fauna were made by Morgan (1918), Thomson (1920), Vaughn (1921), Reed (1921), Cox (1930), and Davies (1934) (Finlay and Marwick, 1937, p. 4). Marshall and Murdoch (1923) in a review of *Lahillia* in New Zealand described *L. neozelanica*. Unfortunately, two of the three figured specimens ascribed to *L. neozelanica* are not conspecific. These figured specimens represent a different species, *Marwickia parthiana* (Marwick, 1927) [*Finlaya*], described formally four years later. Because Marshall and Murdoch did not choose a type, the species named *neozelanica* is conserved. Marwick (1924b) in his review of the Naticidae of New Zealand, described six new species from Boulder Hill and Wangaloa. The described naticids from Boulder Hill represent the first recorded fossils from this locality, which was discovered by H. E. Fyfe in 1920.

The classic monograph on the Wangaloan molluscan faunas of New Zealand by Finlay and Marwick (1937) could be viewed as one of the most important New Zealand paleontological contributions and the most significant work on the Danian (Paleocene) of the southern hemisphere to date. Twenty-two bivalve, 68 gastropod and 2 scaphopod species were described by Finlay and Marwick, including 30 new genera and subgenera.

From 1938 to the present few systematic papers on "Wangaloan" taxa have been published, although around the world the "Wangaloan" fauna has received wide attention. Marwick (1944) described *Nemocardium* (*Pratulum*) *modicum*. In a review of the Notocenozoic or Cretaceo-Tertiary of New Zealand, Cotton (1954, 1955) discussed the age and biostratigraphic significance of the "Wangaloan" fauna. The significance and age of "Wangaloan" fauna was also discussed by Hornibrook and Harrington (1957). A list of fossils from localities not included in Finlay and Marwick's work was given by C. A. Fleming *in* Harrington (1958). Robinson (1958; unpublished M. S. thesis) commented on probable "Wangaloan" taxa in the Taieri Mouth area. A short list of important "Wangaloan" taxa was made by Wellman (1959). Daniel (1961) listed "Wangaloan" fossils collected from the Dunedin area. Fleming (1966) refigured all of the "Wangaloan" taxa drawn by J. Marwick. Scott *in* Gage (1970) listed a few possible "Wangaloan" taxa from Broken River, Canterbury. Suggate *et al*. (1978) commented on and figured important "Wangaloan" taxa and Speden and Keyes (1981) refigured key "Wangaloan" taxa from their work. Recent discussions of the "Wangaloan" fauna have been presented by Zinsmeister (1979, 1982, 1984), Zinsmeister and Camacho (1980), Thornton (1985), Stevens (1989), Beu and Maxwell (1990), and Stilwell and Zinsmeister (1992). Brief mention of this fauna was given by Lindqvist (1986) and Lindqvist and Douglas (1987). In a review of Inoceramidae and Isognomonidae, Crampton (1988c) described the inferred "Wangaloan" species *Isognomon* (*I*.) *wellmani* from the Castle Hill Basin, Canterbury. The most recent contributions to our knowledge of New Zealand Paleocene molluscs are those of Beu and Maxwell (1990), who redescribed and refigured key taxa and Stilwell (1993), who described three new taxa, *Leionucula palaioanaxea*, *Pyropsis* zinsmeisteri and Wangacteon grebneffi (new genus, new species). Paleocene types are housed at the Institute of Geological and Nuclear Sciences (IGNS), Auckland Institute and Museum (AIM), Otago Museum (OM), University of Otago Geology Department (OU), and Natural History Museum, London (BMNH).

Paleoecology

Published paleoecological research on the latest Cretaceous and Paleocene molluscan faunas of New Zealand is sparse. Warren and Speden's (1978) widely used table on inferred life habits of Cretaceous molluscs (including 64 species of bivalves, gastropods and scaphopods) from Haumuri Bluff is a valuable source of paleoecological information, but in this work only 40% of the taxa recorded in the present work are covered. Evans (1985) provided the first account of the paleoecology of latest Cretaceous molluscs from Kaipara, Northland and identified the fossils at genus-level, family-level or as uncertain. Six faunal associations were recognised in his work, namely 1) Nucula-Nuculana-Natica association; 2) inoceramid-ostreid association; 3) ammonite association; 4) rhynchonellid association; 5) Thyasira association; and 6) Perissoptera association. Crampton (1988a) produced a faunal list (including 18 taxa of bivalves and gastropods) of Late Cretaceous fossils from northern Hawke's Bay, North Island, citing relative abundance and inferred life habits. Crampton and Moore (1990) included a lengthy appendix of paleoecological data on 67 Late Cretaceous taxa from the Maungataniwha Sandstone of Hawke's Bay. They included information on inferred relation to substrate, mode of attachment, whether siphonate or asiphonate, burrowing depth, mobility and feeding strategy. A reconstruction of the newly described New Zealand Late Cretaceous boring pholadid bivalve Pholadidea (Hatasia) wiffenae Crampton, 1990, was given in Crampton's paper. In a recent review and taxonomic revision of the Late Cretaceous gastropod Protodolium Wilckens, 1922, Stilwell (1994b) reassigned this genus from carnivorous Tonnidae to herbivorous Neritopsidae. Cretaceous species of Protodolium were interpreted by Stilwell to be epifaunal herbivores in the littoral to sublittoral zone. Inferred feeding habits of all 329 latest Cretaceous and Paleocene molluscs of New Zealand are presented in Tables 1-2.

Minimal comment has been published on the paleoecology of Paleocene molluscs from New Zealand. The monograph on Cenozoic Mollusca of New Zealand by Beu and Maxwell (1990) is the only collective source of information on Paleocene molluscs, although the information is scattered throughout their work. It should be stated that P. A. Maxwell's monographs (1988b, 1992) on Miocene and Eocene molluscan faunas are also important sources of information applicable to Paleocene molluscs, as some Paleocene genera are found to be in common with various taxa in these works.

Paleobiogeography

The paleobiogeographic significance of the Late Cretaceous and early Paleogene molluscan faunas of New Zealand has been commented on by various workers, but a comprehensive study has yet to be accomplished (see notable contributions by Woods, 1917;

Wilckens, 1920, 1922, 1926; Benson, 1923; von Ihering, 1925; Finlay and Marwick, 1937; Fleming, 1949, 1962, 1963, 1975, 1979; Freneix, 1956, 1958, 1980, 1981; Sohl, 1964; Kauffmann, 1973; Zinsmeister, 1979, 1982; Clark and Crame, 1989; Stevens, 1989; Stilwell, 1991, 1994a; Stilwell and Zinsmeister, 1992; Darragh, in press). Of the latter references, Zinsmeister (1979, 1982) provided the first paleobiogeographic syntheses of the Late Cretaceous-early Paleogene molluscan faunas of the southern rim of the southern circum-Pacific. Preliminary analyses of changes in composition of the Late Cretaceous-early Paleogene molluscan faunas using 605 genera from around the southern circum-Pacific and faunal changes across the Cretaceous-Tertiary boundary in New Zealand were given by Stilwell (1991 and 1994a) respectively.

BIOSTRATIGRAPHY

Comprehensive biostratigraphic reviews of Upper Cretaceous and lower Paleogene rocks of New Zealand were presented by Finlay and Marwick (1947), Wellman (1959), Hornibrook (1962) and Suggate et al. (1978). Only a short review of the biostratigraphy will be presented here. In addition, data collected during the course of this investigation and information from key papers published before/after Suggate et al will be given. Refer to Figures 8-9 for maps of New Zealand depicting all Late Cretaceous and Paleocene fossil localities referred to in the text in terms of their particular NZMS 260 metricated 1:50,000 map sheets. See also maps (Figures 2, 99) showing particular fossil localities mentioned in the text. Appendix A provides full details on fossil localities and collections.

Distribution of Late Cretaceous faunas

Uppermost Cretaceous (Campanian?-Maastrichtian) rocks containing molluscan faunas extend from the northern reaches of Northland, North Island to southeastern Otago, South Island (see field photos, Figures. 10-27). Latest Cretaceous fossils have been collected in the northern tip of North Island, represented by map sheets:

N02 (e. g. Parenga Wharf, Motupia Island, Parengarenga Harbour),
R10 (e. g. Hauraki Gulf).

In northwestern Northland many new inferred Maastrichtian species have been described in this thesis that have been hitherto unrecorded, represented by sheets:

O04 (e. g. Taipa Estuary),

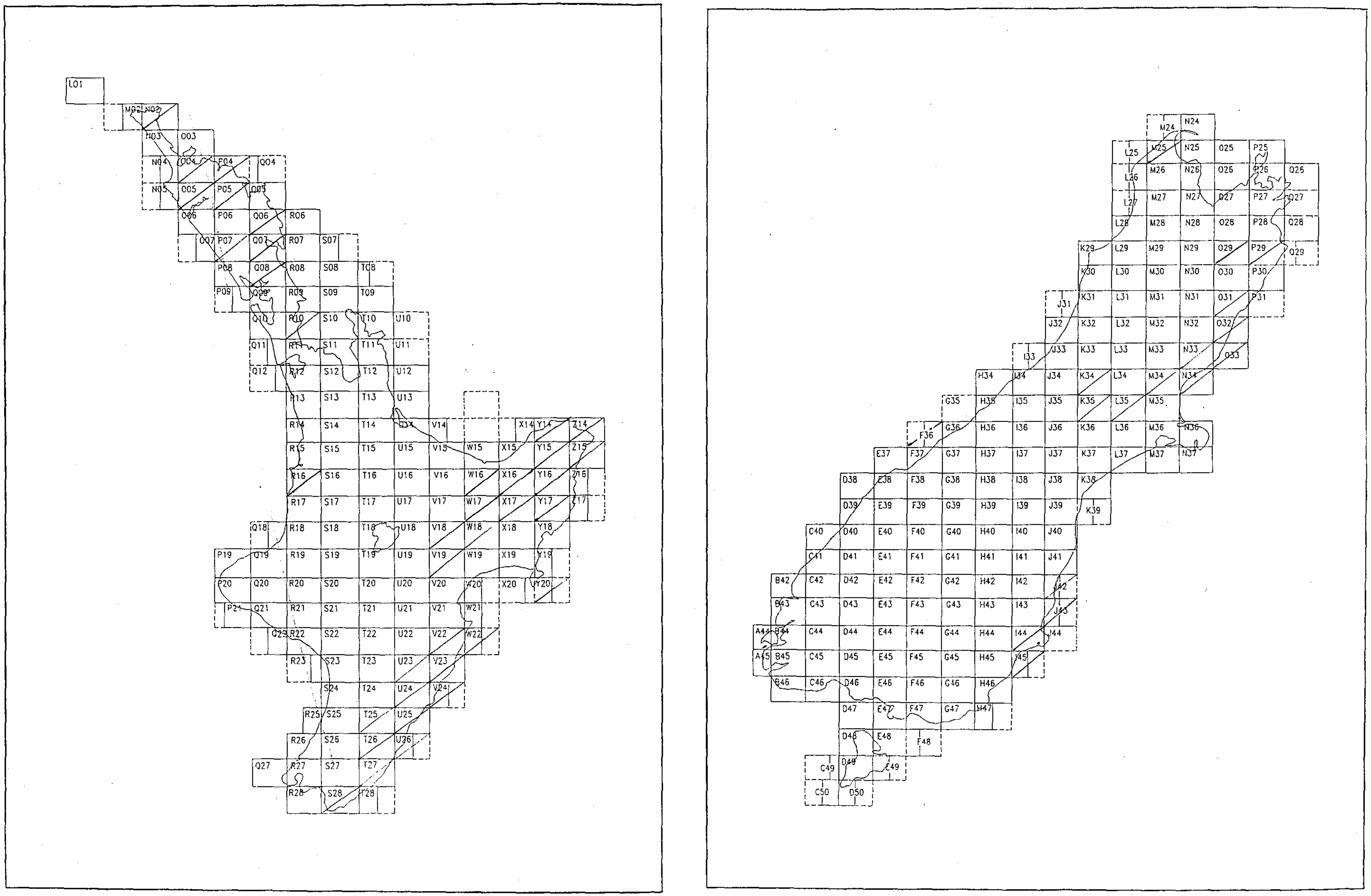


Figure 8. Map of New Zealand showing all latest Cretaceous (Campanian? to Maastrichtian) fossil localities in North and South Islands referred to in the text in terms of their NZMS 260 1:50,000 map sheet areas. Fossil localities are present in map sheets denoted by diagonal lines.

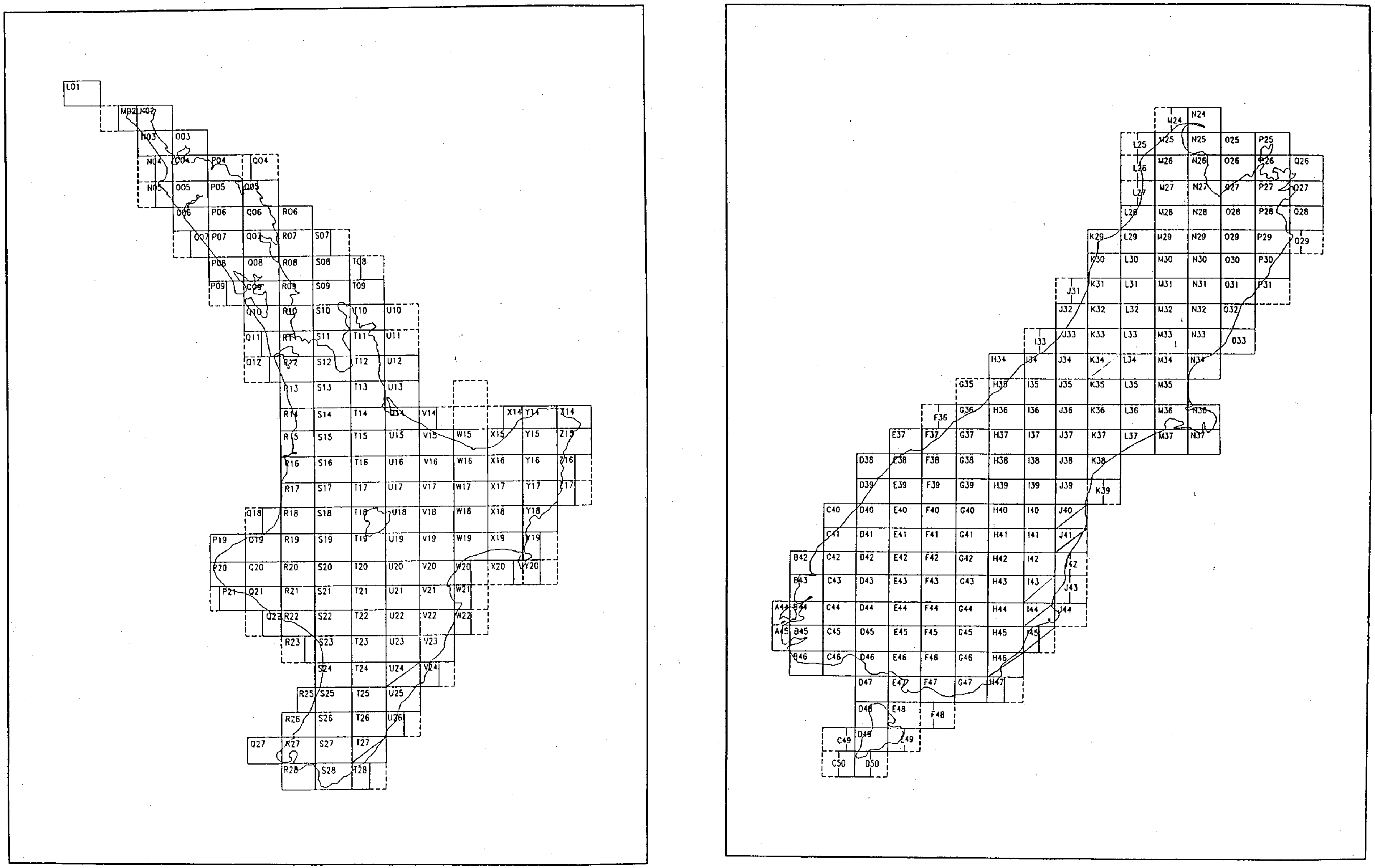


Figure 9. Map of New Zealand showing all Paleocene (Danian to Thanetian) fossil localities in North and south Islands referred to in terms of their NZMS 260 1:50,000 map sheet areas. Fossil localities are present in map sheets denoted by diagonal

Figure 10. Bull Point, Kaipara, Northland. Grid reference: Q08/263548. Unit IV of Evans (1985), "Northland Allochton", Maastrichtian. All photos were taken by J. D. Stilwell unless stated otherwise.

Figure 11. Promontory between Te Opu and Whakapirau Creeks, Kaipara, Northland. Grid reference: Q08/263583. Unit IV of Evans (1985), "Northland Allochthon", Maastrichtian.

Figure 12. Matakohe Arm, Kaipara, Northland. Grid reference: Q08/187622. Unit IV of Evans (1985), "Northland Allochthon", Maastrichtian.

Figure 13. Haumuri Bluff, southern Marlborough.

Figure 14. Macrofossils in Okarahia Sandstone (Campanian?), Haumuri Bluff. Grid reference: O32/c.51455065.

Figure 15. Inoceramus australis Woods, 1917, in Tarapuhi Grit (Maastrichtian), Haumuri Bluff. Grid reference: O32/c.51455065.

Figure 16. Macrofossiliferous horizons in Okarahia Sandstone (Campanian?), Haumuri Bluff. Grid reference: O32/c.51455065.

Figure 17. Boby's Creek Gorge, Waipara, North Canterbury.

Figure 18. Ostreid bioherm, comprised mostly of Crassostrea sp., at Oyster Hill, Malvern Hills, Canterbury. Selwyn Rapids Beds (= Conway Formation?). Grid reference: L35/217463.

Figure 19. Conchothyra parasitica Hutton, 1877, beds of Waimakariri Gorge, Canterbury. Two main beds c. 0.5 m thick are present, separated by laminated to massive, soft, grey sandstone. Conway Formation (Maastrichtian). Grid reference: L35/245692.

Figure 20. The author, J. D. S., studying the main Conchothyra bed shown above in Figure 19. Same grid reference. Photograph courtesy of R. E. Fordyce.

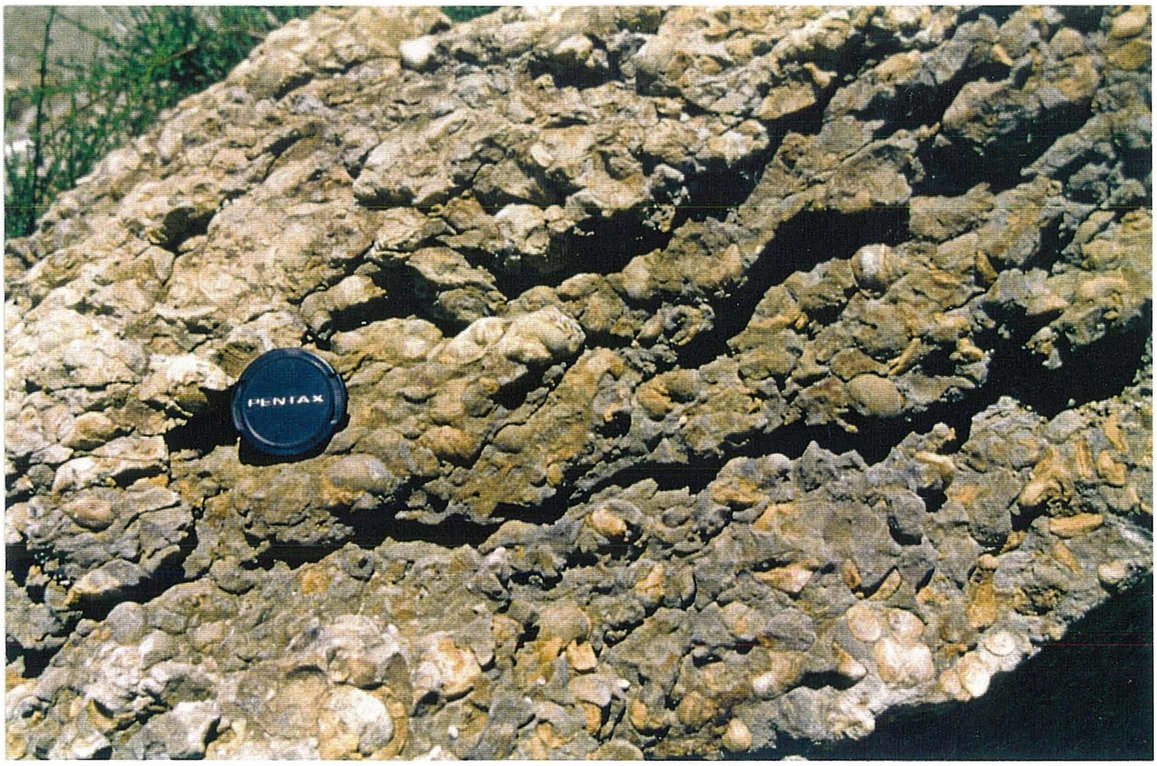


Figure 21. Close-up of main Conchothyra bed showing closely packed, randomly oriented, adult shells of C. parasitica. Other fossils are rare. The assemblage is inferred here to be parautochthonous. Same grid reference as Figure 19.

Figure 22. View of Conchothyra beds along strike showing lateral continuity. J. D. S. in foreground and P. A. Maxwell in background. Same grid reference as Figure 19.

Figure 23. Waianakarua River cliff section of uppermost Cretaceous marine rocks of lower Katiki Formation and Otepopo Greensand (boundary of two units in middle of cliff at top of very light sandstone), overlain by Wanganui Series gravels, North Otago. Grid reference: J42/363483.

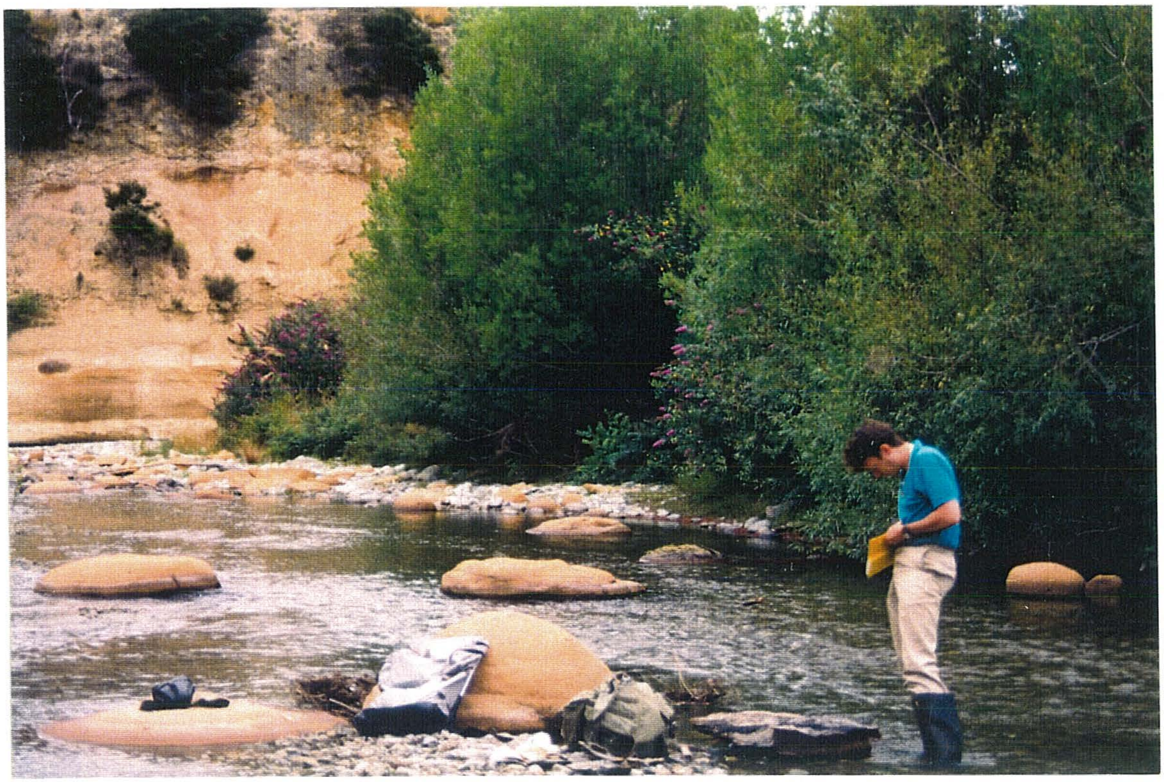


Figure 24. Fossiliferous concretionary sandstone of Katiki Formation (Maastrichtian) in creek bed, North Branch, Waianakarua River. Photograph of J. D. S. courtesy of J. D. Campbell. Grid reference: J42/359484.

Figure 25. Large fossiliferous concretions in Katiki Formation in North Branch, Waianakarua River. J. D. Campbell studying concretion. Grid reference: J42/35754850.

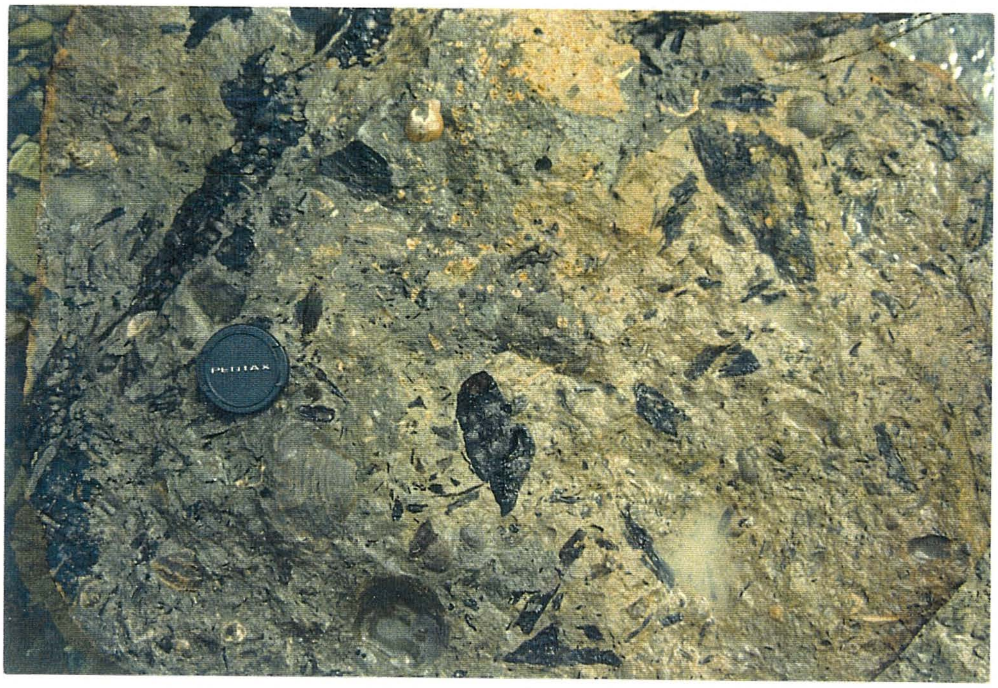


Figure 26. Section of in situ concretion shown in Figure 24. Fossils include abundant carbonaceous material, Leionucula suboblonga (Wilckens, 1905), Pacitrigonia hanetiana (d'Orbigny, 1842), Eriphyla meridiana Woods, 1917, Lahillia aotearoa n. sp., and ?Costacolpus solitaria (Wilckens, 1922). Grid reference: J42/359484.

Figure 27. Fairfield Quarry section, Dunedin, Otago. Taratu Formation (Ta), Wangaloa Formation (Wa); Fairfield Greensand (Fa); Saddle Hill Siltstone (Sa); Steel Greensand (St); Quarries Siltstone (Qu), informal name of MacMillan (1993) (Maastrichtian), Abbotsford Formation (Ab) (Paleocene-Eocene), and colluvium (co). Grid reference: I44/c. 085762.

O05 (e. g. Hokianga River, Kawaka Peninsula),

P07 (e. g. Tangowahine Stream),

Q08 (e. g. many richly fossiliferous localities in the Kaipara Harbour region including Bull Point, Paparoa River, Matakohe River, Te Opu Creek, Whakapirau Creek, Gittos Point, Booboo Stream).

Northeastern Northland localities include sheets:

P04 (e. g. Whangaroa Harbour),

P05 (e. g. Okaihau, Waikaraki Stream, Waitangi River),

Q06 (e. g. Hukerenui Survey District),

Q07 (e. g. near Onemama Point).

On the west coast of North Island, a small region represented by sheet:

R16 (e. g. Te Waitere Coast), has sparse fossils.

In the region of Raukumara Peninsula, northeastern North Island, molluscs have been recorded from localities within map sheets:

W16 (e. g. Oponai and Waiata streams, Waiiti River),

W17 (e. g. upper Anini Stream),

X16 (e. g. several localities including Logging Road, Whakamaria Stream, Mangatu River, Mangaotane/Te Rata Stream, Motu River, Mangatu River, Birch Hill Road, Te Whaka Stream, Waitangarua Stream),

X17 (e. g. Ron Stream),

Y14 (e. g. Orete Point, Rewatu Stream, Waikahau Stream),

Y15 (e. g. Mata River, Waiorongomai River, Raparapaririki Stream),

Y16 (e. g. Gorge Stream, Tikihore Stream, Te Weraroa Stream, Te Rata, Waitahaia Stream),

Y17 (e. g. Mangakuri Stream),

Y20 (e. g. Taiporutu Stream),

Z14 (e. g. Totaurangakautuku River, Clarke River),

Z15 (e. g. Mangaoporo River, Mangarua Creek, Tapuroa River, Ford Creek).

The Hawke's Bay region of eastern North Island has diverse molluscan assemblages, represented by sheets:

V18 (e. g. Waiau River),

V19 (e. g. Mangahouanga Stream, Te Hoe River),

V22 (e. g. Waipawa River),

V23 (e. g. Outside Survey District),

V24 (e. g. Porangahau),

W18 (e. g. Waikokopu Stream, Waihoroihika, Orakei Stream, Ruatahuna Stream, Mimiha Stream), W22 (e. g. Waimarama).

Southern North Island localities are found in sheets:

S28 (e. g. Pukemuri Stream),

T25 (e. g. Makirikiri Stream),

T26 (e. g. Waihora Stream, Rewa Rewa Stream, Makirikiri Stream, White Creek, Tinui, Motuwaireka Stream, Mangapokia Stream, Ngaiana Stream),

T27 (e. g. Mangapiuiti, Nagaumu State Forest, Kowhai Stream, Kaiwhata River, Waihingaia Stream),

U23 (e. g. Mangawarawara),

U24 (Tangaruhe Stream, Waimata River, Mangaorapa Stream, Mangaotakito Stream),

U25 (e. g. Waipara Stream, Akitio River, Waipaua Stream, Pongaroa, Owahanga River, Mataikona River, Pakowhai River, Waimata River, Marauhika Stream, Takiritine Stream), U26 (e. g. south of Castle Point, Mangapakeha, Mt. Percy).

Northeastern South Island has few localities, represented by sheet M25 (Paturau River, near Golden Bay).

The province of Marlborough yields significant assemblages of fossils which are amongst the first recorded by early geologists last century; map sheets include:

P29 (e. g. Nidd Stream, Lulworth Stream, Ess Creek, Mirza Creek, Ess Gully, Waddy Creek, Glenfield Stream),

O29 (e. g. Ribble River),

O31 (e. g. Kaikoura Peninsula),

O32 (e. g. Haumuri Bluff area).

Canterbury Province also has important molluscan assemblages, represented by sheets:

O33 (e. g. Manuka Bay, Cheviot, Kapuka River),

K34 (e. g. Castle Hill Basin (formerly known as Trelissik Basin)),

K35 (e. g. Acheron River),

L35 (e. g. Selwyn River, Oyster Hill, Malvern Hills, Waimakiriri River),

M34 (e. g. Grey River, Middle Waipara, McKay's Creek, Boby's Creek, Weka Creek, Birch Hollow),

N33 (e. g. Mt. Stych, Lowry Peaks, Kaiwara River),

N34 (e. g. Gorries Creek, Boby's Creek, Waipara River).

Fossil localities in Otago are predominantly along the east coast and include sheets:

I44 (e. g. Brighton area, Fairfield Quarry, Saddle Hill),

I45 (e. g. near Taieri River mouth),

J42 (e. g. Moeraki, Waianakarua River),

J43 (Shag Point, Pukeiwitahi).

Zonation of Late Cretaceous faunas

Incomplete knowledge of stratigraphic ranges of particular mollusc taxa in the New Zealand Late Cretaceous record, the isolated nature of some important fossil localities with respect to key reference sections, facies restricted faunas, paucity of microfossils, and rarity of biostratigraphically important index species result in significant correlation problems from one locality to another in New Zealand. Furthermore, the strongly provincial nature of New Zealand Late Cretaceous and early Paleogene molluscan faunas hampers international stratigraphic correlation. Excellent recent papers on New Zealand Late Cretaceous microfossil biostratigraphy (e. g. Wilson, 1992a; Hollis, 1993) shed little light on ages of key macrofossil localities such as Haumuri Bluff, Selwyn Rapids, and Hawke's Bay because macrofossils are rare or poorly preserved in their studied sections in eastern Otago and Marlborough. At present, it is virtually impossible in the field or laboratory to establish whether certain molluscan faunules (e. g. Waianakarua River, Shag Point, Selwyn Rapids, Waimakiriri River, Mangahouanga Stream, and Te Hoe River) are Piripauan (Campanian?) or Haumurian (Maastrichtian) in age (Figure 28). See Figure 30 (this work) for the New Zealand Upper Cretaceous - lower Paleogene lithostratigraphic and chronostratigraphic nomenclature with tentative international time correlations.

The Piripauan and Haumurian stages (and their deficiencies) were reviewed in detail by Warren and Speden (1978). The boundary of the Piripauan and Haumurian stages was placed

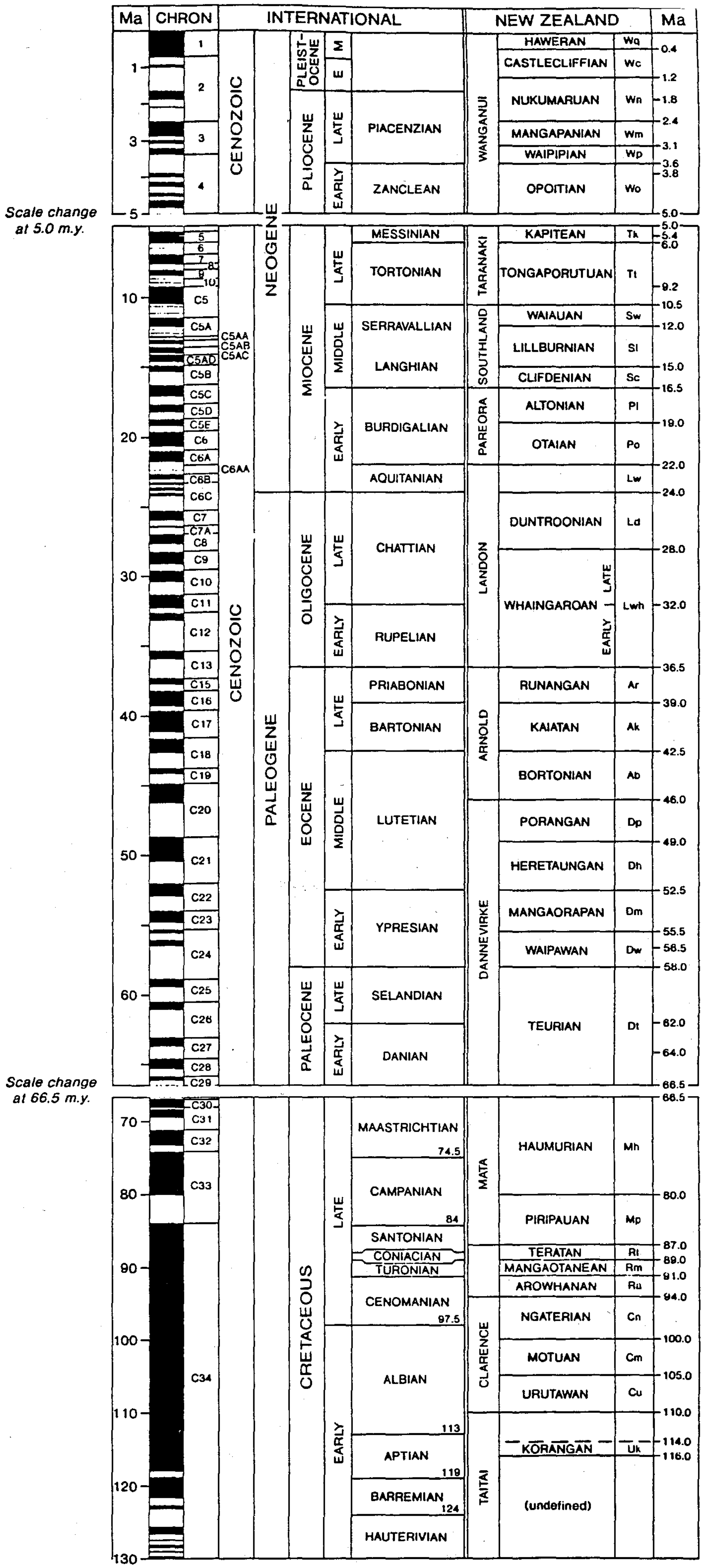


Figure 28. New Zealand Cretaceous-Cenozoic timescale showing stages, series and symbols, and absolute age, magnetostratigraphy (chron) and international stage correlations (from Campbell et al., 1993), based on interpretations by Edwards et al., 1988).

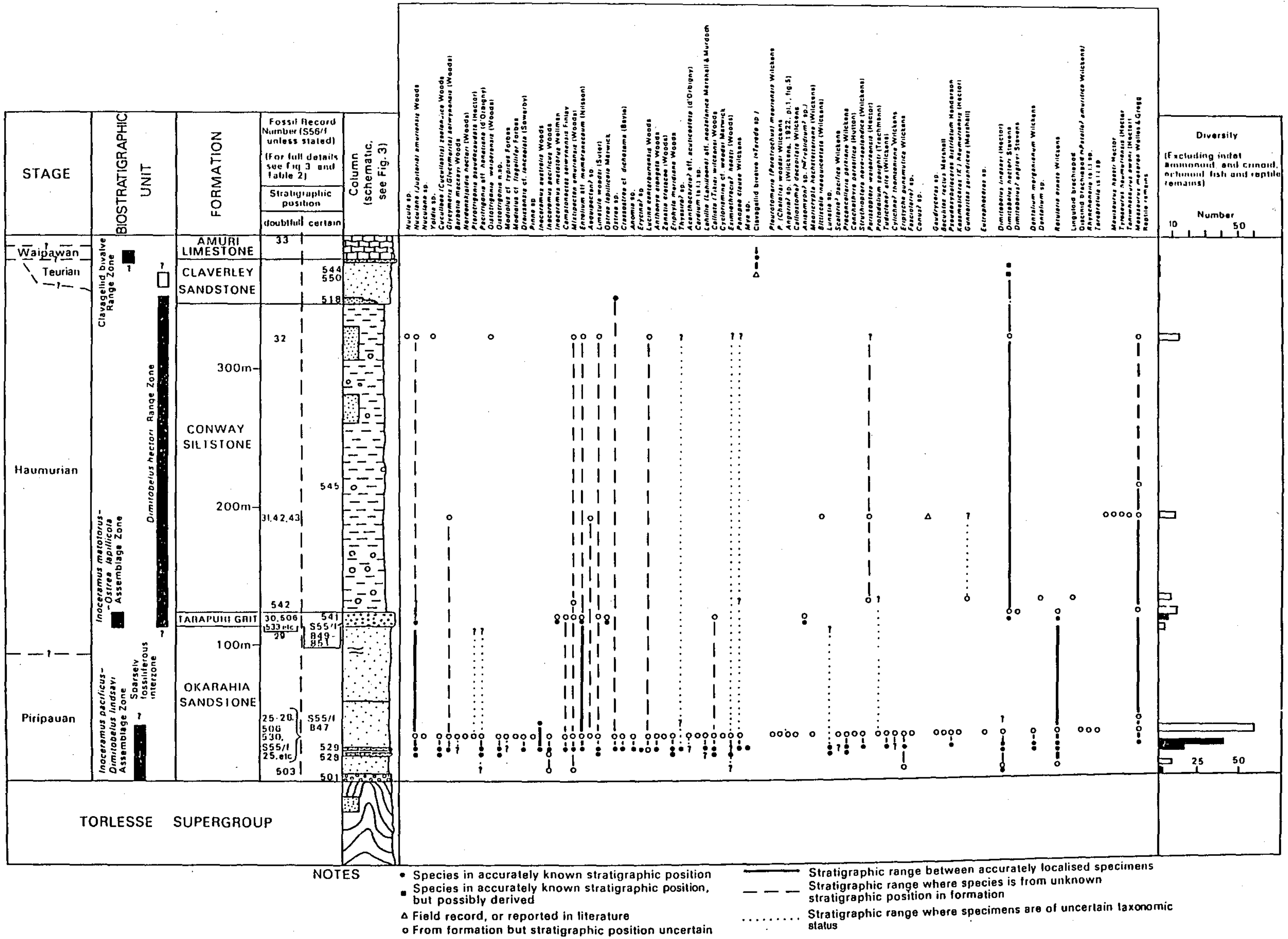


Figure 27 Recorded stratigraphic ranges of macrofossil species, north face of Haumuri Bluff.

*As *Dimitobelus hectori* occurs in the type section of Claverley Sandstone, a solid circle should replace the small dot shown.

†The upper part of the Claverley Sandstone, the Teredo Limestone Member, is Waipawan in age. Consequently, the base of the Waipawan in the "Stage" column should be 2-3 mm lower than shown.

Figure 29. Recorded stratigraphic ranges of macrofossil species, Haumuri Bluff (Warren and Speden, 1978, Fig. 27). Refer to Table 1 and Systematic Paleontology (this work) for proposed new combinations.

International		
Ma	Epoch	Age
58 62	early Paleogene	Danian - Thanetian
66.5	Late Cretaceous	Maastrichtian
74.5		Campanian
84		

New Zealand Divisions		
Series	Stage	
Dannevirke	Teurian	Dt
	"Wangaloan"	"Dwg"
Mata	Haumurian	Mh
	Piripauan	Mp

Local formations						
Otago	Canterbury	Marlborough	Wairarapa	Hawkes Bay	South Auckland	North Auckland
Wangaloa; Steel Greensand; Abbotsford; Kauru; Taratu	Amuri Limestone; Broken River; Kauru; Waipara Greensand	Amuri Limestone; Claverley Sandstone	Waipawa Black Shale	Whangai	Wanstead?; Whangai	unnamed unit in "Northland Allochthon"
Abbotsford; Brighton; Katiki; Herbert; Otepopo Greensand; Wangaloa Taratu	Selwyn Rapids; Conway; Broken River	Amuri Limestone; Conway; Tarapuhi Grit	unnamed ?	Maungataniwha Sandstone (Tahora Fm.)	Whangai; Tapuwaeroa	unnamed unit in "Northland Allochthon"; Punakitere Sandstone; Otamatea beds
No rocks of this age?	No rocks of this age?	Okarahia Sandstone; Paton Sandstone	Tongaruhe Fm.	Maungataniwha Sandstone (Tahora Fm.); Tongaruhe Fm.	No rocks of this age?	unnamed unit in "Northland Allochthon"

Figure 30. New Zealand Campanian to Thanetian Stages, International Equivalents and Main lithostratigraphic units.

tentatively in the upper part of the Okarahia Sandstone about 100 m above the base of the unit which rests unconformably on older Mesozoic Torlesse (Triassic?-Jurassic?) rocks (see Warren and Speden, 1978, p. 46, Fig. 27; Figure 29 herein). These authors erected four biostratigraphic units (*Inoceramus pacificus* - *Dimitobelus lindsayi* Assemblage-zone, *Inoceramus matotorus* - *Pseudoperna lapillicola* [*Ostrea*] Assemblage-zone, *Dimitobelus hectori* Range-zone, and Clavagellid bivalve Range-zone) and attempted to relate these to current stage nomenclature. The reference sections of these zones are on the north face of Haumuri Bluff, southern Marlborough. As stated by Warren and Speden (1978, p. 39) "The paucity of macrofossils through most of the section and the incompleteness of the exposures mean that the stratigraphic range of most zones is poorly known. The scheme suggested can be no more than a starting point for a badly needed local, regional, and national study of the distribution and usefulness of biostratigraphic units in this part of the column." These authors stated that 48 of the species are restricted to the *I*. *pacificus* - *D*. *lindsayi* Zone in the Okarahia Sandstone of Haumuri Bluff, which is both the reference section of the assemblage zone and also type section. Interestingly enough, species Warren and Speden listed as restricted to this zone (e. g. *Pacitrigonia* aff. *hanetiana*, *Mixtipecten amuriensis*, *Entolium membranaceum*, *Eriphyla meridiana*, *Dentalium* (*Laevidentalium*) *morganianum*) either are present in localities elsewhere in New Zealand inferred to be Haumurian (Maastrichtian) in age or are known to have have closely related species in inferred Maastrichtian rocks outside New Zealand. For example, *Pacitrigonia* n. sp.? cf. *P. hanetiana* and *Entolium membranaceum* are recorded from Bull Point, Kaipara, Northland in beds referred to as Unit 4 of "Northland Allochthon" by Evans (1985); ammonites and microfossils from the latter unit indicate a Haumurian age (Henderson, 1970; Webb, 1971). In Europe *E. membranaceum* ranges from lower Campanian to Maastrichtian (Dhondt, 1985a), so is probably not a good age indicator. *Mixtipecten amuriensis* is closely related to *M. chilensis* (d'Orbigny) from the Maastrichtian of Chile. *Eriphyla meridiana* is present in inferred Haumurian rocks in the vicinity of Shag Point. Away from the type section of the Okarahia Sandstone, the name bearers of this zone, *I. australis* and *D. lindsayi*, are either absent, rare, difficult to identify or fragmentary at many localities (J. D. S., pers. obs.). *Anthonya elongata*, also restricted to the *I. australis* - *D. lindsayi* zone at Haumuri Bluff, has been identified in Haumurian rocks of Kaipara, Northland. Other taxa identified during the course of this investigation in rocks of Kaipara, Northland include *Eriptycha punamutica* and *Cylichnania thomsoniana*; these taxa were previously identified by Warren and Speden (1978) only from the lower part of the Okarahia Sandstone in the *I. australis* - *D. lindsayi* Zone. Based on ammonites, Henderson (1970) stated that the age of the Okarahia Sandstone is probably Campanian to Maastrichtian, but the presence of *Kossmaticeras* s. s. suggests an age potentially as old as Santonian.

Warren and Speden (1978) concluded that there is good evidence to correlate internationally the upper part of the

Haumurian Stage with the Maastrichtian and "weaker" but "reasonable" support for correlating the Piripauan Stage with the Campanian (p. 48). It is suggested here that the claim of a possible Campanian age for the Okarahia Sandstone be re-examined in light of discovery of many so-called "restricted" taxa in the Okarahia Sandstone in younger strata elsewhere in New Zealand. In a recent abstract on Late Cretaceous inoceramids Crampton (1994) suggested that the Piripauan be correlated with the Santonian rather than the Campanian, based on similarities of *Inoceramus australis* with a Late Coniacian Japanese species, *I*. (*C*.) *kawashitai*. The danger here is correlating rocks and basing ages using single groups, especially since many macroinvertebrate taxa display marked heterochroneity (see Zinsmeister and Feldmann, 1984; Clarke and Crame, 1989). If Crampton's correlations are correct, the Haumurian may have spanned approximately 20 million years! Perhaps resistant microfossils such as dinoflagellates, which have been found to be extremely useful in correlating Upper Cretaceous and lower Paleogene rocks of the Dunedin area (Wilson, 1992a-b), should be utilised in other key areas.

Distribution of Paleocene faunas

Macrofossiliferous Paleocene rocks are much less extensive in New Zealand than uppermost Cretaceous rocks. However, Paleocene rocks are more widespread than previously recorded (see map of New Zealand depicting all fossil localities referred to in the text in terms of their NZMS 260 1:50,000 map sheet areas; Figure 9 herein). See field photos Figures 31-49. Paleocene macroinvertebrates are rare in North Island, a few localities being recorded on sheets U24 (e. g. Wimbledon in southern Hawke's Bay) and T27 (e. g. Kaiwhata River in southeastern-most North Island).

In South Island, Paleocene molluscs have been recorded in several areas represented by map sheets:

K34 (e. g. Broken River area in Castle Hill Basin in Canterbury),
J40 (e. g. southern Waihao River in South Canterbury) (this work),
J41 (e. g. Raupo Creek, Five Forks, Kakanui River, Dunrobin Road, all in North Otago),
I43 (e. g. Mount Watkin in North Otago),
I44 (e. g. Boulder Hill, East Taieri in eastern Otago,
I45 (e. g. near Taieri Mouth in southeastern Otago),
H45 (e. g. near Tokomairiro River mouth in southeastern Otago),
H46 (e. g. Wangaloa area including Mitchells Rocks, Measly Beach and Smiths Beach of southeastern Otago).

Until now Paleocene molluscs were known mainly from Wangaloa and Boulder Hill.

Zonation of Paleocene faunas

The biostratigraphy of New Zealand Paleocene rocks has received a great deal of attention over the years. As mentioned previously, the first Paleocene molluscs were collected from Measly Beach, Wangaloa in late 1868 or early 1869. Based on stratigraphic and taxonomic grounds the Wangaloa fossils have been assigned varied ages in the literature--as young as "upper Tertiary" (Hector, 1872) or "Upper Miocene" (Hutton, 1875) to as old as Late Cretaceous (Finlay and Marwick, 1937, 1940). Note that Finlay and Marwick used Danian as a latest Cretaceous unit, following convention at that time, not earliest Tertiary as it is at present (see Figures 50-51, stratigraphic sections of rocks at Wangaloa). Hector (1892, p. lvii) assigned the Wangaloa beds and fossils to his "Cretaceo-Tertiary" as a lower horizon than the "Ototara stone". Suter (1911, p. 595) used information given to him by J. Park on the supposed occurrence of *Conchothyra parasitica* and *D*. *lindsayi* [*Belemnites*] at Wangaloa to support an Upper Cretaceous age. (Note: Fleming *in* Brown *et* *al*. (1968, p. 287) stated that the early report of belemnites in the Teurian strata (Paleocene) was, in fact, derived from Haumurian rocks. In support of this I discovered a probable belemnite (most likely reworked; *Dimitobelus* (*D*.) *hectori*?) in Paleocene rocks at Raupo Creek during the course of this investigation.) Park regarded the Upper Kaitangata coal-bearing series including the beds at Wangaloa as Upper Cretaceous in age. A Late Cretaceous age for the Wangaloa fossils was still supported by Marshall (1916a-b), who stated that species *Pugnellus* *australis* (now assigned to *Conchothyra*) and *Avellana* *paucistriata* (now assigned to *Superstes*) represent genera which are not known higher than the Cretaceous. Marshall (1916a, p. 115) did remark that he could not find *Conchothyra* nor *Belemnites* at Wangaloa. One year later Marshall (1917, p. 459) commented that "The Cretaceous complexion of these beds is still more strongly maintained by the occurrence of belemnites at Brighton [c. 45 km to the north] in beds that are admittedly of the same age as those at Wangaloa." He called the fossiliferous sandstones at Measly Beach and Mitchells Rocks the Wangloa Beds. In conclusion, Marshall (1917) decided that the

Figure 31. Oyster bed in Broken River Formation ("Wangaloan"), c. 0.7 km below junction with Porter River, Broken River area, Canterbury. Grid reference: K34/096770.

Figure 32. Close-up of oyster bed in Figure 31. Same grid reference.

Figure 33. Fossiliferous concretionary sandstone of Raupo Concretionary Sandstone Member, Kauru Formation ("Wangaloan"), Kakanui River, North Otago. Grid reference: J41/338697.

Figure 34. Raupo Concretionary Sandstone Member, Kauru Formation, Kakanui River. Grid reference: J41/336696.

Figure 35. Angular unconformity in Raupo Creek, North Otago, between Haast Schist and overlying Raupo Concretionary Sandstone Member. Fossils are present just mm above burrowed erosion surface. Grid reference: J41/327702.

Figure 36. Raupo Creek. Fossils, including the first recorded crinoids from the New Zealand Paleocene, were collected from this locality. Grid reference: J41/326702.

"To the great naturalist Linnaeus, whose comprehensive mind seems, in many instances, to have anticipated the objections which envy or ignorance would raise against his system, and his fame, we are indebted, according to the judgement of a large majority, for the most perspicuous arrangement of testaceous animals which has hitherto been offered to the public."

Rev. E. I. Burrow, 1815, p. x

"Gastropods have remained surprisingly underutilized as models for objects of evolutionary studies. No other animal group offers an equal opportunity to conbine the findings of comparative morphological and molecular studies on the diverse extant fauna with data derived from the extensive fossil record."

Rüdiger Bieler, 1992, p. 330

"While it is currently assumed that flood basalt eruptions and rifting were produced by mantle plumes that formed by instabilities associated with heat released non-uniformly from the earth's core, we support earlier views that impacts may have initiated continental rifting and basaltic volcanism. Our work results suggest that impacts may have been constantly at work shaping the continents...Impacts of asteroids and comets may have initiated breakup of Gondwana and other continental land masses."

Verne R. Oberbeck, John R. Marshall, and Hans Aggarwal,
1993,p. 17

"All of these what-ifs, uncertainties, and perhaps, downright misconceptions are both frustrating and exhilarating. They are frustrating because I really want to know what caused the pattern in my extinction time series, and I remain ignorant. At the same time, they are exhilarating because a huge wealth of research problems remains in our continuing quest for knowledge about Earth and life history."

J. John Sepkoski, 1994, p. 17

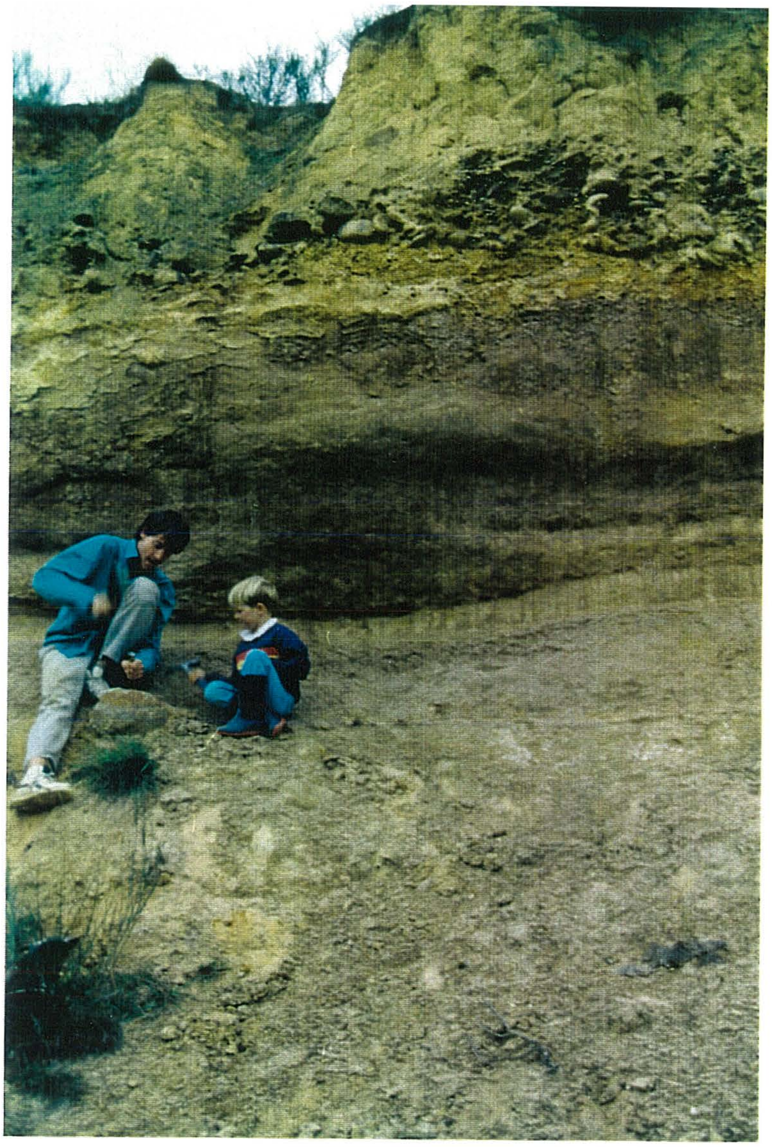


Figure 37. Breaking concretions in Raupo Creek. P. J. Rolfe (L) and D. Ewing (R). Grid reference: J41/c.327703.

Figure 38. Isolated outcrop (fossiliferous lens) of Raupo Concretionary Sandstone Member northeast of Trig U off Dunrobin Road, Kakanui Valley, North Otago. Grid reference: J41/304728.

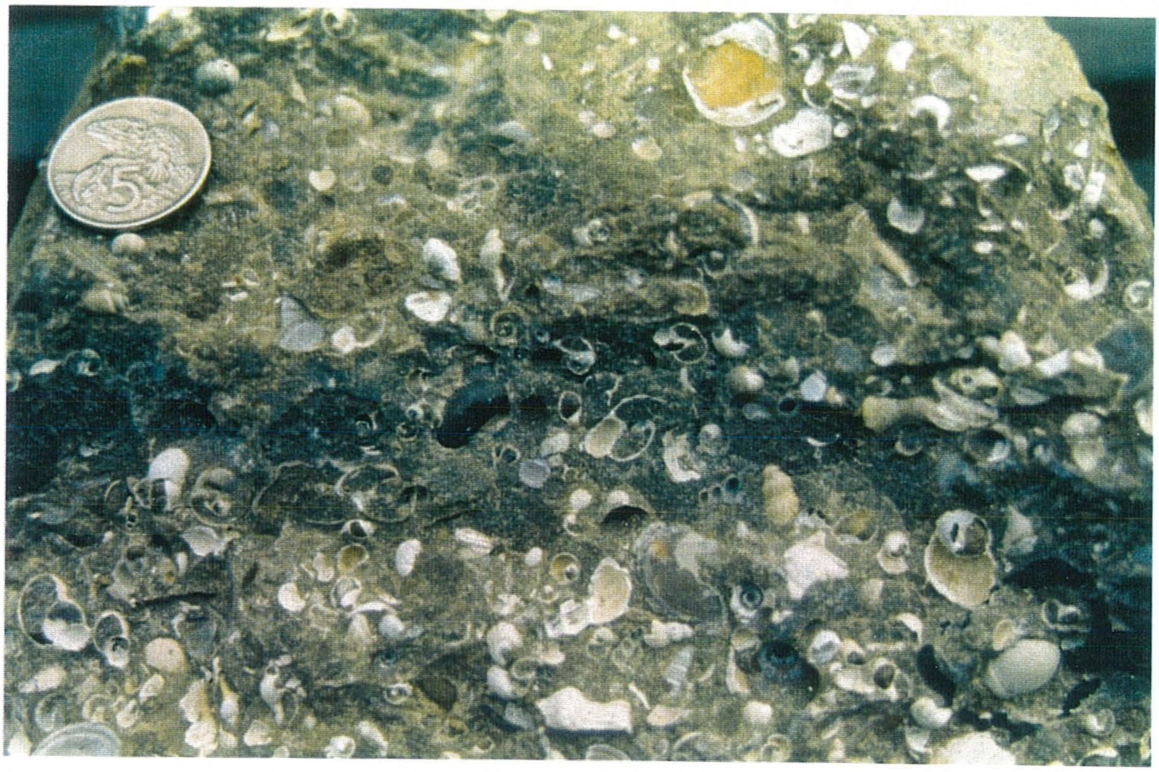


Figure 39. Well-preserved molluscs collected from locality above in Figure 38. Circled specimen in lower righthand corner is Superstes exquisitus n. sp. Grid reference same as above.

Figure 40. Outcrop of Raupo Concretionary Sandstone Member along Dunrobin Road. Grid reference: J41/307732.

Figure 41. Boulder Hill section, eastern Otago. Non-marine Taratu Formation (uppermost Cretaceous) overlain by Wangaloa Formation (Paleocene). Grid reference: I44/055876.

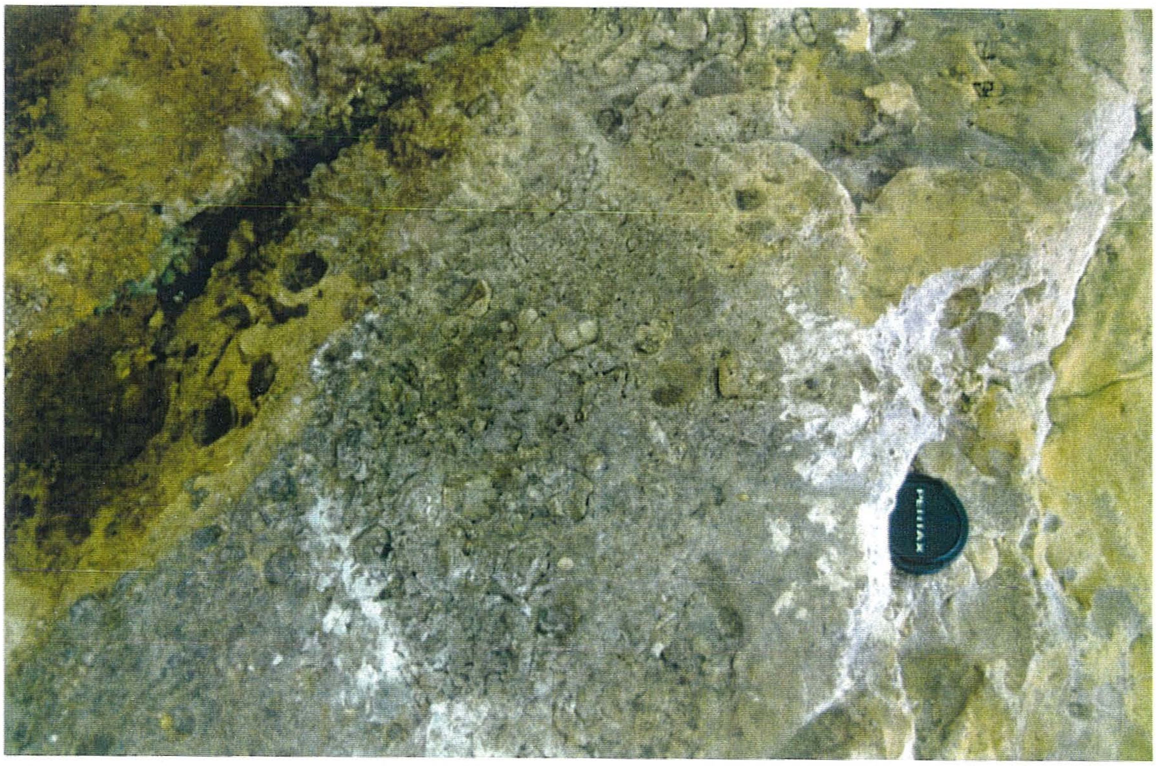


Figure 42. Large fossiliferous concretion in Wangaloa Formation, Boulder Hill. Grid reference: I44/c.056875.

Figure 43. Decalcified molluscs from same locality in Figure 42. Most Paleocene localities at Boulder Hill comprise poorly preserved fossils. Apparently, the original lens of well-preserved fossils discovered by H. E. fyfe in 1920 was completely collected ou

Figure 44. Mitchells Rocks, Wangaloa, southeastern Otago. Wangaloa Formation (upper Lower Paleocene at this locality). View to the south from southernmost extent of Measly Beach. Grid reference: H46/767336.

Figure 45. Southernmost extent of fossiliferous rocks of Wangaloa Formation. Juvenile Hooker's sea lion resting on lens of mostly Zeacolpus (Leptocolpus) semiconcavus shells. Grid reference: H46/765329.

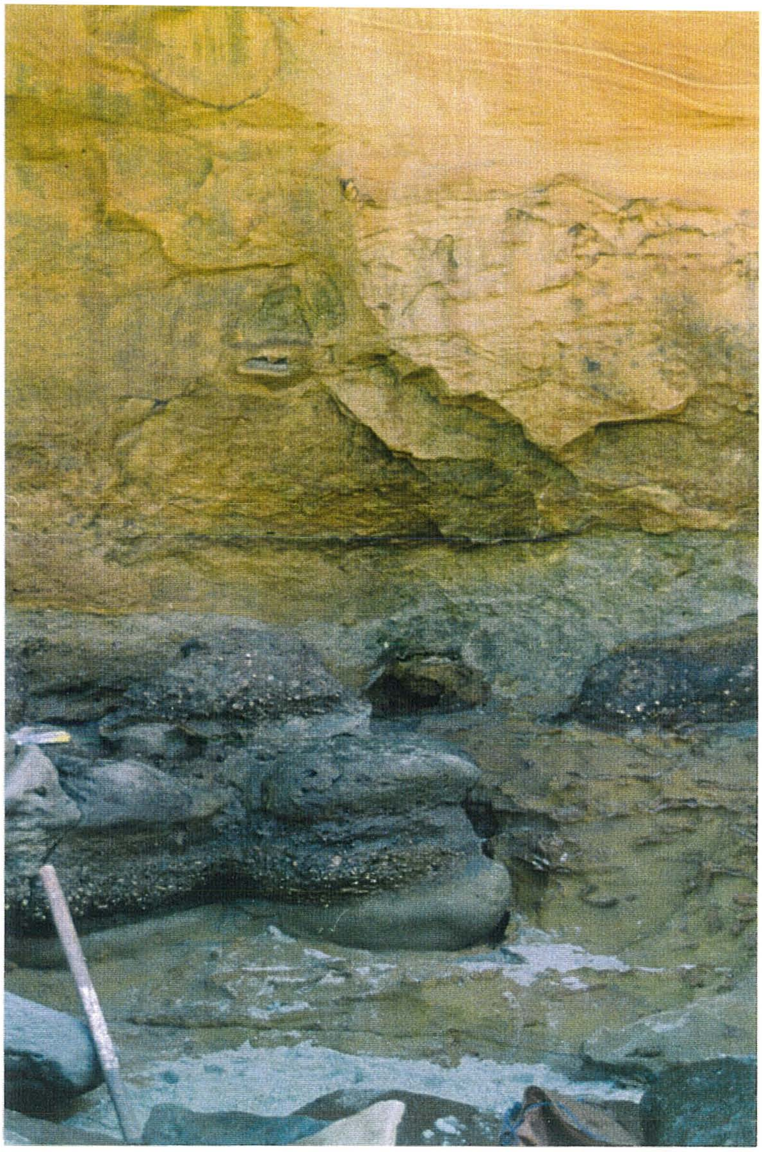


Figure 46. Coastal cliff section (2.75 m) of Wangaloa Formation at Mitchells Rocks near Wangaloa. Shell beds (mostly lenses within concretions or shelly seams) are discontinuous. Fossils are rare outside the concretionary lenses. Note Ophiomorpha galleries at bottom right. Grid reference: H46/765329.

Figure 47. "Micromollusc horizon", Mitchells Rocks, Wangaloa Formation. Grid reference: H46/76803350.

Figure 48. Coastal cliff section a few metres south of Figure 46 illustrating lateral variability in shell beds. Same grid reference.

Figure 49. "Micromollusc horizon". Shell lag accumulation probably due to oscillatory flow during waning phase of storm deposition. Note alternating stratified sand and shell deposits. Deposition in troughs. Same grid reference as Figure 47.

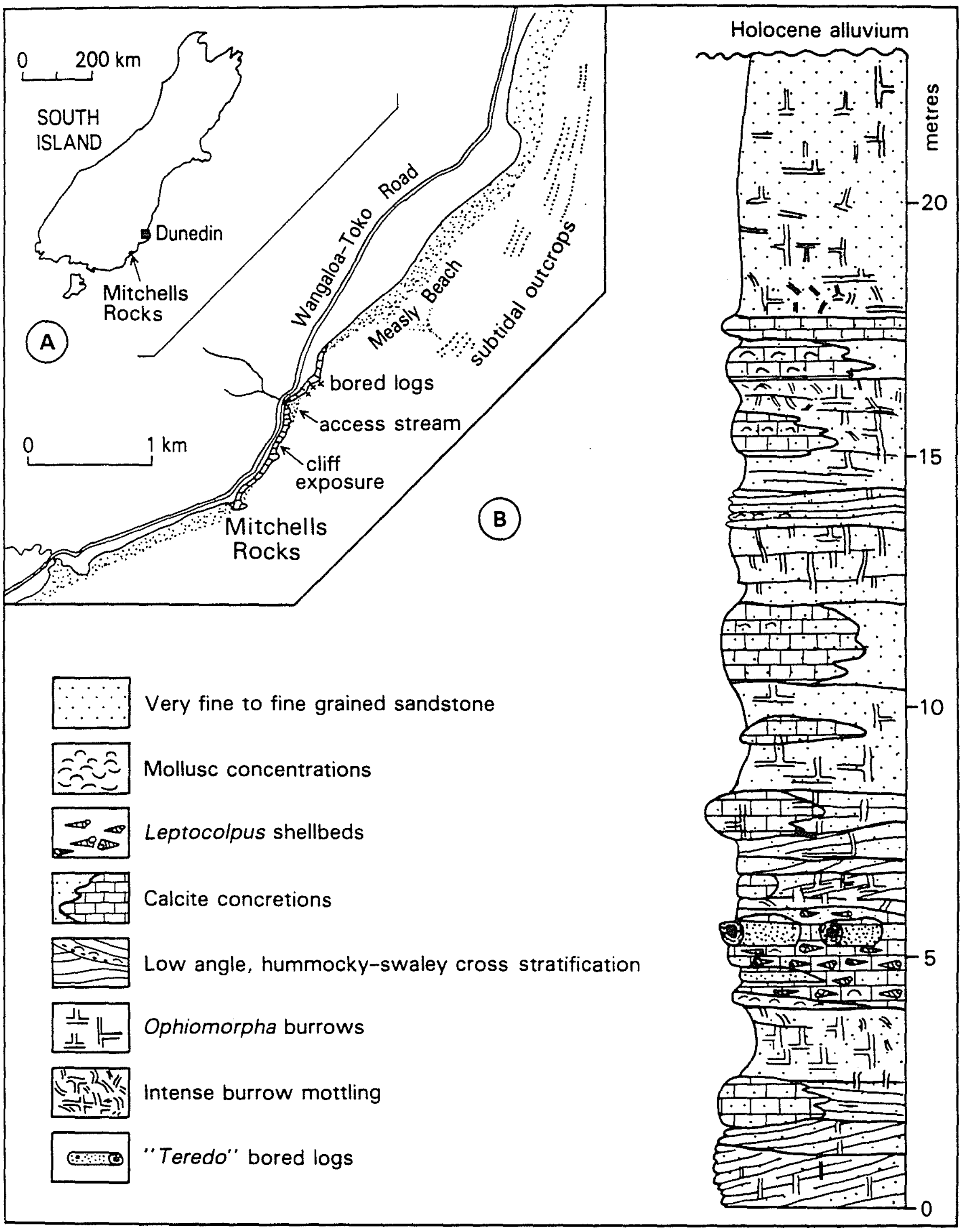


Figure 50. Coastal cliff stratigraphic column of Wangaloan stratotype of Morgan in Chapman (1918) at Mitchells Rocks (from Lindqvist, 1986).

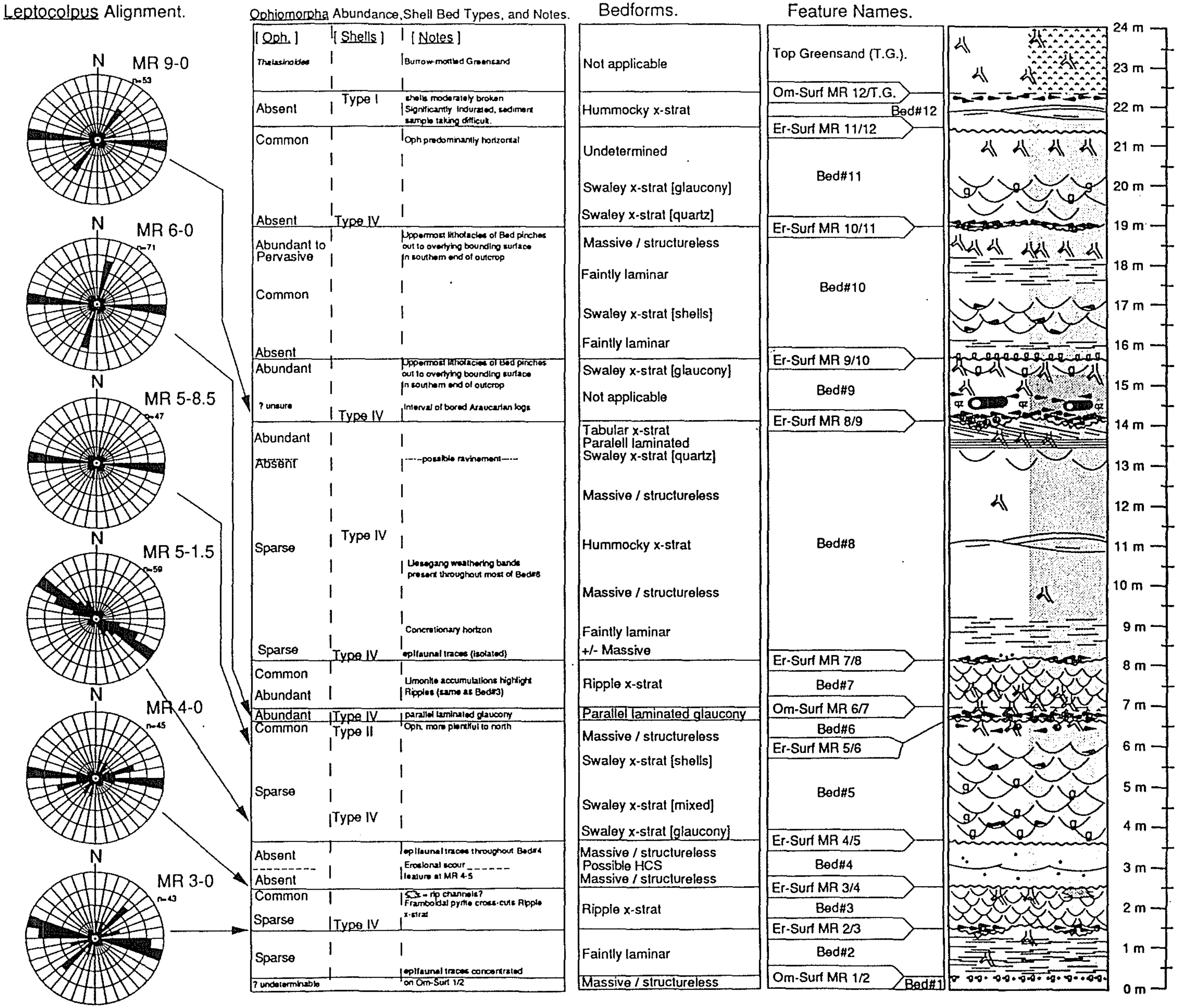


Figure 51. Stratigraphic column (24 m) of fossiliferous rocks at Mitchells Rocks, Wangaloa, Wangaloa Formation (from Smith, 1993).

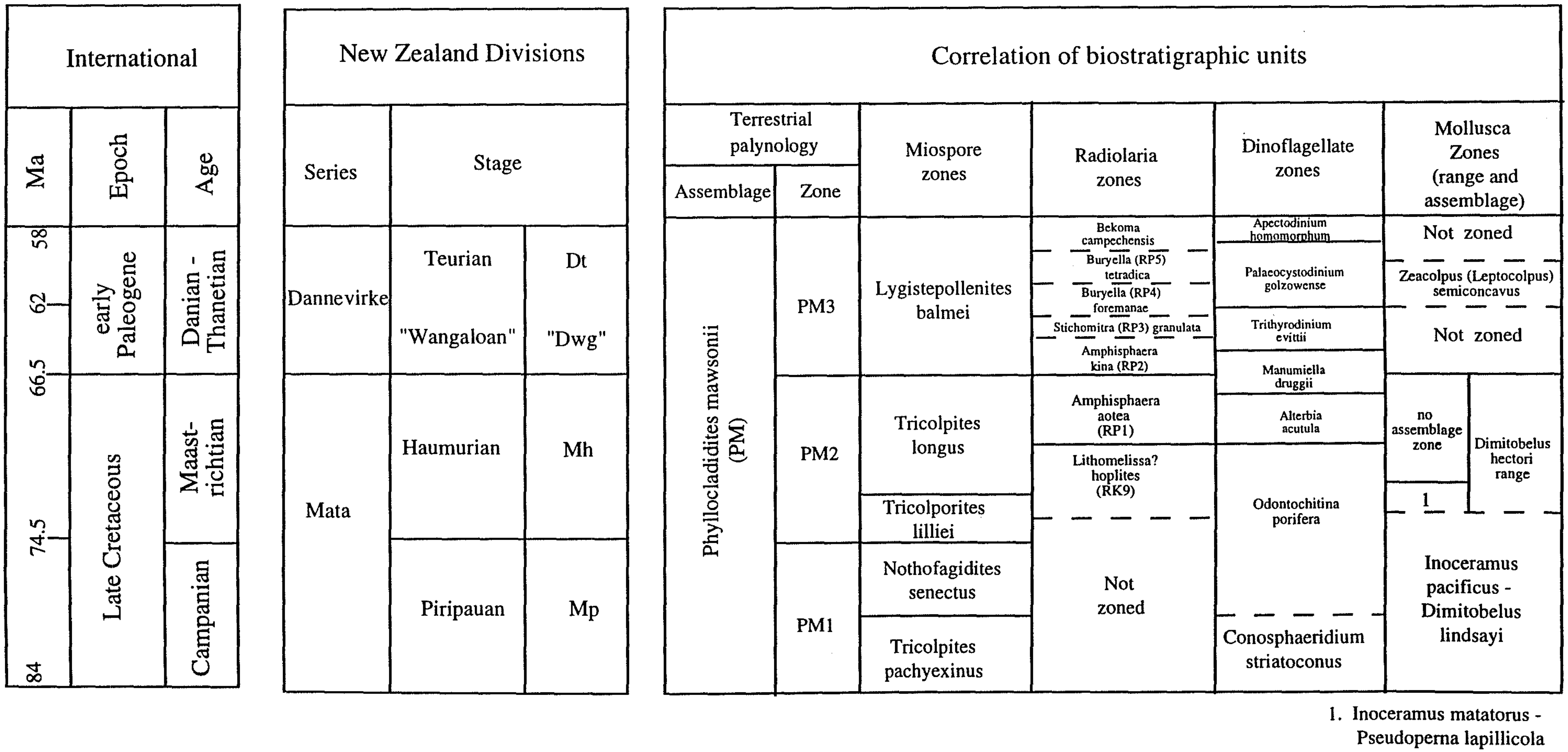


Figure 52. Zonation of New Zealand Campanian to Paleocene rocks. (information from Warren and Speden, 1978; Wilson, 1984, 1988; Browne and MacKinnon, 1989; Hollis, 1993; this work).

mixed Cretaceous-Tertiary and puzzling aspect of the fauna with restricted Cretaceous forms and apparently restricted Eocene taxa such as Heteroterma, Gilbertia and Nucleopsis, point to a "very old Tertiary--perhaps even older" age (p. 460). C. T. Trechmann, who collected fossils with P. Marshall at Wangaloa, thought that the age of these taxa should be regarded as Maastrichtian or possibly Danian, but at least higher than the Selwyn Rapids Beds, which he considered to be Senonian (Upper Cretaceous) (Marshall, ibid; Trechmann, 1917, p. 296).

Thomson (1917, pp. 409-410) assigned the beds at Wangaloa to the Kaitangatan Group, which was proposed by Thomson to encompass the Kaitangata coal measures and the intermediate marine horizon containing the molluscan fossils. The Wangaloan Stage was proposed as part of the Kaitangatan a year later by Morgan in Chapman (1918, Table of Cretaceous and Tertiary formations in New Zealand, p. 40), based on the rocks at Wangaloa. Morgan did not discuss the upper and lower boundaries of the Wangaloan Stage and, as Webb (1973b, p. 161) pointed out, Thomson (1917) a year earlier gave a much more detailed discussion on the potential value of the Wangaloa beds as a stratotype for a stage. Thomson (1920, p. 385-394) included the Wangaloa beds in the Kaitangatan Group between the Piripauan and the Oamaruian. Suter (1921, p. 96) advocated an Eocene or Upper Cretaceous ("Kaitangatan") age for the Wangaloa beds.

The Wangaloan Stage and its peculiar molluscs received much attention in the 50 years spanning the 1920s-70s (noteworthy articles include those of Wilckens, 1921; Marshall and Murdoch, 1923; Marwick, 1923, 1924a-b, 1926, 1946; Henderson, 1930;

Service, 1934; Finlay and Marwick, 1937, 1940, 1947, 1948; Singleton, 1943; Ongley, 1939; Hornibrook, 1953, 1962; Cotton, 1955; Hornibrook and Harrington, 1957; Freneix, 1956, 1958; Harrington, 1958; Robinson, 1958; Fleming, 1953, 1959, 1965; Wellman, 1959; Daniel, 1961; Chiplonkar, 1968; McGowran, 1968; Carter, 1969, 1974, 1988a-b; Darragh, 1969; Gage, 1970; Hamill, 1972; Powell, 1979). Finlay and Marwick (1937, pp. 7-9) stated that the position of the Wangaloan Stage is clearly established between the Piripauan (Upper Senonian) and the Bortonian, as "The absence of Ammonites, Belemnites, Inoceramus, and Trigonia is fairly conclusive that the fauna is younger than the Piripauan and the common occurrence of Lahillia and Conchothyra as well as the general evolutionary grade of many familes just as clearly points to a pre-Bortonian age." Upper and lower limits of the Wangaloan Stage were not defined by the proposer Morgan, or the major revisers, Finlay and Marwick. See similar comments on the Wangaloan Stage by Finlay and Marwick (1940, 1947).

At first the Teurian Stage (proposed by Finlay and Marwick, 1947) was included in the Mata Series and correlated with the upper Senonian and later with the Danian. Eventually, the Teurian was transferred to the Dannevirke Series when the international community accepted the Danian as part of the Cenozoic and not Mesozoic Era. Finlay and Marwick (1937, p. 229) placed the Teurian, defined by them on presence of foraminifera in the type section at Te Uri Stream, between the older Piripauan and younger Wangaloan stages.

In a paper on the status of the Wangaloan Stage, Hornibrook and Harrington (1957) proposed that the Wangaloan be omitted from the sequence of stages in New Zealand because the Teurian Stage (redefined by Hornibrook and Harrington (1957); based on the type section at Te Uri Stream, Hawke's Bay) and the Dannevirke Series were inferred to represent complete sequences so that the Wangaloan must be a partial equivalent to the Teurian. The Wangaloa Formation was proposed the following year by Harrington (1958), who outlined the stratigraphic limits and the content of the formation. The stratotype is exposed in reefs and low coastal cliffs at Mitchells Rocks (Figures 50-51; see this preferred name in New Zealand Map Series 1 imperial (S180) 1:63,360 and New Zealand Map Series 260 metric (H46) 1:50,000 topographic maps; also known as Mitchell Point, Mitchell's Point, or Mitchell's Rocks), Measly Beach, Smiths Beach, Wangaloa Stream estuary, Bold Creek, and Tokomairiro River.

Comment seems warranted on the name Wangaloa. According to Webb (1973b, p. 113), the name "Wangaloa" is derived from the Wangaloa Post Office and adjacent community. A diligent search on information about the early history of this community and derivation of the name reveals that the name Wangaloa is possibly the southern equivalent of Whangaroa (= "long bay") which uses the "l" of the southern dialect (Waite, 1948, p. 191). Waite also stated that, long before this settlement was called Wangaloa, Surveyor Tuckett regarded it as "Te Akaroa" (undoubtedly a much older Maori name for an earlier settlement) and Wright (1955, p. 36) wrote that "Wangaloa was already known as Akaroa when d'Urville sailed into its "splendid harbour which could have easily accomodated fifty vessels", and which he preferred to the more exposed Piraki". That the harbour at Wangaloa could be considered "splendid" is puzzling. The relationship of Te Akaroa in southeastern Otago to Akaroa in Banks Peninsula is uncertain and the latter seems a much more likely candidate as a harbour that could accomodate 50 vessels! On the sketch map of the "Edinburgh Block" (= Otago) done by F. Tuckett in 1844 (original in Hocken Library, University of Otago, J.D.S., pers. obs., 1994) he clearly shows the presence of three place names and/or villages in the Wangaloa area; these are "Waikaro" (= Measly Beach) to the north, "Te Awa houhou" just south of Waikaro (= Smiths Beach? on recent maps), and "Te Akaroa" to the south (= Wangaloa). Wangaloa was first settled by Europeans in 1860 (Waite, 1948, pp. 74-75; Anon., 1966, p. 31). I could not find the name Wangaloa on any maps previous to 1860. Also, Mitchells Rocks was probably named after the Donald Mitchell family of Ardmore who were amongst the earliest settlers and owned property at Wangaloa (c. 1860, possibly before) (Waite, 1948, p. 75).

Little advance was made in correlating the rocks at Wangaloa with other Paleocene localities until the early 1970s through work by P. N. Webb, formerly of New Zealand Geological Survey, Lower Hutt (now at Ohio State University). The Wangaloan "problem" was then reviewed by Webb (1973a-b), who retrieved foraminifera from beds overlying the "Mitchell Point Facies"; these younger beds were informally given the name "Trig C Facies". Foraminifera from the Trig C facies were assigned a "Teurian (early Paleocene)" age (Webb, 1973a, p. 109). Webb

(1973b, pp. 158, 164) summarised the Wangaloan problem as involving "...correlation of sediments which contain a geographically restricted assemblage of littoral mollusca, with successions of thicker, deeper water and more offshore sediments in which foraminifera are abundant but mollusca are almost totally absent...Hornibrook argued that since the Wangaloan was probably the correlative of the Teurian, and because it was still not possible to make direct correlation between the molluscan-based Wangaloan and the foraminiferan-based Teurian, it was best that the more restricted Wangaloan be omitted from the standard succession of stages." The notion that the "Wangaloan" fauna is geographically restricted has persisted to date (see most recent account by Beu and Maxwell, 1990). However, through further collecting and through taxonomic work, I have found that rocks containing the "Wangaloan" fauna are much more widespread than previously recognised. Indeed, these inferred shallow marine rocks may be more extensive in New Zealand than seemingly more restricted coeval deeper water and more offshore sediments which contain rich microfossils.

For example, this study reveals that conspecific taxa range from the Castle Hill Basin in North Canterbury to Wangaloa, southeastern Otago. The presence of Purpurocardia cf. P. fyfei (Finlay and Marwick, 1937), Zeacolpus (Leptocolpus) semiconcavus (Suter, 1911) and Conchothyra australis (Marshall, 1916b) in association with a Teurian dinoflagellate assemblage in the Broken River Formation of Castle Hill Basin all point to a "Wangaloan" age.

Further to the south an unequivocal "Wangaloan" assemblage has been recovered from the Raupo Concretionary Sandstone Member of the Kauru Formation in the eastern reaches of the Waihao River, southern Canterbury. Age diagnostic taxa from the latter locality include *Spineilo elongata* (Marshall, 1917), *Purpurocardia fyfei* (Finlay and Marwick, 1937), *Panopea* n. sp.? aff. *P. worthingtoni* Hutton, 1873c, *Zeacolpus* (*Leptocolpus*) *semiconcavus* (Suter, 1911), *Colposignma mesalia* Finlay and Marwick, 1937, *Pseudofax ordinarius* (Marshall, 1917), *Saulopsis* n. gen. *zelandica* (Marshall, 1917), *Acteon semispiralis* (Marshall, 1917), and *Wangaloa plana* (Marshall, 1917).

Several localities in the Five Forks-Kakanui River-Raupo Creek-Dunrobin Road area of North Otago (Raupo Concretionary Sandstone Member of Kauru Formation) also have a characteristic "Wangaloan" fauna, which was remarked on by Marwick *in* Gage (1957, pp. 109-110, Tab. 11, see list of taxa) and Beu and Maxwell (1990, p. 77). According to Beu and Maxwell (1990, p. 77) the presence of *Spineilo*, *Lahillia*, *Zeacolpus* (*Leptocolpus*), *Amauropsona*, *Tudiclana*, *Fyfea*, *Microfulgur* and *Heteroterma* (herein assigned to *Saulopsis* n. gen.) indicates a probable "Wangaloan" age, but Maxwell thought that the absence of these taxa at Raupo Creek and others indicates a possible significantly younger age for these localities. Evidence for a younger age of the faunule at Raupo Creek comes from the presence of *Serripecten*, *Hedecardium*, *Spirocolpus*, *Zeacolpus* s. s., *Sigapatella* and *Eoturris* (Beu and Maxwell, ibid). I suggest that differences between these faunules probably reflect disparity in facies and wave/current energy, more than significant age differences, especially since I have recorded inferred restricted "Wangaloan" species of genera *Spineilo*, *Ledina*, *Glycymerita*, *Limopsis* (*Limopsista*), *Purpurocardia*, *Nemocardium* (*Pratulum*), *Saulopsis* n. gen., *Bittiscala* and *Taioma* from Raupo Creek. The important faunule at Dunrobin Road, North Otago, is an unusual mixture of "Wangaloan" and younger elements, but again the presence of *Glycymerita concava* (Marshall, 1917), *Nemocardium* (*Pratulum*) *modicum* (Marwick, 1944), *Dosinia* (*Dosinobia*) *ongleyi* (Finlay and Marwick, 1937), *Polinices* (*Polinella*) *finlayi* (Marwick, 1924), *Saulopsis* n. gen. *zelandica*, *Cosmasyrinx* (*Tholitoma*) *dolorosa* (Finlay and Marwick, 1937), and a new species of *Cylichnania* all point to a "Wangaloan" age.

The identification of *Spineilo elongata*, *Bittiscala simplex* and *Tudiclana simulator* from the Steel Greensand of Mount Watkin, North Otago, indicates a "Wangaloan" age for these sediments.

In the Steel Greensand of East Taieri, eastern Otago, *Cucullaea* (*Cucullastis*) *barbara* Finlay and Marwick, 1937, *Marwickia parthiana* (Marwick, 1927), *Panopea* n. sp.? aff. *P. worthingtoni*, *Zeacolpus* (*Leptocolpus*) *semiconcavus*, *Euspira fyfei* (Marwick, 1924b), *Priscoficus obtusa* (Marshall, 1917), *Pseudofax ordinarius*, and *Saulopsis* n. gen. *zelandicus* indicate another characteristic "Wangaloan" fauna.

A. Scott *in* Robinson (1958) identified *Colposigma mesalia* and *Priscaphander cingulatus* (Marshall, 1917) among other probable "Wangaloan" taxa from a road cutting along the Akatore fault scarp, south of Taieri River mouth, southeastern Otago. I visited this locality in early 1992. The fossils (I noted species of *Spineilo*?, *Ledina*?, *Glycymerita*, *Acteon* and

Priscaphander) are present in well-cemented sandstone concretions (Wangaloa? Formation) and are mostly poorly preserved molds, casts and shell fragments. I did not find any fossils outside the concretions. This "Wangaloan" locality bridges a gap from Boulder Hill to the north to Wangaloa to the south. Sparse "Wangaloan" taxa have also been recorded in the time-transgressive Abbotsford Formation in the Dunedin area (unpublished data).

In summary "Wangaloan" rocks with a characteristic Paleocene fauna are, therefore, much more widespread than previously recognised. Expulsion of the "Wangaloan" Stage from the local stage scheme may not be entirely satisfactory because age-diagnostic zonal microfossils of the Paleocene (Teurian Stage) are generally very rare or absent in these geographically widespread shallow marine rocks of South Island. Wangaloan is probably a senior synonym for some of the Teurian, too. Beu and Maxwell (1990) did not advocate reintroduction of the "Wangaloan" into the local stage scheme, but used "Wangaloan" as a convenient term for the distinctive, shallow marine molluscan faunas of the early Tertiary of New Zealand. Also, the relationship of the Wangaloan to the long (c. 8 Ma) Teurian Stage is still unclear.

Ongoing work on the New Zealand Cretaceous-Cenozoic Project (CCP) by the Institute of Geological and Nuclear Sciences, Lower Hutt, has further advanced our knowledge of the microfossil biostratigraphy of uppermost Cretaceous to lowermost Tertiary rocks. Samples collected for microfossils by myself and others at key Paleocene localities (e. g. Wangaloa, Waihao River, several localities in the Kakanui Valley) were processed by G. Wilson (1992b, open file report, GJW 232/92). These samples all revealed a Teurian age, indicated by diagnostic index dinoflagellate *Palaeocystodinium golzowense*. Samples at Wangaloa (e. g. from H46/148A and H46/f166A) yielded fairly sparse dinoflagellate assemblages containing *Palaeocystodinium golzowense*, *Senegalinium dilwynense* and *Spinidinium densispinatum*. The presence of the latter two species at Wangaloa provides additional evidence of a Lower Paleocene age for these rocks, because these taxa are restricted to the lower part of the *P. golzowense* Zone (Wilson, 1988, p. 10). In contrast, the absence at the Wangaloa section of zone index species *Isabelidinium* (= *Manumiella*) *druggii* and other restricted taxa for this earliest Paleocene zone (see Wilson, 1984, p. 111, Fig. 4) and *Trithyrodinium evittii* (see Wilson, 1988, p. 10), directly below the *P. golzowense* Zone, is significant. The stratigraphic occurrence of dinoflagellates indicates to me that the Mitchells Rocks molluscs at Wangaloa are not earliest Paleocene in age, but are probably of late Early Paleocene or mid Paleocene age.

At the base of the Wangaloa Formation (H46/f112) the miospore *Tricolpites lilliei* Couper, characteristic of zone PM2, Haumurian Stage in New Zealand (J. I. Raine *in* Edwards *et al*., 1988), has been recorded as a common species along with *T. pachyexinus* Couper, *Quadraplanus brossus* Stover, *Camarozonosporites ohaiensis* (Couper), and others; these taxa are restricted to the Cretaceous (D. C. Mildenhall and G. J. Wilson, pers. commun. *in* Lindqvist and Douglas, 1987). Sample H46/f112 was taken approximately 10 m or more below the shell beds at Mitchells Rocks. "The preservation of the dominant, Cretaceous palynoflora indicates that there is no evidence for reworking into the early Tertiary." (D. Mildenhall, pers. commun. in Stilwell, 1993, p. 362). Stilwell (ibid) thought it likely that the Cretaceous-Tertiary boundary lies within the Wangaloa Formation below the shell beds at Mitchells Rocks, but more data and sampling are needed. More importantly, because the boundary between the Cretaceous underlying unit, inferred non-marine Taratu Formation, and Wangaloa Formation is seemingly conformable (evidence for interdigitation of marine and non-marine facies--probably beachface deposition) reliable correlation may be possible with more sampling between the Wangaloa section and type sections for the Paleocene in Waipara River, North Canterbury (I. druggii and Trithyrodinium evittii zones) and Waipawa, Hawke's Bay (P. golzowense Zone). Future work at Wangaloa may resolve the "Wangaloan" problem and may see the reintroduction of the Wangaloan into the local stage scheme, especially since the Wangaloan has priority and is the older name (Teurian came much later) and its relationship to the Teurian could be established.

I propose that an assemblage zone be established for the widespread Paleocene molluscan-rich faunas of South Island. Because of improved biostratigraphic control based on study of dinoflagellate assemblages, the beds at Wangaloa containing diagnostic "Wangaloan" fossils can now be correlated to other coeval microfossil-poor rocks with some degree of certainty. The name *Zeacolpus* (*Leptocolpus*) *semiconcavus* Assemblage-zone is proposed (Figure 52); stratigraphically important species, in addition to the zone index include: *Spineilo elongata*, *Cucullaea* (*Cucullastis*) *barbara*, *Glycymerita concava*, *Lahillia neozelanica*, *Nemocardium* (*Pratulum*) *modicum*, *Dosinia* (*Dosinobia*) *ongleyi*, *Panopea* n. sp.? aff. *P*. *worthingtoni*, *Bittiscala simplex*, *Polinices* (*Polinella*) *finlayi*, *Colposigma mesalia*, *Pseudofax ordinarius*, *Saulopsis* n. gen. *zelandica*, *Tudiclana simulator*, and *Taioma tricarinata*. *Zeacolpus* (*L*.) *semiconcavus* spans c. 21 m of section at Wangaloa and decreases in abundance up-section. The *Z*. (*Leptocolpus*) *semiconcavus* Zone can be correlated to the lower part of the *P*. *golzowense* Zone, based on dinoflagellate ranges and occurrences in various "Wangaloan" localities in South Canterbury and Otago.

LATEST CRETACEOUS AND EARLIEST PALEOGENE MOLLUSCAN FAUNAS OF NEW ZEALAND: COMPOSITION AND PALEOBIOGEOGRAPHY

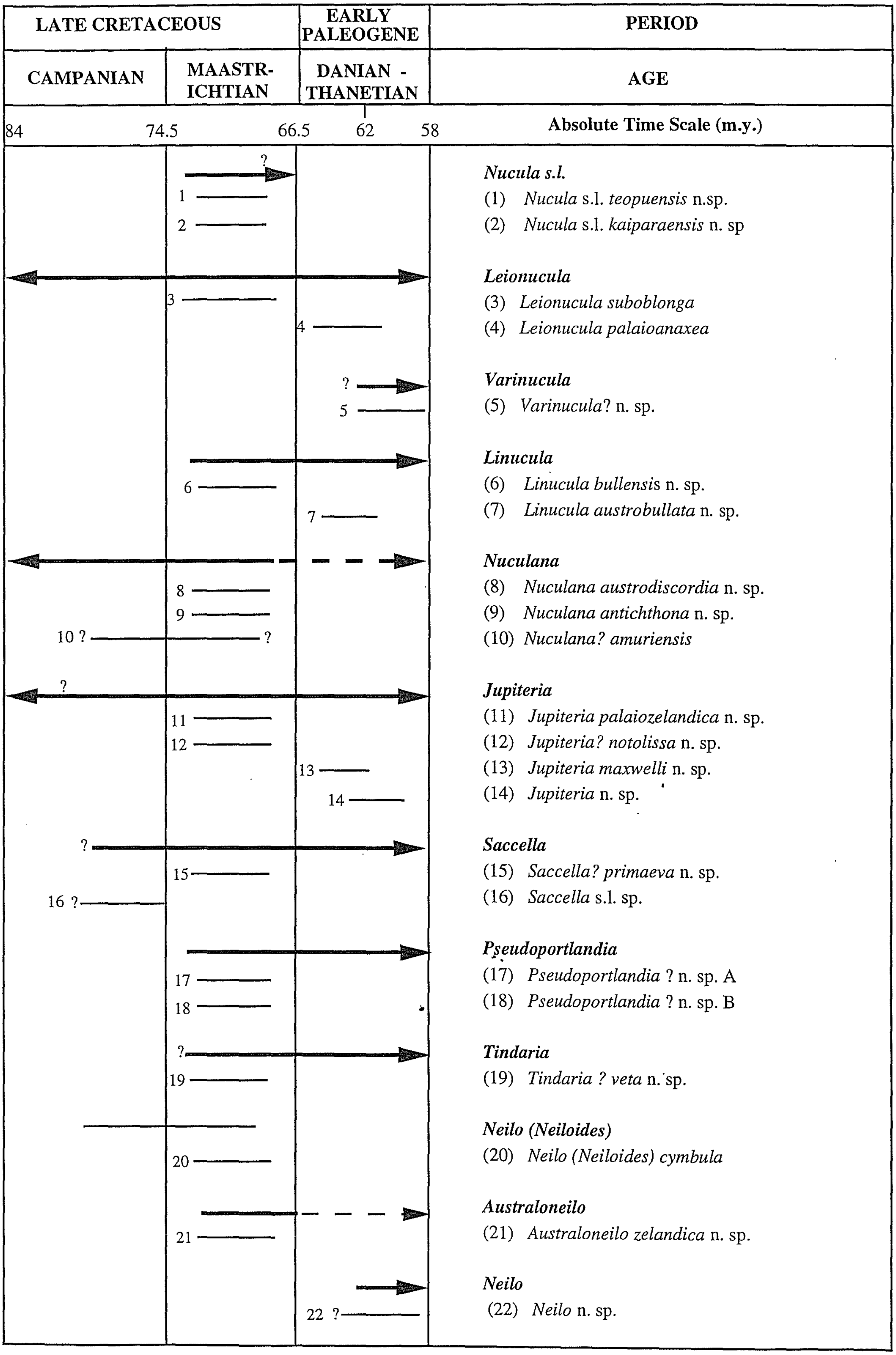
The Late Cretaceous-Paleogene interval encompasses events which largely shaped the contemporary marine faunal assemblages of the southern continents. These events included:

1) the Cretaceous-Tertiary (K-T) extinction;
2) the effective separation of the southern continents by opening of the Southern Ocean and a substantial new segment of the Indian Ocean and the Tasman Sea; and
3) the worldwide oceanic thermal decline which had ensuing changes to global circulation.

It is an interval of paramount interest for southern hemisphere biogeography. Molluscs present one of the best groups with which to document patterns and interpret biotic changes caused by the events because of their robust shells favoured for preservation and the widespread occurrence of shallow marine sedimentary sequences of appropriate age in the southern hemisphere.

From a global perspective, the latest Cretaceous and earliest Paleogene molluscan faunas of New Zealand are important in that faunas of this interval elsewhere in the southern hemisphere are generally not as well documented or the record is not as complete, as in New Zealand. This thesis shows that the composition of molluscan faunas changed dramatically across the K-T boundary in New Zealand, both in terms of paleobiogeographic elements (e. g. endemic, cosmopolitan, Indo-Pacific/Tethyan, paleoaustral) and evolution and extinction.

Table 4: Ranges of New Zealand Campanian to Thanetian Mollusca at genus- and species- level. Arrows indicate extended ranges. Question marks denote uncertain ranges. Dashed lines refer to ranges of taxa outside New Zealand



Nucula s.l.
(1) *Nucula* s.l. *teopuensis* n.sp.
(2) *Nucula* s.l. *kaiparaensis* n. sp

Leionucula
(3) *Leionucula suboblonga*
(4) *Leionucula palaioanaxea*

Varinucula
(5) *Varinucula*? n. sp.

Linucula
(6) *Linucula bullensis* n. sp.
(7) *Linucula austrobullata* n. sp.

Nuculana
(8) *Nuculana austrodiscordia* n. sp.
(9) *Nuculana antichthona* n. sp.
(10) *Nuculana? amuriensis*

Jupiteria
(11) *Jupiteria palaiozelandica* n. sp.
(12) *Jupiteria? notolissa* n. sp.
(13) *Jupiteria maxwelli* n. sp.
(14) *Jupiteria* n. sp.

Saccella
(15) *Saccella? primaeva* n. sp.
(16) *Saccella* s.l. sp.

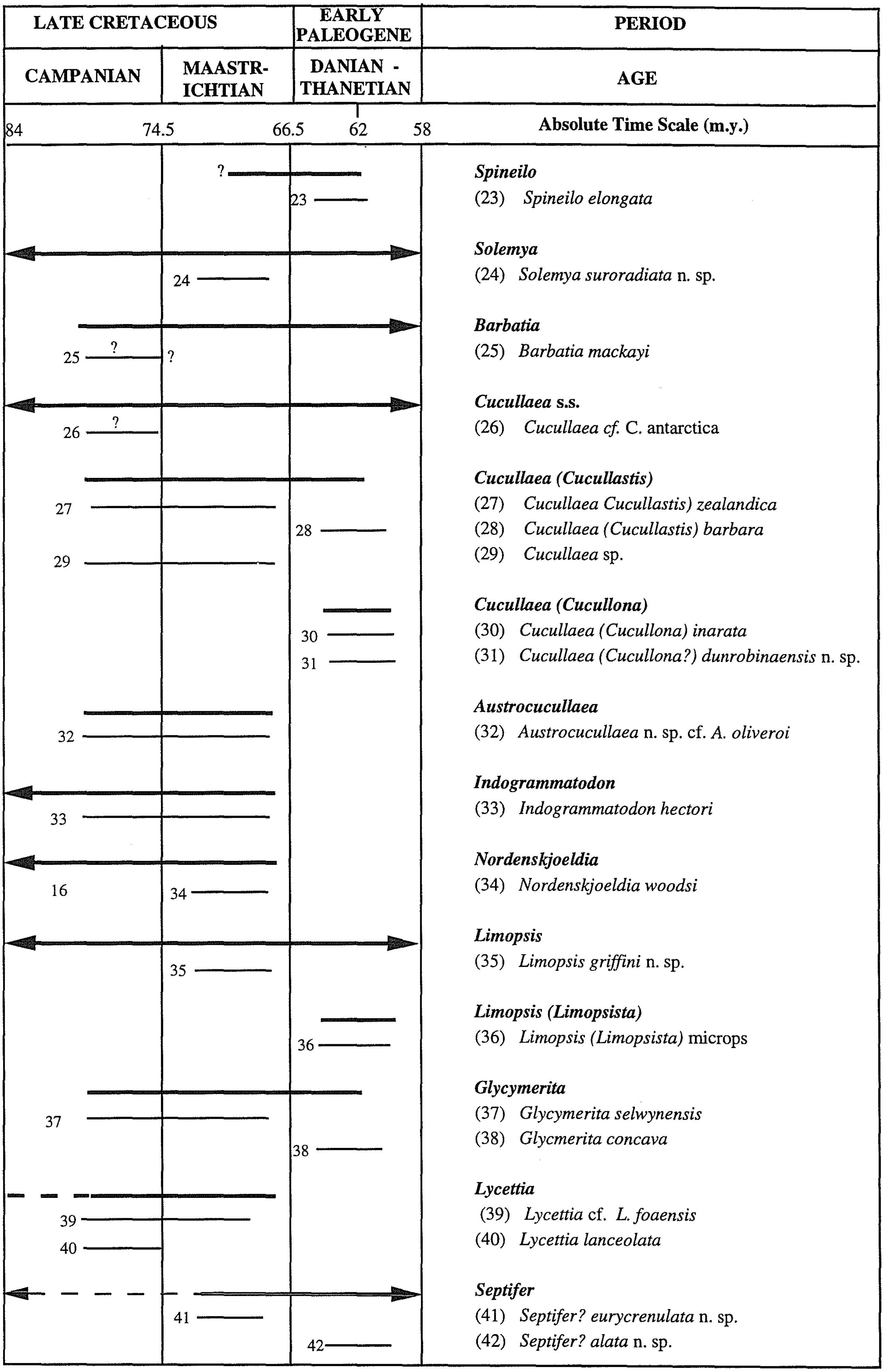
Pseudoportlandia
(17) *Pseudoportlandia* ? n. sp. A
(18) *Pseudoportlandia* ? n. sp. B

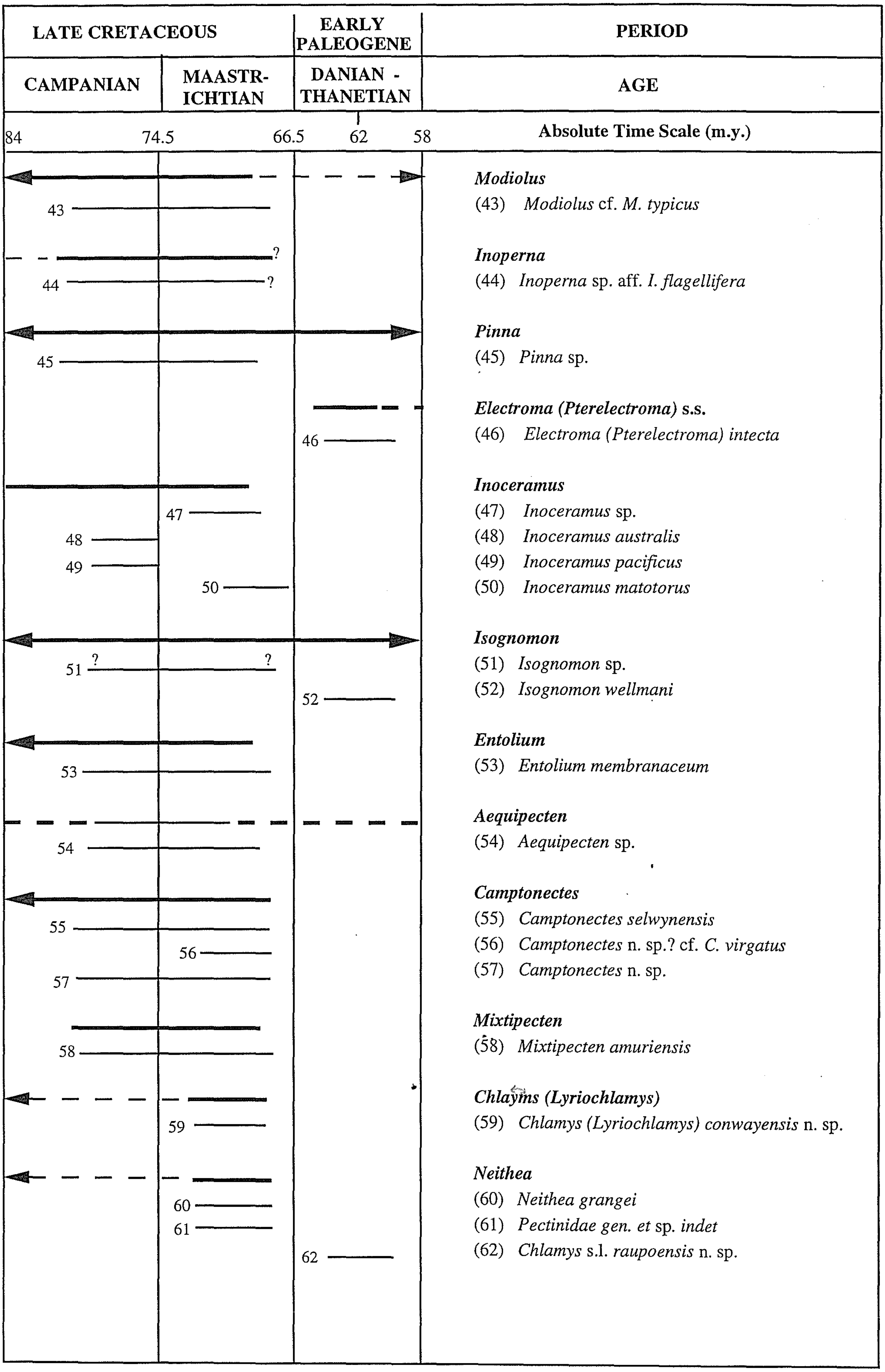
Tindaria
(19) *Tindaria ? veta* n. sp.

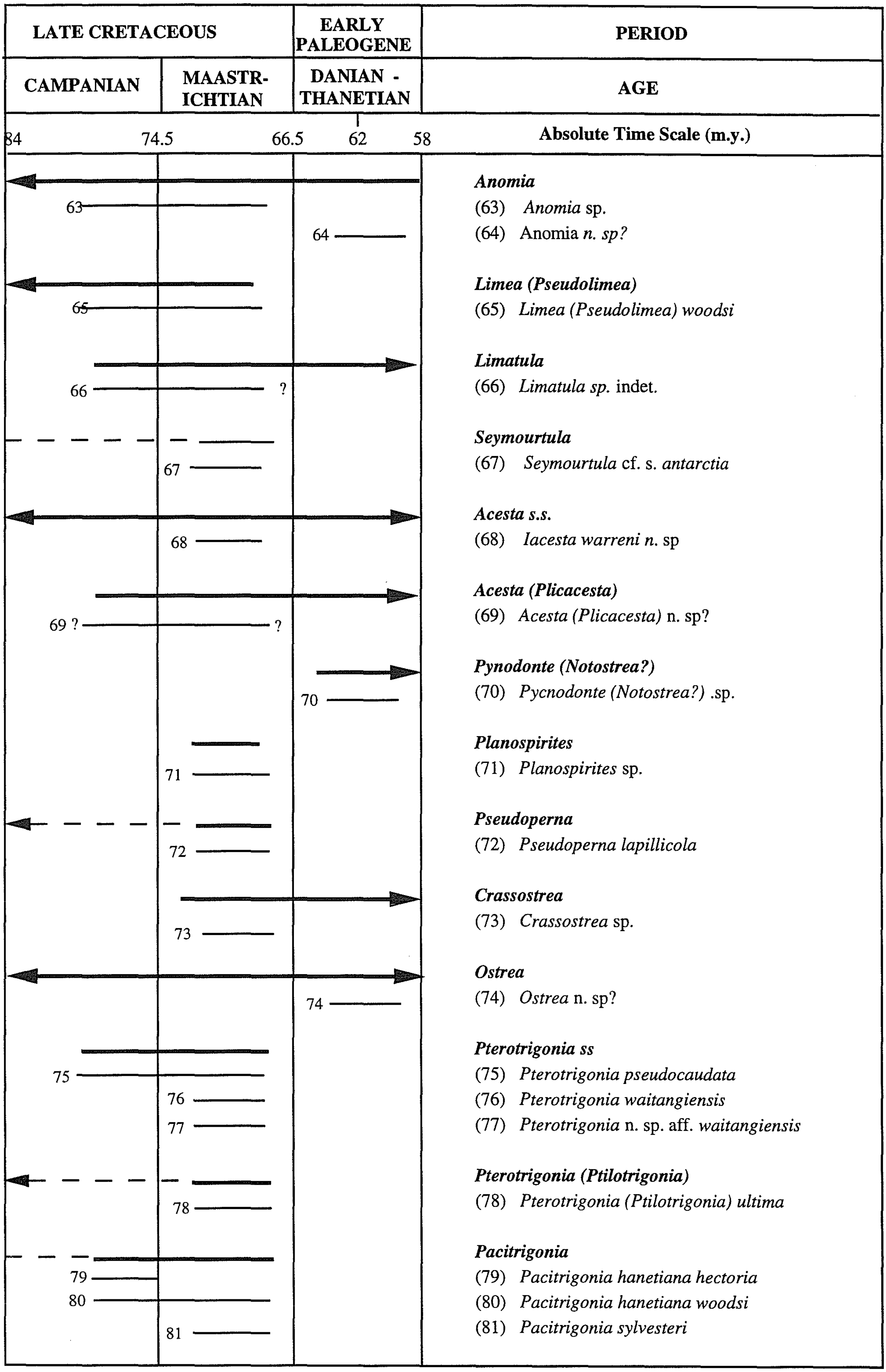
Neilo (Neiloides)
(20) *Neilo (Neiloides) cymbula*

Australoneilo
(21) *Australoneilo zelandica* n. sp.

Neilo
(22) *Neilo* n. sp.


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
?
23
Spineilo
(23) *Spineilo elongata*
24
Solemya
(24) *Solemya suroradiata* n. sp.
25
?
?
Barbatia
(25) *Barbatia mackayi*
26
?
Cucullaea s.s.
(26) *Cucullaea cf.* C. antarctica
27
28
29
Cucullaea (Cucullastis)
(27) *Cucullaea Cucullastis) zealandica*
(28) *Cucullaea (Cucullastis) barbara*
(29) *Cucullaea* sp.
30
31
Cucullaea (Cucullona)
(30) *Cucullaea (Cucullona) inarata*
(31) *Cucullaea (Cucullona?) dunrobinaensis* n. sp.
32
Austrocucullaea
(32) *Austrocucullaea* n. sp. cf. *A. oliveroi*
33
Indogrammatodon
(33) *Indogrammatodon hectori*
16
34
Nordenskjoeldia
(34) *Nordenskjoeldia woodsi*
35
Limopsis
(35) *Limopsis griffini* n. sp.
36
Limopsis (Limopsista)
(36) *Limopsis (Limopsista)* microps
37
38
Glycymerita
(37) *Glycymerita selwynensis*
(38) *Glycmerita concava*
39
40
Lycettia
(39) *Lycettia* cf. *L. foaensis*
(40) *Lycettia lanceolata*
41
42
Septifer
(41) *Septifer? eurycrenulata* n. sp.
(42) *Septifer? alata* n. sp.


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR- ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
43
44
?
?
45
46
47
48
49
50
51
?
?
52
53
54
55
56
57
58
59
60
61
62
Modiolus
(43) *Modiolus* cf. *M. typicus*
Inoperna
(44) *Inoperna* sp. aff. *I. flagellifera*
Pinna
(45) *Pinna* sp.
Electroma (Pterelectroma) s.s.
(46) *Electroma (Pterelectroma) intecta*
Inoceramus
(47) *Inoceramus* sp.
(48) *Inoceramus australis*
(49) *Inoceramus pacificus*
(50) *Inoceramus matotorus*
Isognomon
(51) *Isognomon* sp.
(52) *Isognomon wellmani*
Entolium
(53) *Entolium membranaceum*
Aequipecten
(54) *Aequipecten* sp.
Camptonectes
(55) *Camptonectes selwynensis*
(56) *Camptonectes* n. sp.? cf. *C. virgatus*
(57) *Camptonectes* n. sp.
Mixtipecten
(58) *Mixtipecten amuriensis*
Chlayms (Lyriochlamys)
(59) *Chlamys (Lyriochlamys) conwayensis* n. sp.
Neithea
(60) *Neithea grangei*
(61) *Pectinidae gen. et* sp. *indet*
(62) *Chlamys* s.l. *raupoensis* n. sp.


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Anomia
(63) *Anomia* sp.
(64) Anomia *n. sp?*
Limea (Pseudolimea)
(65) *Limea (Pseudolimea) woodsi*
Limatula
(66) *Limatula sp.* indet.
Seymourtula
(67) *Seymourtula* cf. s. *antarctia*
Acesta s.s.
(68) *Iacesta warreni n.* sp
Acesta (Plicacesta)
(69) *Acesta (Plicacesta)* n. sp?
Pynodonte (Notostrea?)
(70) *Pycnodonte (Notostrea?)* .sp.
Planospirites
(71) *Planospirites* sp.
Pseudoperna
(72) *Pseudoperna lapillicola*
Crassostrea
(73) *Crassostrea* sp.
Ostrea
(74) *Ostrea* n. sp?
Pterotrigonia ss
(75) *Pterotrigonia pseudocaudata*
(76) *Pterotrigonia waitangiensis*
(77) *Pterotrigonia* n. sp. aff. *waitangiensis*
Pterotrigonia (Ptilotrigonia)
(78) *Pterotrigonia (Ptilotrigonia) ultima*
Pacitrigonia
(79) *Pacitrigonia hanetiana hectoria*
(80) *Pacitrigonia hanetiana woodsi*
(81) *Pacitrigonia sylvesteri*
63
64
65
66 ?
67
68
69 ? ?
70
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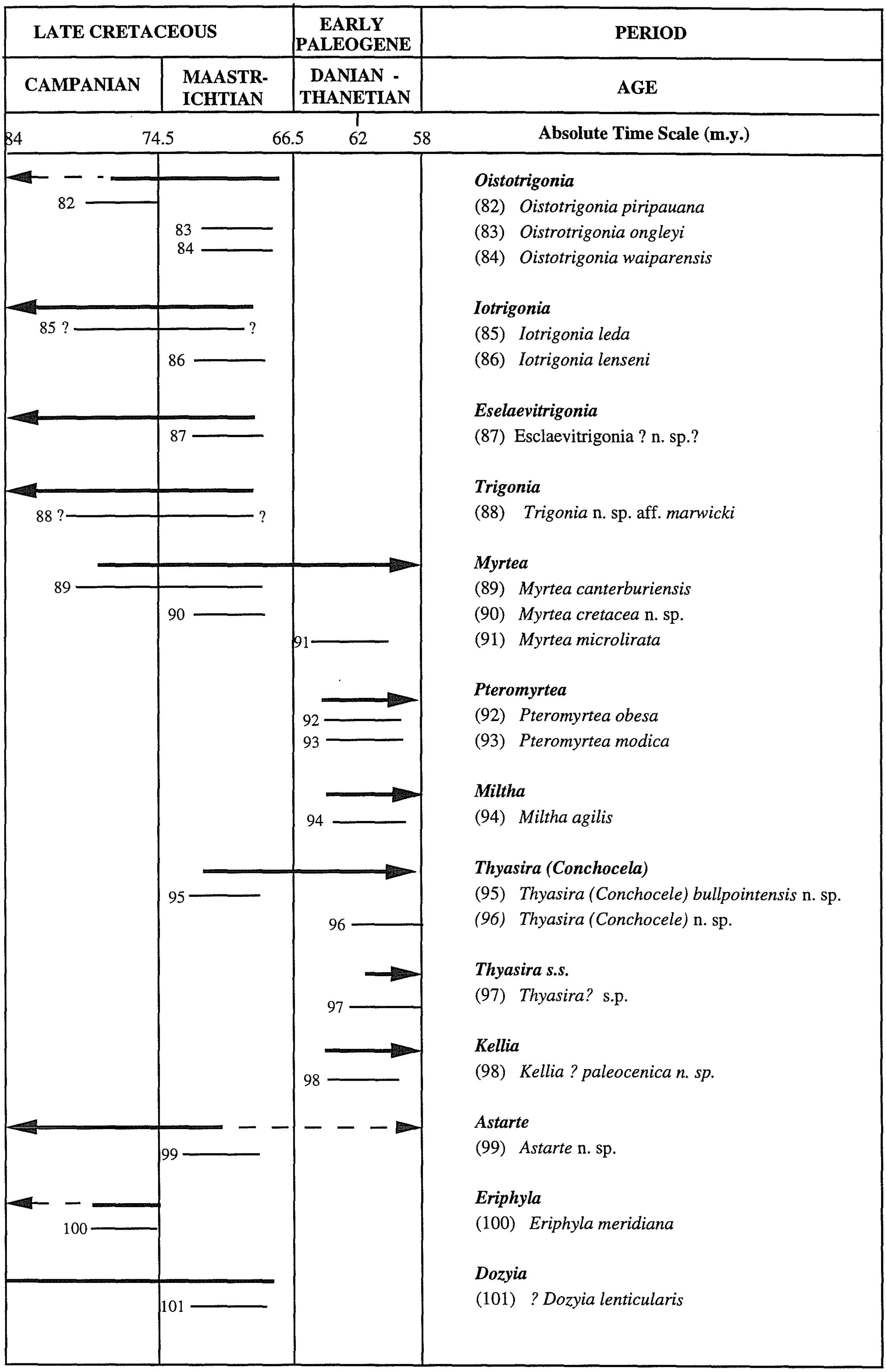
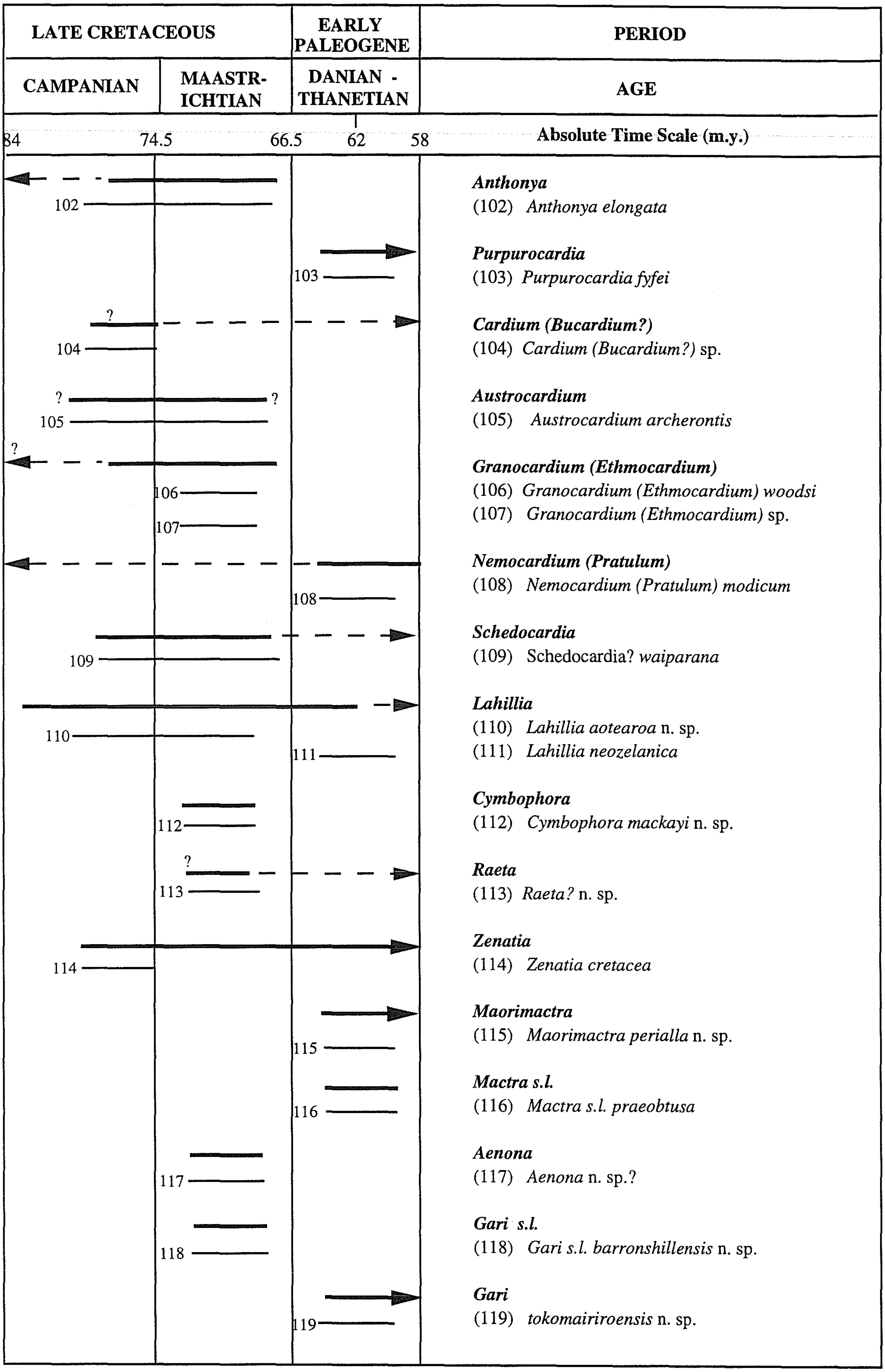

LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Oistotrigonia
82
83
84
(82) Oistotrigonia piripauana
(83) Oistrotrigonia ongleyi
(84) Oistotrigonia waiparensis
Iotrigonia
85 ? ?
86
(85) Iotrigonia leda
(86) Iotrigonia lenseni
Eselaevitrigonia
87
(87) Esclaevitrigonia ? n. sp.?
Trigonia
88 ? ?
(88) Trigonia n. sp. aff. marwicki
Myrtea
89
90
91
(89) Myrtea canterburiensis
(90) Myrtea cretacea n. sp.
(91) Myrtea microlirata
Pteromyrtea
92
93
(92) Pteromyrtea obesa
(93) Pteromyrtea modica
Miltha
94
(94) Miltha agilis
Thyasira (Conchocela)
95
96
(95) Thyasira (Conchocele) bullpointensis n. sp.
(96) Thyasira (Conchocele) n. sp.
Thyasira s.s.
97
(97) Thyasira? s.p.
Kellia
98
(98) Kellia ? paleocenica n. sp.
Astarte
99
(99) Astarte n. sp.
Eriphyla
100
(100) Eriphyla meridiana
Dozyia
101
(101) ? Dozyia lenticularis


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Anthonya
(102) *Anthonya elongata*
Purpurocardia
(103) *Purpurocardia fyfei*
Cardium (Bucardium?)
(104) *Cardium (Bucardium?)* sp.
Austrocardium
(105) *Austrocardium archerontis*
Granocardium (Ethmocardium)
(106) *Granocardium (Ethmocardium) woodsi*
(107) *Granocardium (Ethmocardium)* sp.
Nemocardium (Pratulum)
(108) *Nemocardium (Pratulum) modicum*
Schedocardia
(109) Schedocardia? *waiparana*
Lahillia
(110) *Lahillia aotearoa* n. sp.
(111) *Lahillia neozelanica*
Cymbophora
(112) *Cymbophora mackayi* n. sp.
Raeta
(113) *Raeta?* n. sp.
Zenatia
(114) *Zenatia cretacea*
Maorimactra
(115) *Maorimactra perialla* n. sp.
Mactra s.l.
(116) *Mactra s.l. praeobtusa*
Aenona
(117) *Aenona* n. sp.?
Gari s.l.
(118) *Gari s.l. barronshillensis* n. sp.
Gari
(119) *tokomairiroensis* n. sp.
102
103
?
104
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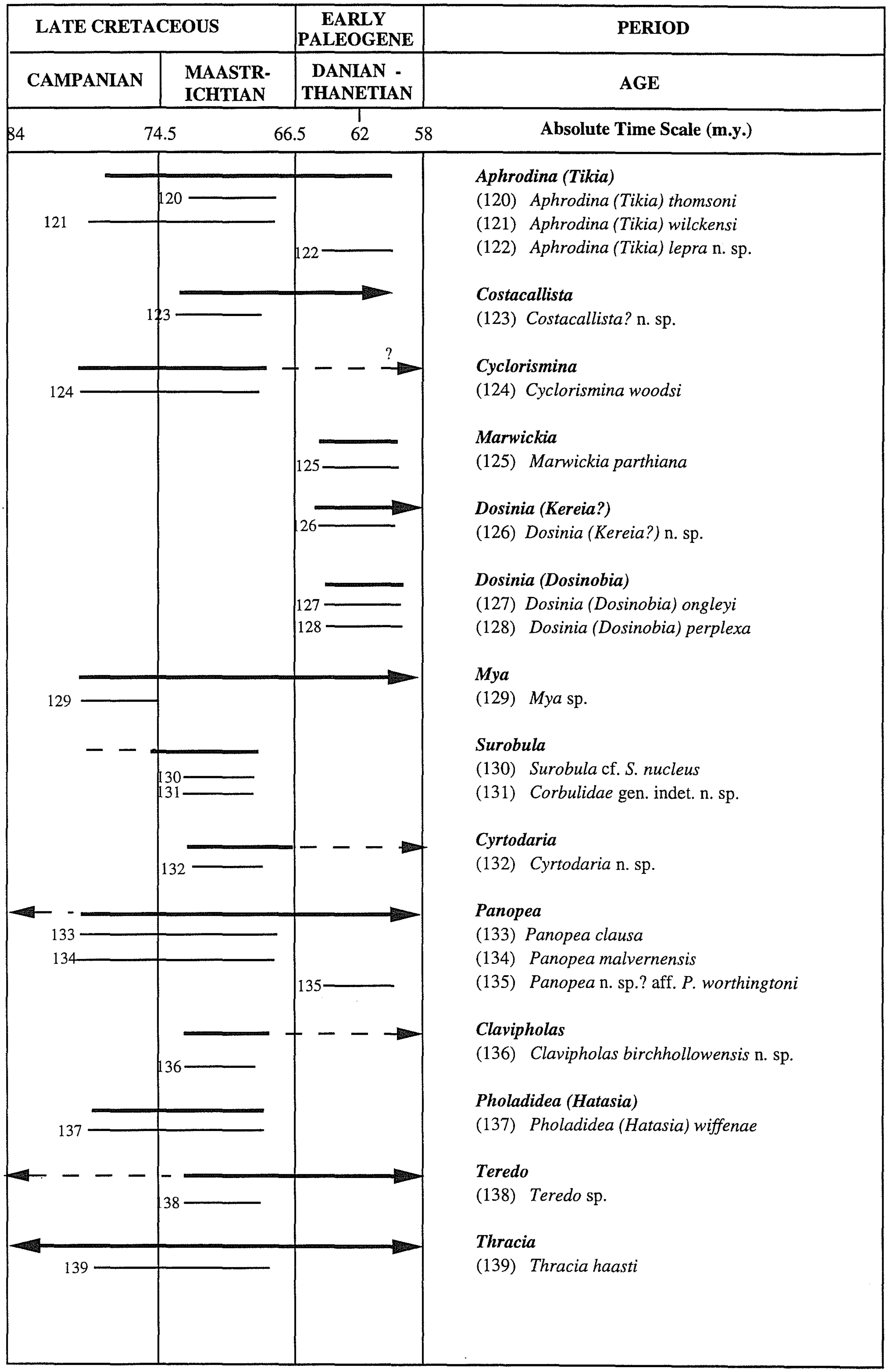
LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Aphrodina (Tikia)
(120) Aphrodina (Tikia) thomsoni
(121) Aphrodina (Tikia) wilckensi
(122) Aphrodina (Tikia) lepra n. sp.
Costacallista
(123) Costacallista? n. sp.
Cyclorismina
(124) Cyclorismina woodsi
Marwickia
(125) Marwickia parthiana
Dosinia (Kereia?)
(126) Dosinia (Kereia?) n. sp.
Dosinia (Dosinobia)
(127) Dosinia (Dosinobia) ongleyi
(128) Dosinia (Dosinobia) perplexa
Mya
(129) Mya sp.
Surobula
(130) Surobula cf. S. nucleus
(131) Corbulidae gen. indet. n. sp.
Cyrtodaria
(132) Cyrtodaria n. sp.
Panopea
(133) Panopea clausa
(134) Panopea malvernensis
(135) Panopea n. sp.? aff. P. worthingtoni
Clavipholas
(136) Clavipholas birchhollowensis n. sp.
Pholadidea (Hatasia)
(137) Pholadidea (Hatasia) wiffenae
Teredo
(138) Teredo sp.
Thracia
(139) Thracia haasti
120
121
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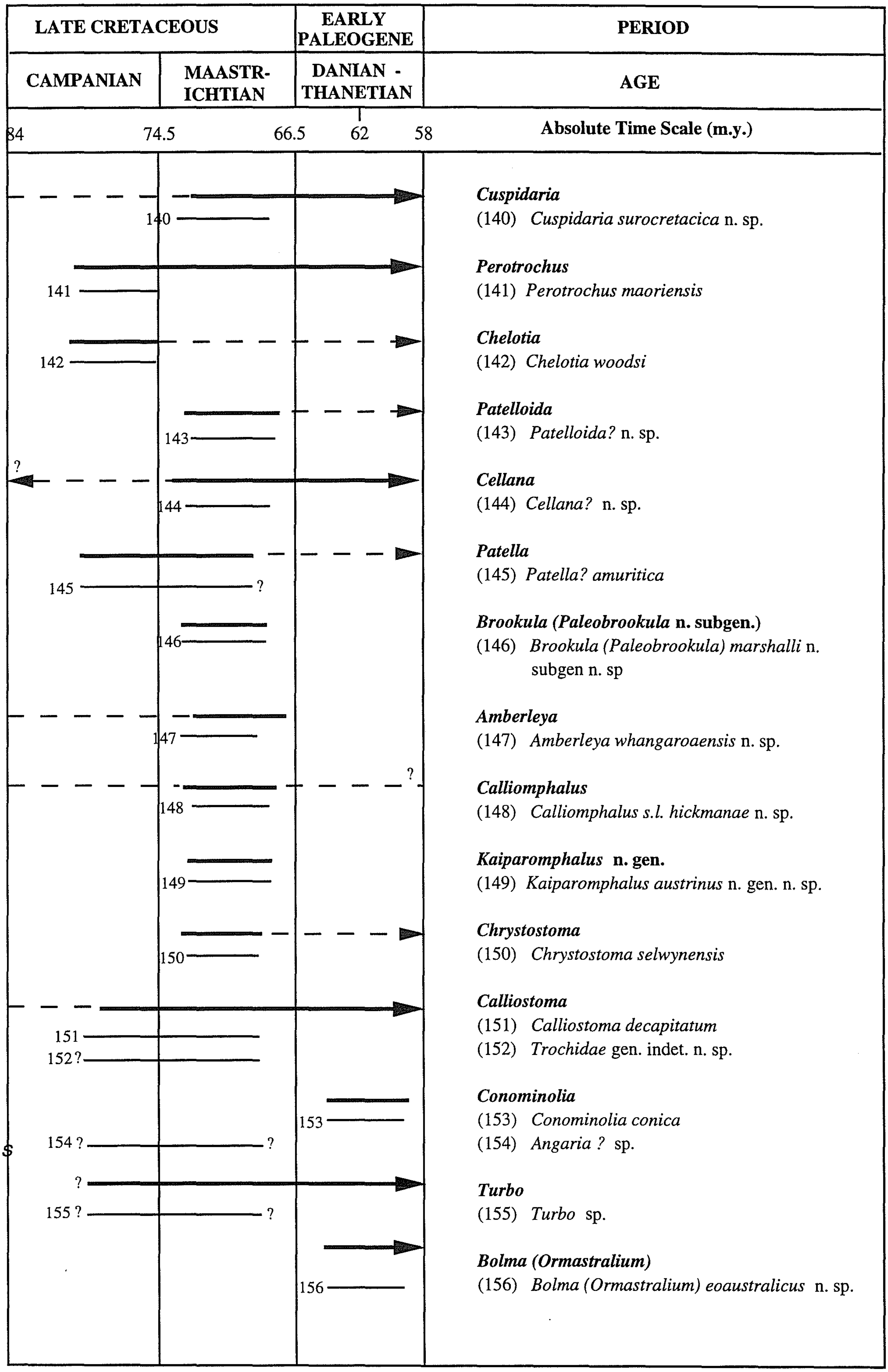
139



Cuspidaria
(140) *Cuspidaria surocretacica* n. sp.

Perotrochus
(141) *Perotrochus maoriensis*

Chelotia
(142) *Chelotia woodsi*

Patelloida
(143) *Patelloida?* n. sp.

Cellana
(144) *Cellana?* n. sp.

Patella
(145) *Patella? amuritica*

Brookula (Paleobrookula **n. subgen.)**
(146) *Brookula (Paleobrookula) marshalli* n. subgen n. sp

Amberleya
(147) *Amberleya whangaroaensis* n. sp.

Calliomphalus
(148) *Calliomphalus s.l. hickmanae* n. sp.

Kaiparomphalus **n. gen.**
(149) *Kaiparomphalus austrinus* n. gen. n. sp.

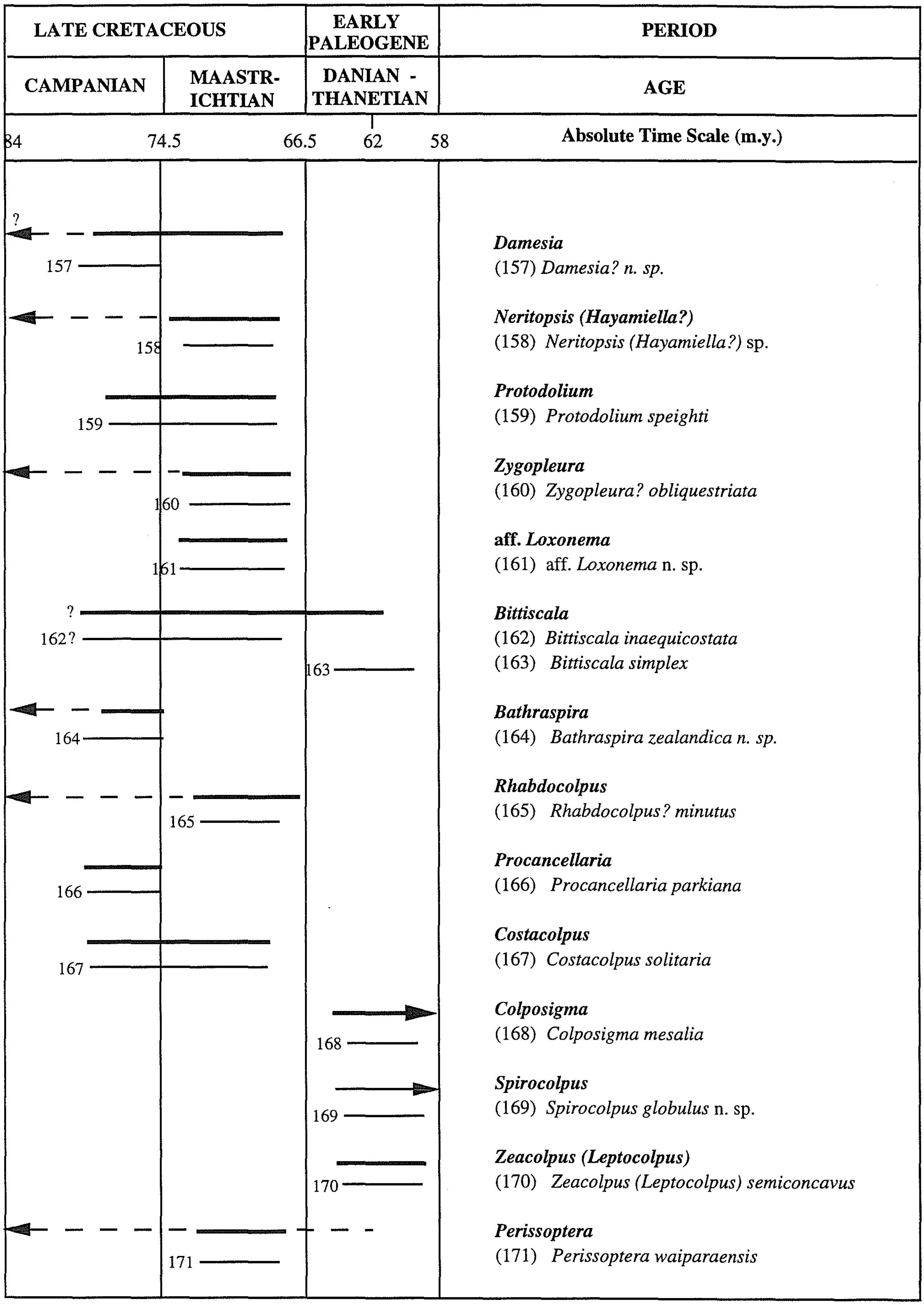
Chrystostoma
(150) *Chrystostoma selwynensis*

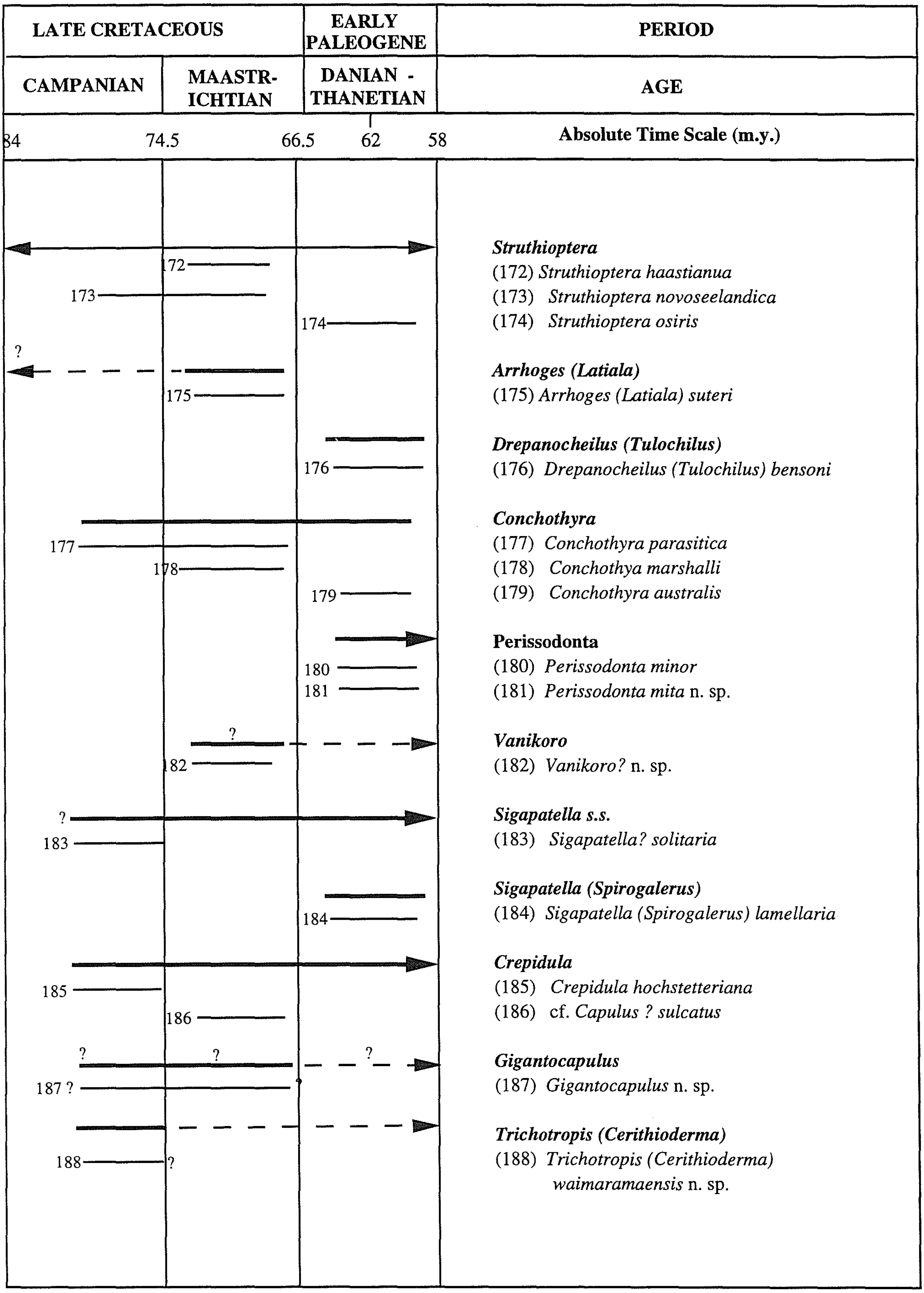
Calliostoma
(151) *Calliostoma decapitatum*
(152) *Trochidae* gen. indet. n. sp.

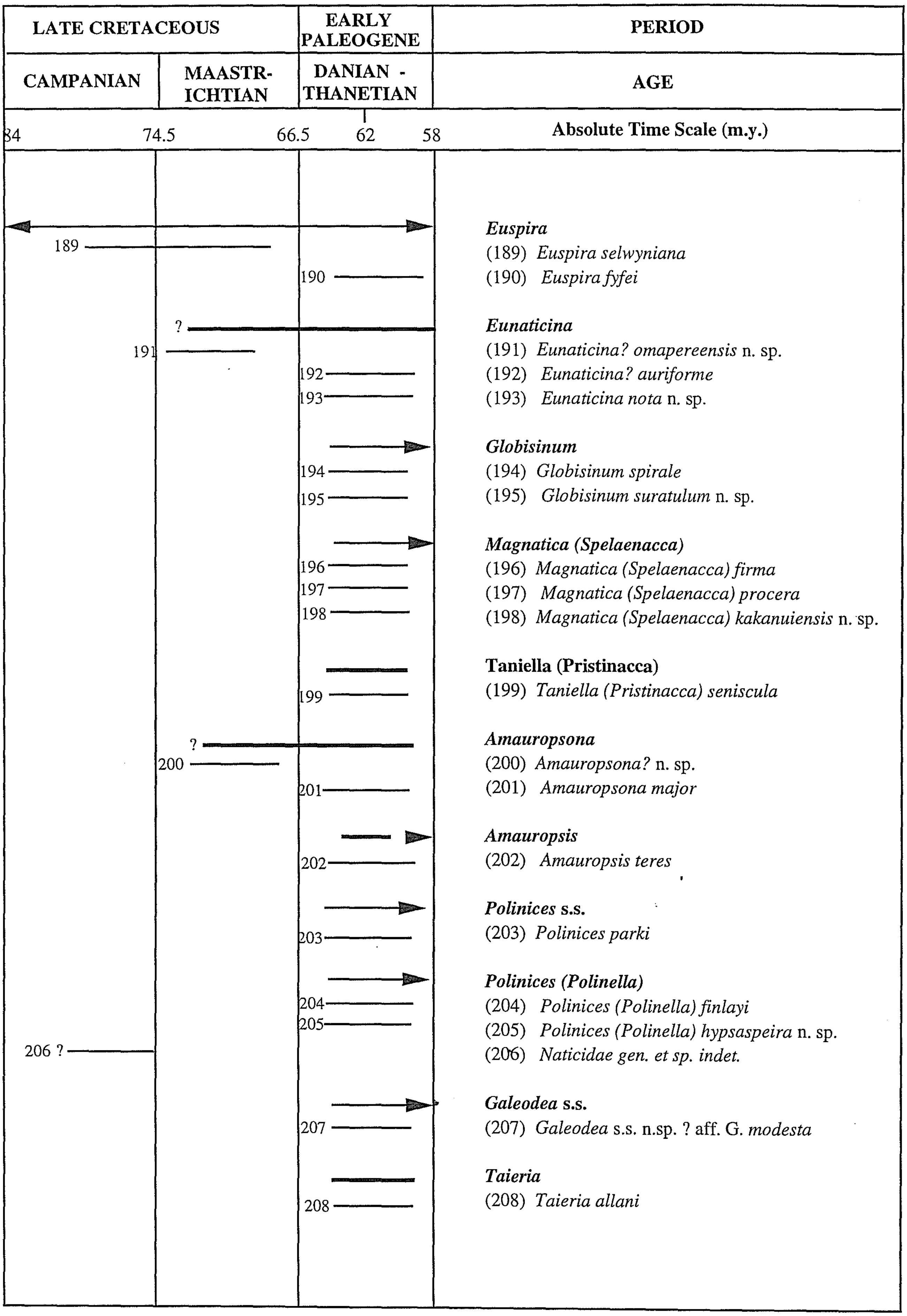
Conominolia
(153) *Conominolia conica*
(154) *Angaria ?* sp.

Turbo
(155) *Turbo* sp.

Bolma (Ormastralium)
(156) *Bolma (Ormastralium) eoaustralicus* n. sp.


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR- ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
?
157
158
159
160
161
?
162?
163
164
165
166
167
168
169
170
171
Damesia
(157) *Damesia? n. sp.*
Neritopsis (Hayamiella?)
(158) *Neritopsis (Hayamiella?)* sp.
Protodolium
(159) *Protodolium speighti*
Zygopleura
(160) *Zygopleura? obliquestriata*
aff. *Loxonema*
(161) aff. *Loxonema* n. sp.
Bittiscala
(162) *Bittiscala inaequicostata*
(163) *Bittiscala simplex*
Bathraspira
(164) *Bathraspira zealandica n. sp.*
Rhabdocolpus
(165) *Rhabdocolpus? minutus*
Procancellaria
(166) *Procancellaria parkiana*
Costacolpus
(167) *Costacolpus solitaria*
Colposigma
(168) *Colposigma mesalia*
Spirocolpus
(169) *Spirocolpus globulus* n. sp.
Zeacolpus (Leptocolpus)
(170) *Zeacolpus (Leptocolpus) semiconcavus*
Perissoptera
(171) *Perissoptera waiparaensis*


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
172
173
174
?
175
176
177
178
179
180
181
?
182
?
183
184
185
186
?
?
?
187 ?
188
?
Struthioptera
(172) *Struthioptera haastianua*
(173) *Struthioptera novoseelandica*
(174) *Struthioptera osiris*
Arrhoges (Latiala)
(175) *Arrhoges (Latiala) suteri*
Drepanocheilus (Tulochilus)
(176) *Drepanocheilus (Tulochilus) bensoni*
Conchothyra
(177) *Conchothyra parasitica*
(178) *Conchothya marshalli*
(179) *Conchothyra australis*
Perissodonta
(180) *Perissodonta minor*
(181) *Perissodonta mita* n. sp.
Vanikoro
(182) *Vanikoro?* n. sp.
Sigapatella s.s.
(183) *Sigapatella? solitaria*
Sigapatella (Spirogalerus)
(184) *Sigapatella (Spirogalerus) lamellaria*
Crepidula
(185) *Crepidula hochstetteriana*
(186) cf. *Capulus ? sulcatus*
Gigantocapulus
(187) *Gigantocapulus* n. sp.
Trichotropis (Cerithioderma)
(188) *Trichotropis (Cerithioderma) waimaramaensis* n. sp.



Euspira
(189) *Euspira selwyniana*
(190) *Euspira fyfei*

Eunaticina
(191) *Eunaticina? omapereensis* n. sp.
(192) *Eunaticina? auriforme*
(193) *Eunaticina nota* n. sp.

Globisinum
(194) *Globisinum spirale*
(195) *Globisinum suratulum* n. sp.

Magnatica (Spelaenacca)
(196) *Magnatica (Spelaenacca) firma*
(197) *Magnatica (Spelaenacca) procera*
(198) *Magnatica (Spelaenacca) kakanuiensis* n. sp.

Taniella (Pristinacca)
(199) *Taniella (Pristinacca) seniscula*

Amauropsona
(200) *Amauropsona?* n. sp.
(201) *Amauropsona major*

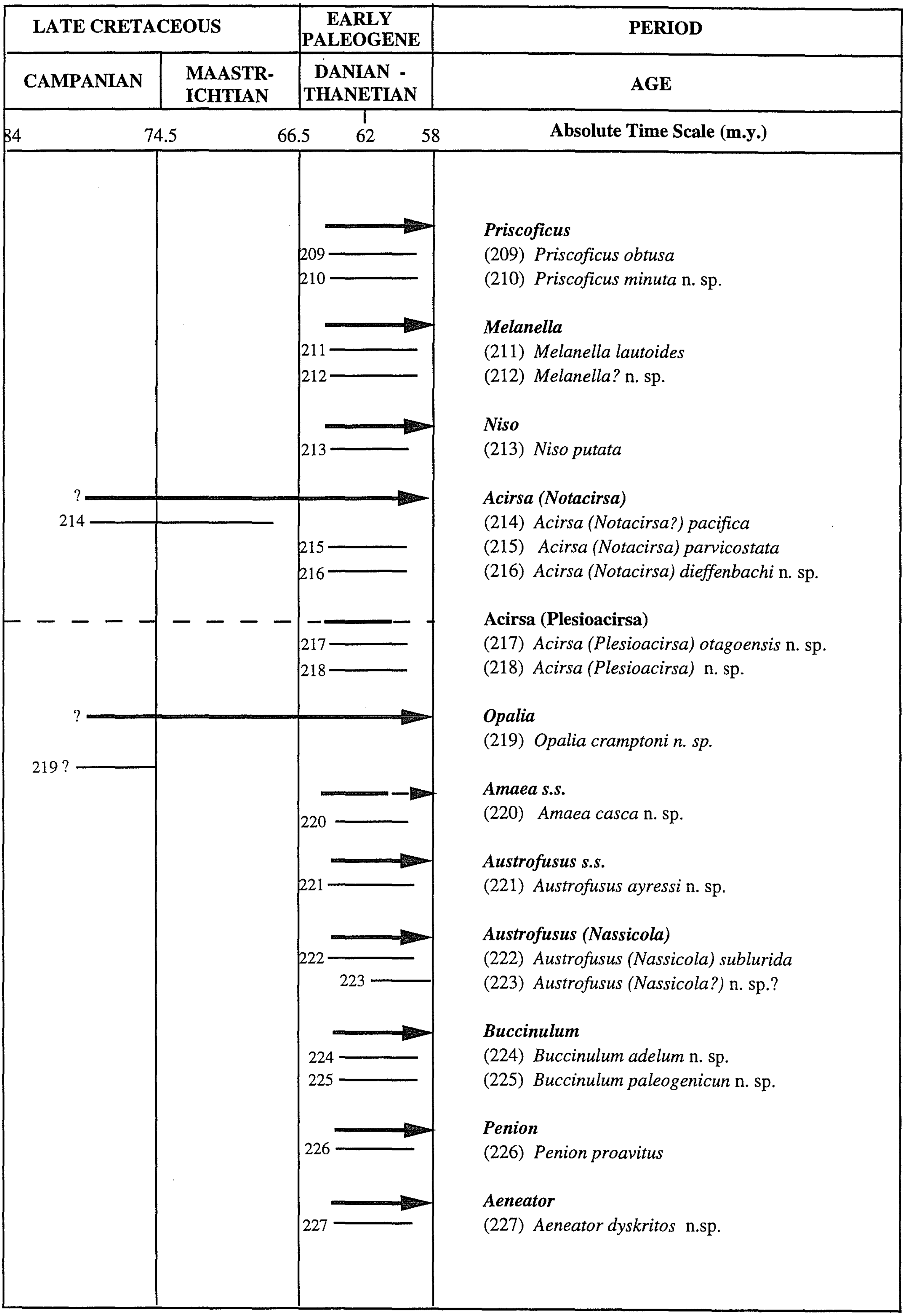
Amauropsis
(202) *Amauropsis teres*

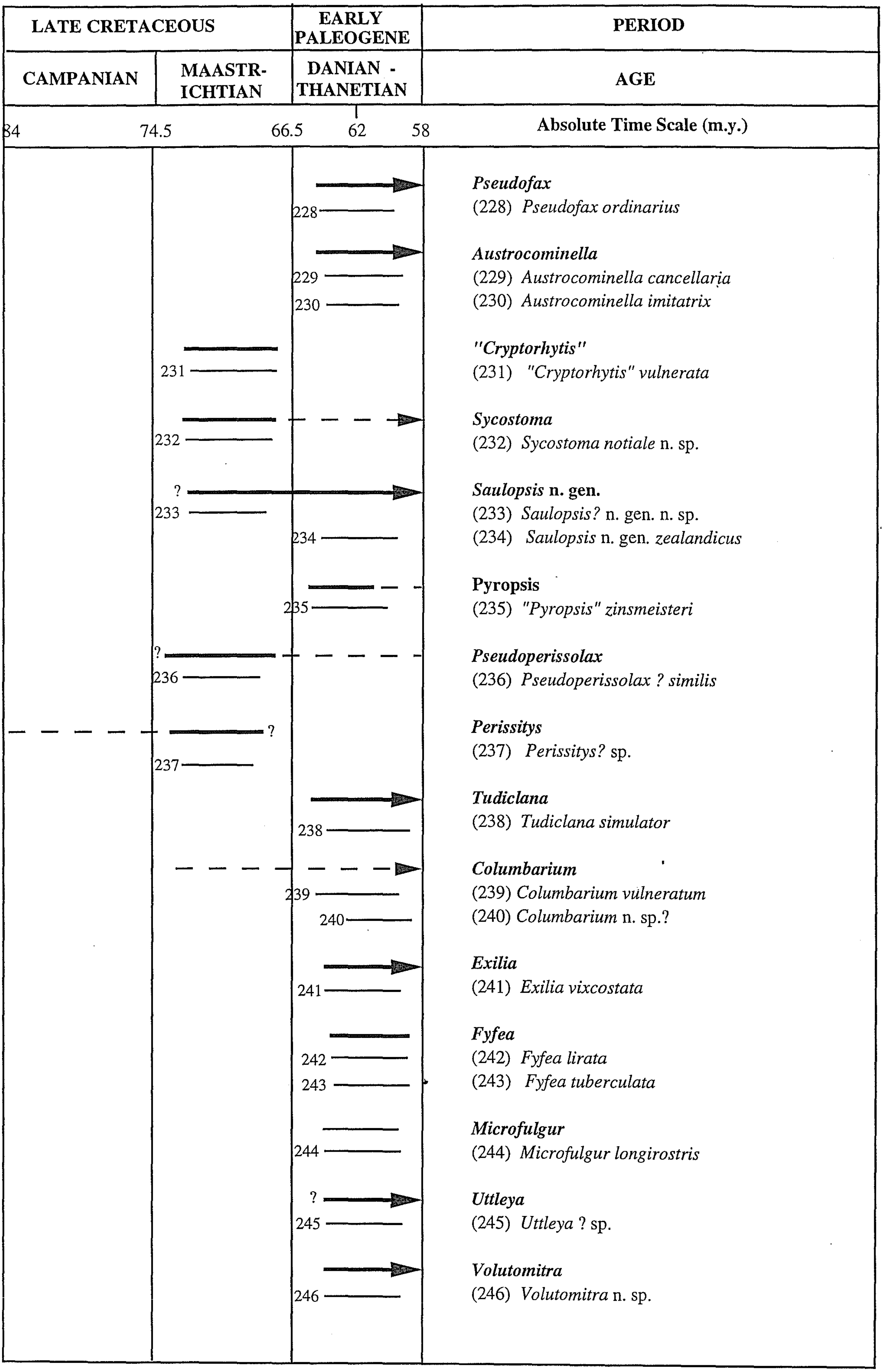
***Polinices* s.s.**
(203) *Polinices parki*

Polinices (Polinella)
(204) *Polinices (Polinella) finlayi*
(205) *Polinices (Polinella) hypsaspeira* n. sp.
(206) *Naticidae gen. et sp. indet.*

***Galeodea* s.s.**
(207) *Galeodea* s.s. n.sp. ? aff. G. *modesta*

Taieria
(208) *Taieria allani*


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
209
210
211
212
213
?
214
215
216
217
218
?
219 ?
220
221
222
223
224
225
226
227
Priscoficus
(209) Priscoficus obtusa
(210) Priscoficus minuta n. sp.
Melanella
(211) Melanella lautoides
(212) Melanella? n. sp.
Niso
(213) Niso putata
Acirsa (Notacirsa)
(214) Acirsa (Notacirsa?) pacifica
(215) Acirsa (Notacirsa) parvicostata
(216) Acirsa (Notacirsa) dieffenbachi n. sp.
Acirsa (Plesioacirsa)
(217) Acirsa (Plesioacirsa) otagoensis n. sp.
(218) Acirsa (Plesioacirsa) n. sp.
Opalia
(219) Opalia cramptoni n. sp.
Amaea s.s.
(220) Amaea casca n. sp.
Austrofusus s.s.
(221) Austrofusus ayressi n. sp.
Austrofusus (Nassicola)
(222) Austrofusus (Nassicola) sublurida
(223) Austrofusus (Nassicola?) n. sp.?
Buccinulum
(224) Buccinulum adelum n. sp.
(225) Buccinulum paleogenicun n. sp.
Penion
(226) Penion proavitus
Aeneator
(227) Aeneator dyskritos n.sp.


LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR- ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Pseudofax
(228) *Pseudofax ordinarius*
Austrocominella
(229) *Austrocominella cancellaria*
(230) *Austrocominella imitatrix*
"Cryptorhytis"
(231) *"Cryptorhytis" vulnerata*
Sycostoma
(232) *Sycostoma notiale* n. sp.
Saulopsis **n. gen.**
(233) *Saulopsis?* n. gen. n. sp.
(234) *Saulopsis* n. gen. *zealandicus*
Pyropsis
(235) *"Pyropsis" zinsmeisteri*
Pseudoperissolax
(236) *Pseudoperissolax ? similis*
Perissitys
(237) *Perissitys?* sp.
Tudiclana
(238) *Tudiclana simulator*
Columbarium
(239) *Columbarium vulneratum*
(240) *Columbarium* n. sp.?
Exilia
(241) *Exilia vixcostata*
Fyfea
(242) *Fyfea lirata*
(243) *Fyfea tuberculata*
Microfulgur
(244) *Microfulgur longirostris*
Uttleya
(245) *Uttleya* ? sp.
Volutomitra
(246) *Volutomitra* n. sp.
228
229
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?
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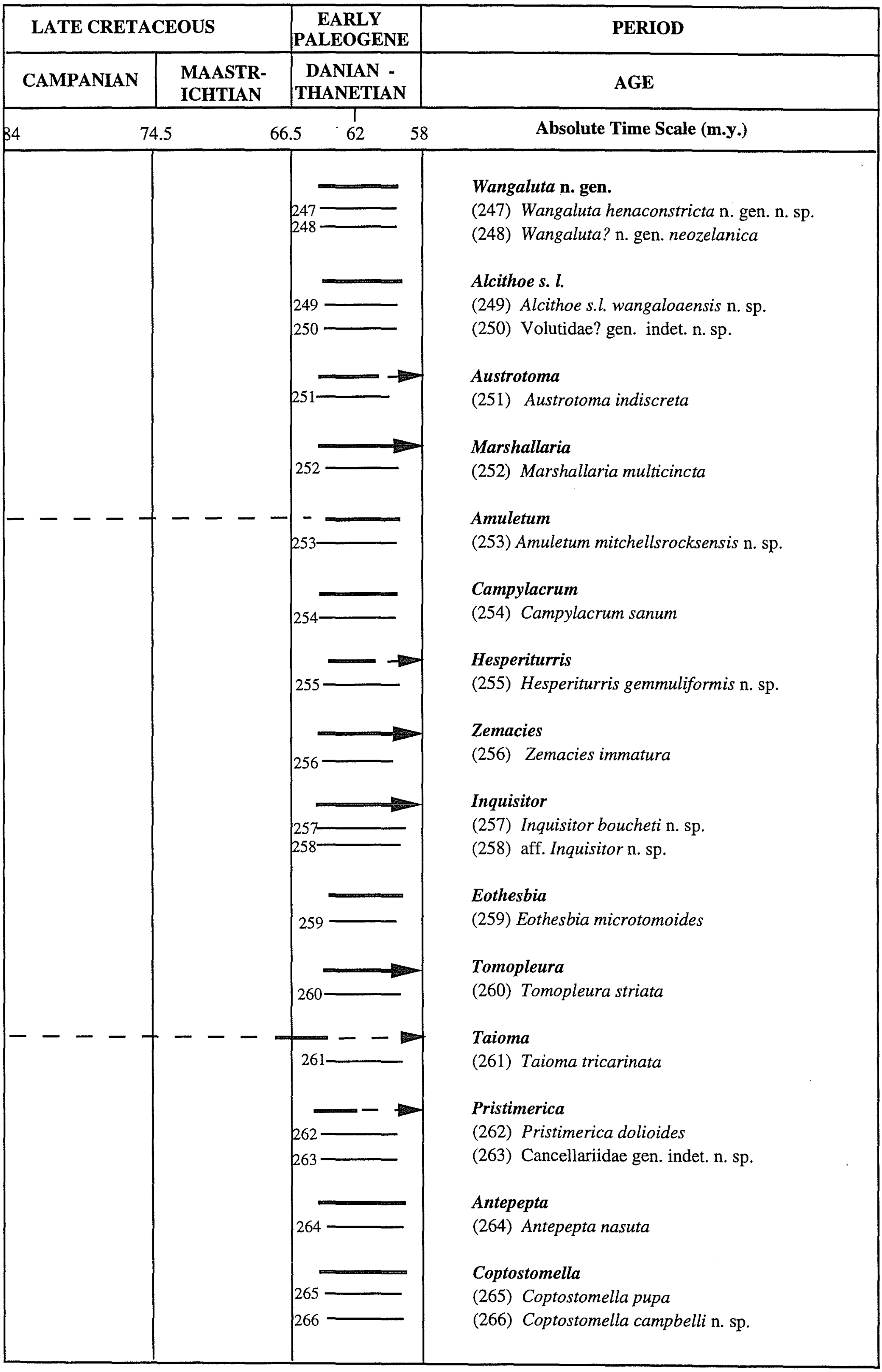
LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Wangaluta n. gen.
(247) Wangaluta henaconstricta n. gen. n. sp.
(248) Wangaluta? n. gen. neozelanica
Alcithoe s. l.
(249) Alcithoe s.l. wangaloaensis n. sp.
(250) Volutidae? gen. indet. n. sp.
Austrotoma
(251) Austrotoma indiscreta
Marshallaria
(252) Marshallaria multicincta
Amuletum
(253) Amuletum mitchellsrocksensis n. sp.
Campylacrum
(254) Campylacrum sanum
Hesperiturris
(255) Hesperiturris gemmuliformis n. sp.
Zemacies
(256) Zemacies immatura
Inquisitor
(257) Inquisitor boucheti n. sp.
(258) aff. Inquisitor n. sp.
Eothesbia
(259) Eothesbia microtomoides
Tomopleura
(260) Tomopleura striata
Taioma
(261) Taioma tricarinata
Pristimerica
(262) Pristimerica dolioides
(263) Cancellariidae gen. indet. n. sp.
Antepepta
(264) Antepepta nasuta
Coptostomella
(265) Coptostomella pupa
(266) Coptostomella campbelli n. sp.
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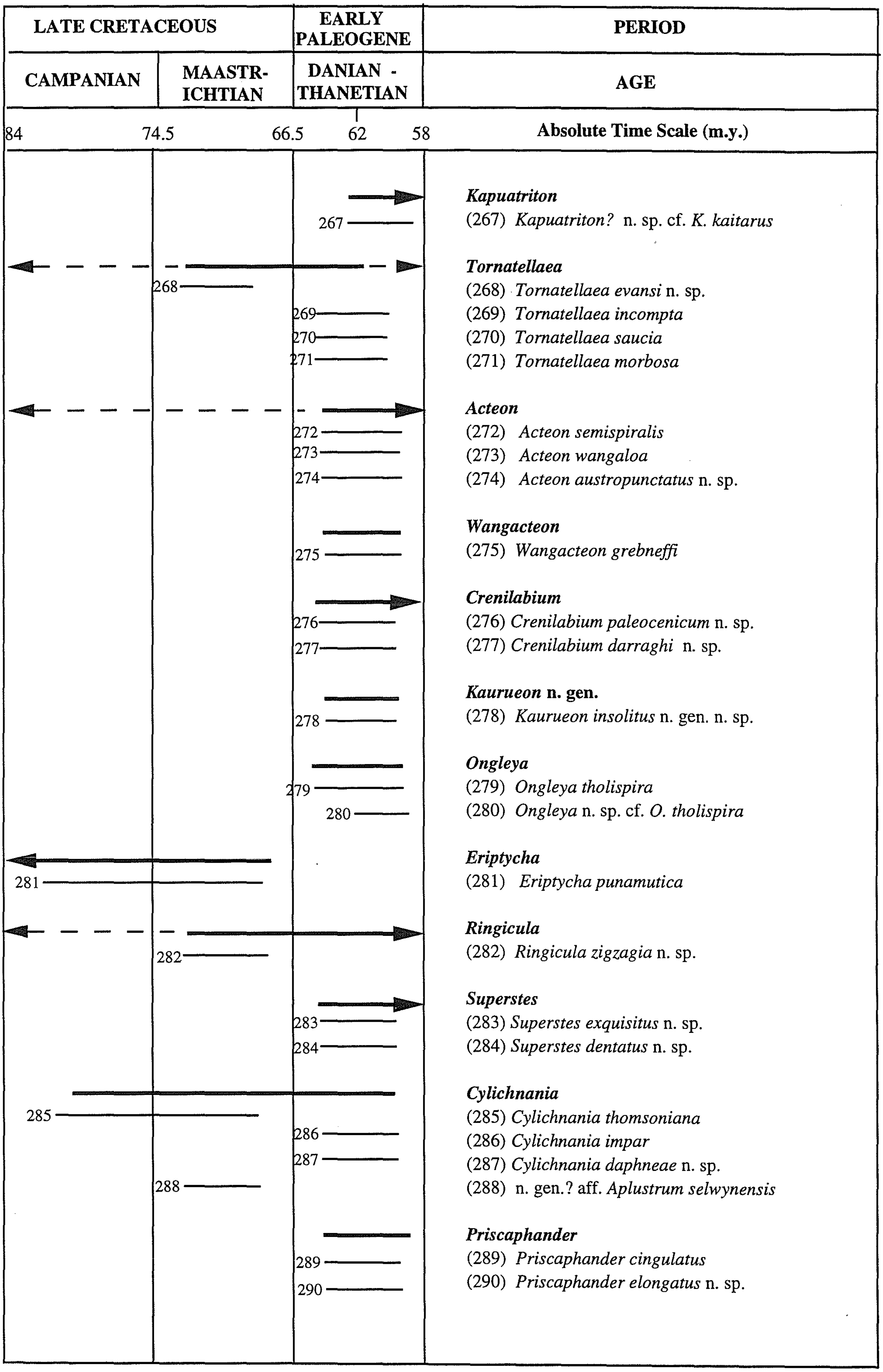
LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Kapuatriton
(267) Kapuatriton? n. sp. cf. K. kaitarus
Tornatellaea
(268) Tornatellaea evansi n. sp.
(269) Tornatellaea incompta
(270) Tornatellaea saucia
(271) Tornatellaea morbosa
Acteon
(272) Acteon semispiralis
(273) Acteon wangaloa
(274) Acteon austropunctatus n. sp.
Wangacteon
(275) Wangacteon grebneffi
Crenilabium
(276) Crenilabium paleocenicum n. sp.
(277) Crenilabium darraghi n. sp.
Kaurueon n. gen.
(278) Kaurueon insolitus n. gen. n. sp.
Ongleya
(279) Ongleya tholispira
(280) Ongleya n. sp. cf. O. tholispira
Eriptycha
(281) Eriptycha punamutica
Ringicula
(282) Ringicula zigzagia n. sp.
Superstes
(283) Superstes exquisitus n. sp.
(284) Superstes dentatus n. sp.
Cylichnania
(285) Cylichnania thomsoniana
(286) Cylichnania impar
(287) Cylichnania daphneae n. sp.
(288) n. gen.? aff. Aplustrum selwynensis
Priscaphander
(289) Priscaphander cingulatus
(290) Priscaphander elongatus n. sp.
267
268
269
270
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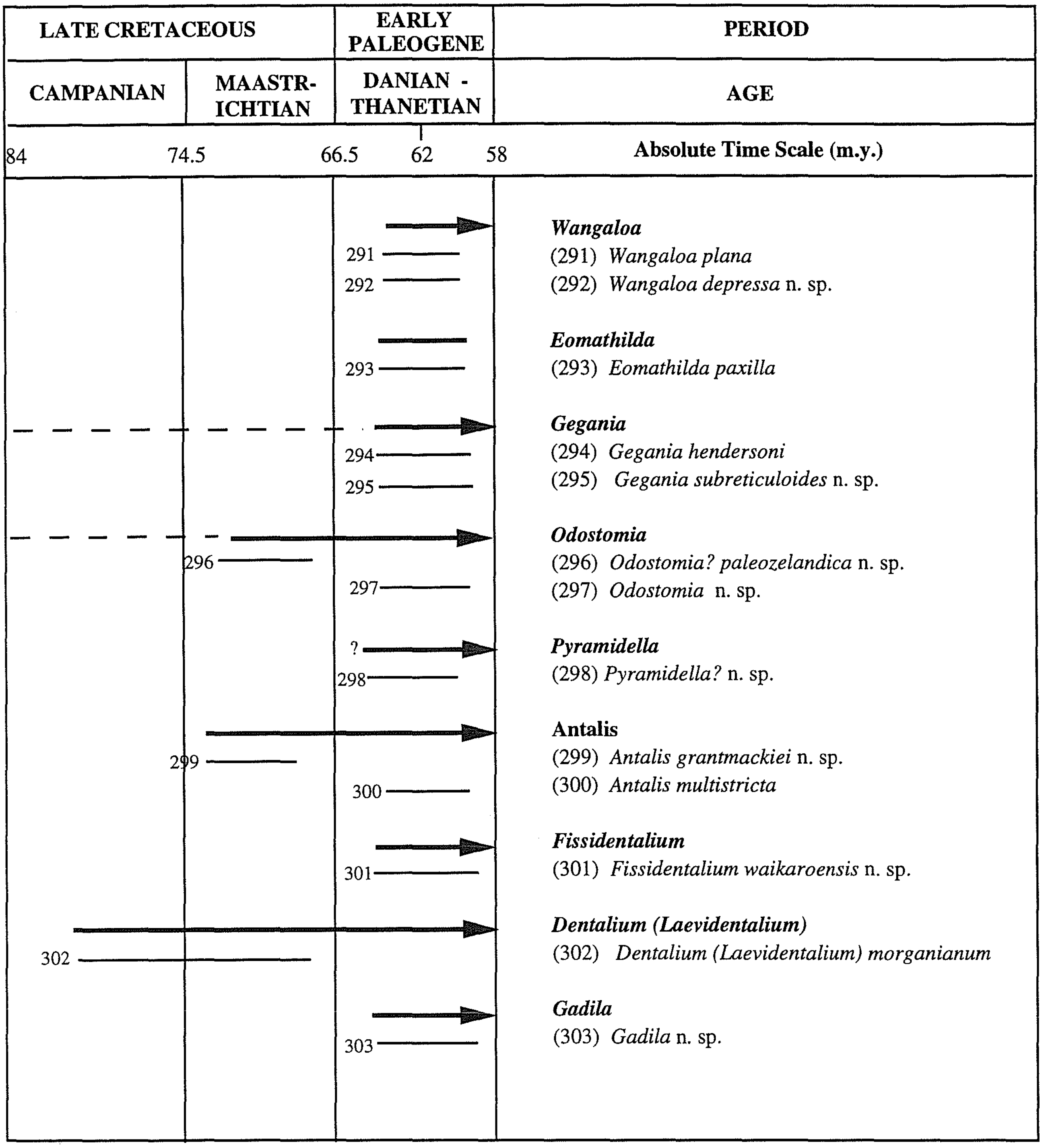

LATE CRETACEOUS
EARLY PALEOGENE
PERIOD
CAMPANIAN
MAASTR-ICHTIAN
DANIAN - THANETIAN
AGE
84
74.5
66.5
62
58
Absolute Time Scale (m.y.)
Wangaloa
291
292
(291) Wangaloa plana
(292) Wangaloa depressa n. sp.
Eomathilda
293
(293) Eomathilda paxilla
Gegania
294
295
(294) Gegania hendersoni
(295) Gegania subreticuloides n. sp.
Odostomia
296
297
(296) Odostomia? paleozelandica n. sp.
(297) Odostomia n. sp.
Pyramidella
?
298
(298) Pyramidella? n. sp.
Antalis
299
300
(299) Antalis grantmackiei n. sp.
(300) Antalis multistricta
Fissidentalium
301
(301) Fissidentalium waikaroensis n. sp.
Dentalium (Laevidentalium)
302
(302) Dentalium (Laevidentalium) morganianum
Gadila
303
(303) Gadila n. sp.

Stratigraphic appearances of Late Cretaceous taxa

Several taxa, which appeared for the first time in the fossil record of New Zealand during the Late Cretaceous, were previously recorded from much younger rocks before this study (see Table 4). The abrupt appearance of many groups at this time reflects probably both the incompletely known record of some New Zealand Cretaceous molluscs older than the Campanian and changing paleogeography associated with New Zealand's separation and soon-to-follow isolation from the Gondwana margin. Of 79 recorded New Zealand bivalve genera/subgenera in this work, 51 (c. 65%) are recorded for the first time in the Late Cretaceous. The paleoaustral nuculid bivalve Linucula made its first appearance in the Haumurian of Northland and crossed the K-T boundary into the "Wangaloan" (Paleocene); previously this genus was recorded in rocks of Duntroonian (Upper Oligocene) and younger stages (Beu and Maxwell, 1990, p. 33, Fig. 6a). The cosmopolitan nuculid Leionucula also made its first appearance at least as early as the latest Cretaceous, with a possible earlier record of Korangan to Urutawan (Lower Cretaceous), but this record by Speden (1975, p. 47, Tab. 5) could not be substantiated by studying his collections at IGNS; Leionucula is also present, as with Linucula, in "Wangaloan" rocks.

Although the nuculanid Nuculana s. s. may have appeared during the Early Jurassic (Marwick, 1953, p. 88), this genus is in a state of taxonomic flux. It is not clear whether the Jurassic species represent Nuculana s. s., or whether the latest Cretaceous species of Nuculana described in this study represent the oldest representatives of this stratigraphically and geographically widespread nuculanid. The first appearance and possibly origins of the nuculanid *Jupiteria* appear to have been in uppermost Cretaceous rocks of Northland; it crossed the K-T boundary into the Paleocene as well. Maxwell (1988b, p. 91) commented that *Jupiteria* and *Saccella* (possibly **sensu lato**; first occurrence in Northland rocks and possibly Marlborough per this study) have been distinct since "at least the Middle Eocene". Presence of these groups in the latest Cretaceous indicates that they became distinct much earlier, although it is acknowledged that the posteroumbonal ridge in Cretaceous species is not as well-developed, compared to Cenozoic species of *Saccella*.

The record of nuculanid *Pseudoportlandia* and malletiid *Tindaria* may extend into the Cretaceous, previously reported from Tertiary to Recent deposits around the globe (Puri *in* Moore, 1969, and McAlester *in* Moore, 1969, respectively). The malletiid *Neilo*, today confined to the New Zealand region (Marshall, 1978, p. 425), has had a long, but patchy record in this country and is first recorded from uppermost Cretaceous rocks of North and South islands. The geographic and stratigraphic occurrence of related genus *Australoneilo* is interesting. A new species of *Australoneilo* described in this work, *A*. *zelandica*, greatly extends the stratigraphic and geographic range to include the Haumurian in New Zealand. *Australoneilo* apparently disappeared in New Zealand after the Maastrichtian, but is recorded from Australia solely in the Paleocene (Darragh, in press) and Antarctic Peninsula and southern South America in the Paleocene (Zinsmeister and Macellari, 1988); species of *Australoneilo* apparently became extinct sometime during the Eocene in the Antarctic region.

The solemyid Solemya first appeared in the Haumurian of Northland; thereafter the record is patchy in New Zealand.

The Jurassic to Recent arcid Barbatia seemingly appeared in the fossil record of New Zealand during the latest Cretaceous and reappeared during the Miocene.

The oldest record, possibly coinciding with the origin, of endemic cucullaeid Cucullaea (Cucullastis) is in the Piripauan of New Zealand where it crossed the K-T boundary and became extinct sometime during the Late Paleocene. The roots of the Maastrichtian cucullaeid Austrocucullaea may lie in the New Zealand region; it was previously recorded solely from uppermost Maastrichtian rocks of Seymour Island, Antarctic Peninsula (Zinsmeister and Macellari, 1988). The Austral cucullaeids Nordenskjoeldia and Indogrammatodon had wide distributions in the southern hemisphere, including the New Zealand region, during the Late Cretaceous but became extinct during the Maastrichtian; New Zealand occurrences are latest for these genera.

The limopsid Limopsis s. s. made its first appearance in the New Zealand record in the Haumurian of Northland; it seemingly disappeared during the Paleocene (most likely lack of suitable facies) and reappeared during the Early Eocene.

The glycymeridid Glycymerita was well-established in the South Pacific during the Late Cretaceous and Tertiary and first appeared in the Piripauan of New Zealand.

The geographic range of the mytilid Lycettia was reduced to Texas, North America (Soot-Ryen in Moore, 1969, p. N273), New

Caledonia (Freneix, 1980, pp. 87-88) and New Zealand (this work) during the Late Cretaceous, after which time it became extinct; it was once widespread during the Jurassic. Although the presence/absence of an umbonal septum in species referred to *Septifer* is not easily determined, the probable first occurrence of this mytilid in New Zealand is in the Haumurian?; the inferred close relationship of *Septifer*? *eurycrenulata* n. sp. from the Malvern Hills, Canterbury and older species from the western coast of North America is probably significant from a paleobiogeographical viewpoint, as will be discussed further. *Modiolus*, another stratigraphically and geographically widespread mytilid, also first appeared in New Zealand during the latest Cretaceous. The mytilid *Inoperna*, more widespread during the Jurassic, has its last records in the latest Cretaceous of New Zealand and New Caledonia before becoming extinct.

The characteristic pinnid bivalve *Pinna* was well-established in most continents of the southern hemisphere during the latest Cretaceous, appearing in New Zealand during the Triassic (Trechmann, 1918).

Around the globe Mesozoic taxa inoceramid *Inoceramus*; entoliid *Entolium*; pectinids *Camptonectes*, *Mixtipecten*, *Chlamys* (*Lyriochlamys*), and *Neithea*; and limids *Limea* (*Pseudolimea*) and *Seymourtula* made their final appearances in the Maastrichtian, New Zealand being no exception.

The oldest record of limid *Acesta* (*Plicacesta*) is a Piripauan? species, *A*. (*P*.) n. sp.?, from the Maungataniwha Sandstone of Hawke's Bay, North Island. *Acesta* s. s. first appeared in the Jurassic of New Zealand (Marwick, 1953) and may extend to the present.

The Maastrichtian gryphaeid *Planospirites* made its first and last appearance in the Maastrichtian of New Zealand.

The ostreid *Pseudoperna lapillicola* from the latest Cretaceous of New Zealand, closely allied to Coniacian to Santonian (Upper Cretaceous) species of North America, probably became extinct in the New Zealand region. The occurrence of *Crassostrea* in the New Zealand latest Cretaceous is the oldest known.

The trigoniids *Trigonia*, *Pterotrigonia* s. s., *P.* (*Ptilotrigonia*), *Pacitrigonia*, *Oistotrigonia*, *Iotrigonia*, and *Eselaevitrigonia* all became extinct in New Zealand and elsewhere during the Maastrichtian, but were previously widespread taxa.

The lucinid *Myrtea* appeared in New Zealand as early as the Piripauan? and crossed the K-T boundary into the Paleocene; the genus became well-established during the Cenozoic with records in Europe, Asia, Australia and North America (Chavan *in* Moore, 1069, p. N499).

The oldest record of astartid *Eriphyla* appears to have been in Turonian (Upper Cretaceous) rocks of western North America; the record of this genus in Piripauan? to Haumurian rocks of New Zealand marked its last occurrence in the fossil record.

The crassatellid *Anthonya* was not a particularly speciose group, but had representative taxa in North America (including type), Western Europe, Africa, Asia, Australia, Japan (Chavan *in* Moore, 1969, p. N574) and New Zealand (Woods, 1917); in New Zealand and elsewhere *Anthonya* became extinct sometime during the

Maastrichtian.

The cardiids *Austrocardium*, *Granocardium* (*Ethmocardium*) and widespread paleoaustral *Lahillia* are first recorded in uppermost Cretaceous rocks of New Zealand; *Lahillia* crossed the K-T boundary into the Paleocene, after which it disappeared from the New Zealand fossil record. *Lahillia* persisted into the Eocene of Antarctica and Miocene of South America.

The thyasirid *Thyasira* first appeared in New Zealand during the Haumurian and crossed the K-T boundary into the mid to upper Teurian of North Island; its absence in the "Wangaloan" is probably due to lack of preservation of suitable facies.

The mactrid *Cymbophora* probably originated sometime during the Late Cretaceous in marine deposits of North America and apparently became extinct during the Maastrichtian in the New Zealand and Central Chile regions. The oldest records of mactrids *Raeta* and *Zenatia* apparently lie in the New Zealand latest Cretaceous record; both of these taxa have representative taxa living today.

The presumed tellinid *Aenona* and endemic psammobiid *Gari* s. l. made their first and last appearance in the New Zealand fossil record in the Haumurian.

The tancrediid bivalve *Tancredia*, first recorded in Lower Jurassic rocks, survived into the Maastrichtian of New Zealand (this work) and South Dakota, North America (Speden, 1970) and became extinct in Arctic regions during the Paleocene (Marincovich, 1993).

Aphrodina (*Tikia*), possibly *Costacallista* and *Cyclorismina*, all Veneridae are recorded in Piripauan? to Haumurian rocks; A. (T.) crossed the K-T boundary in New Zealand to the "Wangaloan" and Cyclorismina may be present in the Eocene of Antarctica (Zinsmeister, 1984).

The corbulid Surobula was apparently short-lived, represented only by Maastrichtian species in New Zealand and Antarctic Peninsula, after which time it became extinct.

The probable occurrence of hiatellid Cyrtodaria in Haumurian rocks of Northland marks the oldest record of the genus, known previously from a possible occurrence in the Maastrichtian of South Dakota (Speden, 1970, pp. 139-140) and Paleocene to Recent of Europe and the Arctic (Keen in Moore, 1969, p. N700). The characteristic hiatellid bivalve Panopea was widespread around the rim of the southern circum-Pacific during the latest Cretaceous and Paleogene, including New Zealand.

The geographic range of the North American Campanian to latest Maastrichtian pholadid Clavipholas has been extended in this work to include the Haumurian of New Zealand; there is a possible record of this genus in the Eocene of Patagonia (Griffin, 1991). Crampton (1990) recorded the oldest known species of pholadid, Pholadidea (Hatasia) wiffenae; this is the only known occurrence of this group in New Zealand.

The thraciid Thracia and cuspidariid Cuspidaria made their first appearance in the Late Cretaceous of New Zealand; Cuspidaria originated perhaps a little later in the Maastrichtian.

Late Cretaceous New Zealand gastropods show a similar pattern of occurrence as for bivalves, with many new records at this time. Of 47 recorded gastropod genera/subgenera, 44 (= c. 94%) are recorded for the first time in Upper Cretaceous New Zealand rocks. New Zealand has the oldest records of the pleurotomariids *Perotrochus* and *Chelotia*, both reported from Piripauan to Haumurian rocks; *Perotrochus* is well represented in Cenozoic rocks and *Chelotia* in Eocene rocks of Europe.

The lottiid *Patelloida* is tentatively recorded in this work from the Haumurian of North Island, previously known from Early Cretaceous to Recent of all oceans to 70° N and to 50° S (Lindberg, 1988; Lindberg and Squires, 1990); this genus is recorded in the Cenozoic of New Zealand only in Pleistocene to Recent (Beu and Maxwell, 1990, p. 402).

The nacellid *Cellana* may have made its first appearance in Haumurian rocks of New Zealand, though poor preservation allows only tentative identification; other records of the genus include the New Zealand Cenozoic (Beu and Maxwell, 1990, p. 464).

Crampton and Moore (1990, pp. 340, 347) reported one of the oldest records of the turbinid *Turbo* in uppermost Cretaceous rocks of New Zealand, but I could not substantiate this occurrence (no specimens located at IGNS).

The new endemic skeneid *Brookula* (*Paleobrookula* n. subgen.) and trochids *Calliomphalus* s. l., *Kaiparomphalus* n. gen. (endemic), *Chrysostoma* and *Calliostoma* s. s. are recorded solely from Haumurian rocks of Northland. The trochid *Amberleya* made its last appearance in the Maastrichtian of New Zealand and Antarctica, previously having been recorded from many areas in Jurassic rocks (including New Zealand).

Possible records of neritopsids Damesia and Neritopsis (Hayamiella?) are reported in this work from Piripauan?-Haumurian rocks of Haumuri Bluff and Shag Point respectively. Protodolium was first reported as endemic to the latest Cretaceous of New Zealand by Wilckens (1922), but later was recorded in coeval rocks of Chatham Islands (Campbell et al., 1993; Stilwell, 1994b) and New Caledonia (Stilwell, 1994b). Protodolium seemingly disappeared sometime during the Maastrichtian.

A possible new genus of zygopleurid related to Zygopleura, from Upper Cretaceous rocks of East Cape, North Island, is the sole occurrence of this group in New Zealand.

Elder and Saul (1993) recorded potamidid Bittiscala from the uppermost Cretaceous Pigeon Point Formation of California, North America; previously the genus was recorded only from K-T boundary rocks of New Zealand (Finlay and Marwick, 1937). I cannot deduce from Elder and Saul's figured species whether it is congeneric or not with Bittiscala.

Mesozoic procerithiid taxa Bathraspira and Rhabdocolpus have end members of their lineages in uppermost Cretaceous rocks of New Zealand.

The endemic fossarid? Procancellaria is recorded solely from Piripauan to Haumurian? rocks of New Zealand as is turritellid Costacolpus.

The alate aporrhaid Perissoptera is predominantly a Cretaceous genus, originating sometime during the Neocomian (see geographic distribution by Wenz, 1940, pp. 923-924); in New Zealand the genus is present in the Haumurian of Northland and in Antarctica from the Maastrichtian to the earliest Paleocene (youngest record). The oldest record of the paleoaustral aporrhaid *Struthioptera* is in the New Zealand region, probably in the Early Cretaceous; this genus straddled the K-T boundary in New Zealand, became extinct or migrated elsewhere during or after the Paleocene, and finally disappeared during the Eocene in Antarctica (Zinsmeister, 1977). Disappearance and probable extinction of *Struthioptera* in the upper units of the La Meseta Formation of Seymour Island, Antarctic Peninsula, coincides with a significant faunal transition, interpreted to be a reflection of facies change and/or general decrease in temperatures at the close of the Eocene (Stilwell and Zinsmeister, 1992, p. 46). The aporrhaid *Arrhoges* (*Latiala*) spanned Turonian to Maastrichtian time from North America to southern India and southern Africa (Popenoe, 1983), and in this work solely the Maastrichtian of New Zealand.

The unusual, endemic struthiolariid *Conchothyra* originated in New Zealand sometime during the Late Cretaceous and became extinct during the Paleocene.

The vanikorid *Vanikoro*, possibly calyptraeids *Calyptraea* and *Crepidula*, capulids *Capulus*? and *Gigantocapulus*, and trichotropid *Trichotropsis* (*Cerithioderma*) made their first appearances in the Late Cretaceous of New Zealand.

Species diversity of the naticid *Euspira* was high by Late Cretaceous time around the globe, including this country; *Euspira* crossed the K-T boundary in New Zealand and disappeared sometime during the Paleocene. The naticid *Amauropsona* originated probably in the New Zealand area during the Haumurian or before and crossed the K-T boundary where it also became extinct during the Paleocene.

The epitoniids *Acirsa* (*Notacirsa*?) and *Opalia* made their first appearance in the latest Cretaceous of New Zealand; *A*. (*Notacirsa*?) crossed the K-T boundary into the Paleocene and younger rocks while Lazarus taxon *Opalia* reappeared during the Middle Eocene.

The fasciolariid "*Cryptorhytis*" is recognised in Upper Cretaceous deposits of Europe North and South Africa, South India, North America, New Zealand (Wenz, 1943) and Antarctic Peninsula (Wilckens, 1910) and became extinct during the Maastrichtian.

Recent work in the Kaipara region has established the sole record of melongenid *Sycostoma* in the Haumurian of New Zealand.

Saulopsis n. gen. of the Tudiclidae ranged from the latest Cretaceous to Early? Eocene in New Zealand. Tentatively identified tudiclids *Pseudoperissolax* and *Perissitys* occur in Piripauan to Haumurian deposits.

The acteonid *Tornatellaea* has come to light in Haumurian rocks of Northland, previously recorded in New Zealand solely in the Paleocene.

The globose ringiculid *Eriptycha* is first recognised in Arowhanan? (lower Upper Cretaceous) rocks; it seemingly disappeared in New Zealand and elsewhere during the Haumurian. The stratigraphic range of *Ringicula* is greatly extended to the Haumurian; it was previously recorded from Mangaorapan (upper Lower Eocene) to Recent (Beu and Maxwell, 1990, p. 386).

A probable new genus related to aplustrid? *Aplustrum* is recognised solely in probable Haumurian rocks of Canterbury.

The paleoaustral cylindrical cylichnid Cylichnania first appeared in the Piripauan? of New Zealand (cf. Finlay and Marwick, 1937, pp. 13, 129) crossed the K-T boundary and in the Cenozoic ranged from "Wangaloan" to Tongaporutuan (upper Lower Paleocene to Upper Miocene) (Maxwell, 1988b).

The cosmopolitan pyramidellid Odostomia is tentatively recorded in Haumurian rocks of Northland and "Wangaloan" to Recent.

The scaphopod Antalis has recently been found in Haumurian rocks of Northland and ranged in the Cenozoic from "Wangaloan" to Recent. The long-ranging Triassic to Recent dentaliid Laevidentalium had a patchy geologic record in New Zealand, first appearing in the Piripauan? or Haumurian, after which time this Lazarus taxon reappeared in the Altonian (Lower Miocene).

Biogeographic elements and trends of Late Cretaceous taxa

The Late Cretaceous molluscan faunas of New Zealand fall into four broad biogeographic groupings at genus-level; these are endemic, paleoaustral, Indo-Pacific/Tethyan and cosmopolitan (Tables 5-6; Figure 53). Few endemic taxa are recorded from New Zealand; these include bivalves Cucullaea (Cucullastis), Austrocardium and Zenatia, and gastropods Brookula (Paleobrookula) n. gen., Kaiparomphalus n. gen., Procancellaria, Bittiscala (although possibly present in the Cretaceous of California), Costacolpus, Conchothyra, and Amauropsona. Of 128 total taxa, the endemic element makes up a small percentage at c. 8%. The paleoaustral element is somewhat stronger than the

Table 5: New Zealand latest Cretaceous bivalve, gastropod and scaphopod genera/subgenera with respective biogeographic elements. Extinct taxa at the end of the Maastrichtian and Lazarus taxa reappearing after the Paleocene in New Zealand are noted. Acronyms used: E, endemic; P, paleoaustral; I, Indo-Pacific/Tethyan; C, cosmopolitan; Ex, extinct; Lz, Lazarus taxon

BIVALVIA

Nuculidae	
Nucula s.l.	(C?) (I?) (Ex?)
Linucula	(P)
Leionucula	(C)
Nuculanidae	
Nuculana	(C)
Jupiteria	(I)
Saccella s.l.	(C) (Lz)
Pseudoportlandia?	(C) (Lz)
Malletiidae	
Tindaria?	(C) (Lz)
Neilo (Neiloides)	(P) (Ex)
Solemyidae	
Solemya	(C) (Lz)
Arcidae	
Barbatia	(C) (Lz)
Cucullaeidae	
Cucullaea s.s.?	(I)
Cucullaea (Cucullastis)	(E)
Austrocucullaea	(P) (Ex)
Nordenskjoeldia	(P) (Ex)
Indogrammatodon	(I) (Ex)
Limopsidae	
Limopsis	(C) (Lz)
Glycymerididae	
Glycymerita	(I)
Mytilidae	
Lycettia	(I) (Ex)
Septifer?	(C)
Modiolus	(C) (Lz)
Inoperna	(C) (Ex)
Pinnidae	
Pinna	(C) (Lz)
Inoceramidae	
Inoceramus	(C) (Ex)
Isognomonidae	
Isognomon	(C)
Entoliidae	
Entolium	(C) (Ex)
Pectinidae	
Aequipecten	(I?) (Lz)
Chlamys (Lyriochlamys)	(I) (Ex)
Mixtipecten	(P) (Ex)
Neithea	(C) (Ex)
Anomiidae	
Anomia	(I)
Limidae	
Limea (Pseudolimea)	(C) (Ex)
Limatula s.s.	(C) (Lz)
Seymourtula	(P) (Ex)
Acesta s.s.	(C) (Lz)
Acesta (Plicacesta)	(C) (Ex)
Ostreidae	
Planospirites	(C) (Ex)
Pseudoperna	(C) (Ex)
Crassostrea	(C) (Lz)
Trigoniidae	
Pterotrigonia s.s.	(C) (Ex)
Pterotrigonia (Ptilotrigonia)	(C) (Ex)
Pacitrigonia	(P) (Ex)
Oistrotrigonia	(C) (Ex)
Iotrigonia	(I) (Ex)
Eselaevitrigonia	(I?) (P?) (Ex)
Trigonia	(C) (Ex)
Lucinidae	
Myrtea	(I)
Thyasiridae	
Thyasira (Conchocele)	(I)
Astartidae	
Astarte	(C) (Lz)
Eriphyla	(I) (Ex)
Dozyia?	(I) (Ex)
Crassatellidae	
Anthonya	(I) (Ex)
Cardiiae	
Cardium (Bucardium?)	(I) (Ex)
Austrocardium	(E) (Ex)
Granocardium (Ethmocardium)	(I) (Ex)
Schedocardia?	(I) (Ex)
Lahillia	(P)

Mactridae

Cymbophora .... (I) (Ex)
Raeta .... (I) (Lz)
Zenatia .... (E) (Lz)

?Tellinidae

Aenona .... (I) (Ex)

Donacidae

Notodonax? .... (P) (Ex)

Psammobiidae

Gari s.l. .... (C)

Tancrediidae

Tancredia .... (C)

Veneridae

Aphrodina (Tikia) .... (P)
Costacallista .... (I) (Lz)
Cyclorismina .... (P)

Myidae

Mya .... (I) (Lz)

Corbulidae

Surobula .... (P) (Ex)

Hiatellidae

Cyrtodaria .... (I) (Lz)
Panopea .... (I)

Pholadidae

Clavipholas .... (I) (Lz)
Pholadidea (Hatasia) .... (I) (Lz)

Teredinidae

Teredo .... (C)

Thraciidae

Thracia .... (C) (Lz)

Cuspidariidae

Cuspidaria .... (C) (Lz)

GASTROPODA

Pleurotomariidae

Perotrochus .... (I) (Lz)
Chelotia .... (I) (Lz)

Lottiidae

Patelloida .... (I) (Lz)

Nacellidae

Cellana .... (I) (Lz)

Patellidae

Patella .... (I?)

Skeneidae

Brookula (Paleobrookula n. subgen.*)* .... (E) (Ex)

Trochidae

Amberleya .... (I) (Ex)
Calliomphalus .... (I) (Lz)
Kaiparomphalus n. gen. .... (E) (Ex)
Chrystostoma .... (I) (Lz)
Calliostoma s.l. .... (C?) (Lz)

Turbinidae

Turbo .... (I) (Lz)

Neritopsidae

Damesia? .... (I) (Ex)
Protodolium .... (P) (Ex)
Neritopsis (Hayamiella?) .... (I) (Ex)

Zygopleuridae

Zygopleura? .... (C) (Ex)
aff. *Loxonema* .... (E?) (Ex)

Potamididae

Bittiscala .... (E)

Procerithiidae

Bathraspira .... (I) (Ex)
Rhabdocolpus? .... (I) (Ex)

? Fossaridae

Procancellaria .... (E) (Ex)

Turritellidae

Costacolpus .... (E) (Ex)

Aporrhaidae

Perissoptera .... (I) (Ex)
Struthioptera .... (P)
Arrhoges (Latiala) .... (I) (Ex)

Struthiolariidae

Conchothyra .... (E)

Vanikoridae

Vanikoro .... (I) (Lz)

Calyptraeidae

Sigapatella? .... (P)
Crepidula .... (I) (Lz)

Capulidae

cf. *Capulus* .... (C?)
Gigantocapulus .... (I?)

Tichotropidae

Trichotropis (Cerithioderma) .... (I) (Lz)

Naticidae

Euspira .... (C)
Eunaticina? .... (I
Amauropsona .... (E)

Epitoniidae

Acirsa (Notacirsa)	(P)
Opalia	(I) (Lz)

Fasciolariidae

"Cryptorhytis"	(I) (Ex)

Melongenidae

Sycostoma	(I) (Lz)

Tudiclidae

Saulopsis? n. gen.	(I)
Pseudoperissolax ?	(I)
Perissitys ?	(I)

Acteonidae

Tornatellaea	(I)

Ringiculidae

Eriptycha	(I) (Ex)
Ringicula	(C) (Lz)

?Hydatinidae

n. gen. ? aff. *Aplustrum*	(E?) (Ex?)

Cylichnidae

Cylichnania	(P)

Pyramidellidae

Odostomia	(C)

SCAPHOPODA

Antalis	(C)
Dentalium (Laevidentalium)	(C) (Lz)

Table 6: New Zealand latest Cretaceous biogeographic elements

BIVALVE GENERA/SUBGENERA (total of 79 taxa)

Endemic	Paleoaustral (w/endemics)	Indo-Pacific/ Tethyan	Cosmopolitan
3	16	33	30
(c. 4%)	(c. 20%)	(c. 42%)	(c. 38%)

GASTROPOD GENERA/SUBGENERA (total of 47 taxa)

Endemic	Paleoaustral (w/endemics)	Indo-Pacific/ Tethyan	Cosmopolitan
7	11	28	5
(c. 13%)	(c. 23.4%)	(c. 60%)	(c. 11%)

Table 8: New Zealand Paleocene biogeographic elements

BIVALVE GENERA/SUBGENERA (total of 35 taxa)

Endemic	Paleoaustral (w/endemics)	Indo-Pacific/ Tethyan	Cosmopolitan
10	18	10	7
(c. 29%)	(c. 51%)	(c. 28.5%)	(c. 20%)

GASTROPOD GENERA/SUBGENERA (total of 76 taxa)

Endemic	Paleoaustral (w/endemics)	Indo-Pacific/ Tethyan	Cosmopolitan
26	49	19	5
(c. 34%)	(c. 64.5%)	(c. 25%)	(c. 6.5%)

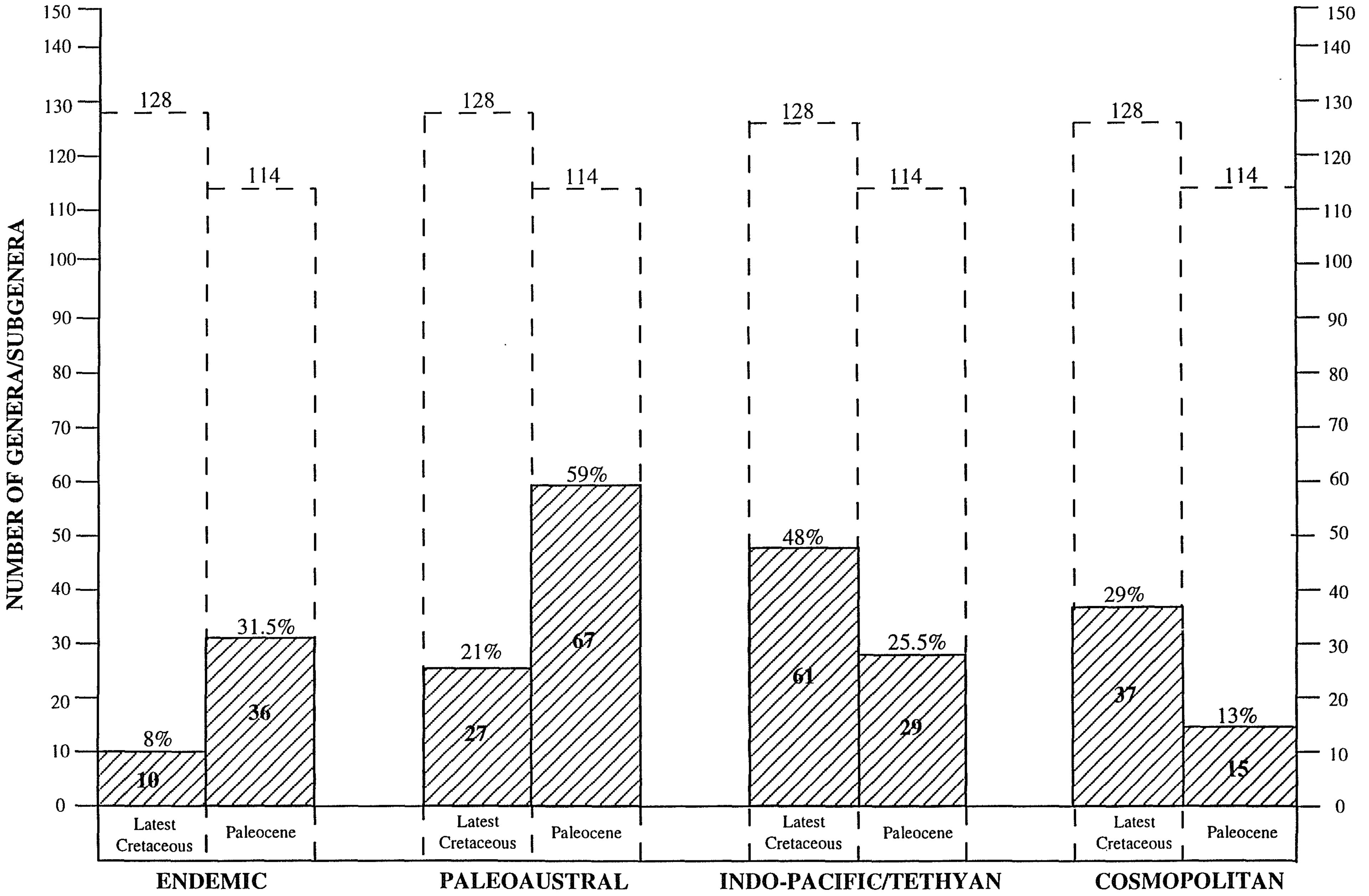


Figure 53. Histograms showing proportions of paleobiogeographic elements of New Zealand latest Cretaceous and earliest Paleogene molluscs

endemic element. The term "paleoaustral", as coined by Fleming (1963), refers to those taxa that have fossil records extending back into the Tertiary or Mesozoic and also groups with inferred poor dispersal capabilities whose present or known fossil distribution reflect past land connections of the southern continents. The paleoaustral concept of Fleming has its origin in Hutton (1872a). I include endemic taxa in this category in contrast to Beu and Maxwell's (1990, p. 77) decision that many of the genus-group taxa cited by Zinsmeister (1982, Tab. 1) as "paleoaustral" should be reclassified as endemic because they have not been recorded outside New Zealand. Whether or not these taxa listed by Zinsmeister have been recorded beyond New Zealand seems immaterial as implied by Fleming's original ideas because, like paleoaustral groups, endemic taxa are inferred to have had poor dispersal capabilities and many have fossil record reaching into the Tertiary and/or Mesozoic. Thus, I advocate the inclusion of endemic taxa in the paleoaustral category. Of 128 taxa recorded 27 of these (c. 21%) can be included in the paleoaustral category, most of which are bivalves (16 taxa). Noteworthy paleoaustral elements include *Linucula*, *Australoneilo* (closely related species in Antarctica), *Austrocucullaea* (closely related species in Antarctica), *Mixtipecten* (allied species in Chile), *Seymourtula* (allied species in New Caledonia and Antarctica), *Lahillia* (common element across the Austral Weddellian Province of Zinsmeister, 1979; discussed fully below), *Cyclorismina* (species extending from New Caledonia to Antarctica), *Surobula* (closely related species in Antarctica), *Protodolium* (species in New Caledonia and Chatham Islands), and the widely discussed gastropod Struthioptera (species also in Chatham Islands, Antarctica and South America). These paleoaustral elements probably evolved during the Campanian or slightly earlier in the Late Cretaceous, many in the New Zealand region.

The Indo-Pacific/Tethyan element is largely taken from Darragh (1985, p. 90) who stated that "This element represents the northern influence in the fauna and consists of taxa, either now or in the past, having their major distribution in the tropical Indo-Pacific Realm, or part of it, and which had their probable origin in the Indo-Pacific Basin; as well as those taxa which had their major distribution in the Early Tertiary through the Palaeogene Tethyan areas of the Mediterranean region east to Indonesia and west to the Caribbean region."; Darragh essentially revised Fleming's (1967) Indo-Pacific element. Due to the generally poorly known and limited Early Cretaceous and early Late Cretaceous of New Zealand and other regions, in practice it is often difficult to document the timing of the origin of many taxa. Uncertainty surrounds not only the origin of some taxa in the Indo-Pacific region or Tethyan Realm, but also the origin of taxa in the endemic, paleoaustral, and cosmopolitan categories. It is possible that some of these taxa originated in the south and dispersed northwards. The Indo-Pacific/Tethyan category is a broad one which necessarily includes inferred warm-water taxa that were/are distributed in these areas and beyond the Austral Realm during the Cretaceous and early Tertiary. The Indo-Pacific/Tethyan element was strong during the Late Cretaceous, encompassing 33 of 79 (c. 42%) New Zealand bivalve taxa; while Indo-Pacific/Tethyan gastropods comprise about 28 of 47 taxa (c. 60%). Many of these taxa are strongly allied with taxa from North America and Europe.

The cosmopolitan element is harder to document because establishing the geographic distribution of a particular group is more difficult than knowing its temporal range (cf. Smith, 1989, p. 263). As discovered during the course of this investigation, many New Zealand taxa previously inferred to be endemic have been identified elsewhere in both northern and southern hemispheres, decreasing the endemic component substantially. Further work will probably expand the lateral and temporal ranges of many taxa. The cosmopolitan element makes up 30 out of 79 bivalve taxa (c. 38%) and only five or so of 47 gastropod taxa (c. 11%). Both New Zealand scaphopods, *Antalis* and *Dentalium* (*Laevidentalium*) are considered to be cosmopolitan elements with closely related species across the globe.

At species-level the Late Cretaceous molluscan fauna of New Zealand comprises a mixture of three groupings: 1) widespread or cosmopolitan species (few in number including *Lycettia lanceolata* (Sowerby, 1823) and *Entolium membranaceum* (Nilsson, 1827)); 2) endemic species of cosmopolitan or wide-ranging Indo-Pacific/Tethyan and paleoaustral genera/subgenera (approximately 146 species, the majority); and 3) endemic species of endemic genera/subgenera (10 species).

Stratigraphic appearances of Paleocene taxa

The "Wangaloan" fauna is highly distinctive at genus- and species-level. Many new groups appeared during the Paleocene (see Table 4). The perceived faunal change across the K-T boundary in New Zealand is a dramatic one, indeed. Many of these "Wangaloan" taxa are the oldest recorded members of their respective lineages. Further, several were apparently short-lived, disappearing after the "Wangaloan" or by the end of the Paleocene. Of the total number of bivalve genera recorded during the Paleocene, 18 genera/subgenera of 35 (= c. 51%) first appeared at this time. Of "Wangaloan" bivalves the nuculid *Varinucula*, tentatively identified from the Kaiwhata River of North Island, may have made its first appearance during the mid to Late Paleocene.

The sareptid *Ledina*, represented by only a handful of Paleogene species worldwide, appeared and disappeared during the "Wangaloan".

The rostrate and pointed to very narrowly rounded posterior end among other characters of the endemic, highly distinctive malletiid *Spineilo* separates this genus from other Late Cretaceous and Cenozoic malletiids; *Spineilo* probably appeared and became extinct sometime during the "Wangaloan", although the geographic/stratigraphic range of this genus could be extended if "*Malletia pencana* Phil. sp." of Wilckens (1904, p. 230, Pl. 19, Fig. 6) proves to be congeneric.

The first appearance of the cucullaeid *Cucullaea* (*Cucullona*) seems to lie in the New Zealand-southeastern Australian region with earliest records in the "Wangaloan"; the subgenus has also been recorded from lower Tertiary rocks of Tierra del Fuego, Argentina (Malumian *et al*., 1978).

The tiny endemic limopsid *Limopsis* (*Limopsista*) is recorded solely from "Wangaloan" rocks where it is widespread and rather common.

The pteriid *Electroma* (*Pterelectroma*) first appeared in "Wangaloan" rocks; it is not recorded in New Zealand in rocks younger than Paleocene.

The gryphaeid *Pycnodonte* (*Notostrea*?) possibly appeared for the first time in the "Wangaloan" and has been recorded in Teurian to Waipawan (Paleocene to Lower Eocene) rocks of Chatham Island (Beu and Maxwell, 1990).

The lucinids *Pteromyrtea obesa* and *P*. *modica* n. sp. from the "Wangaloan" are the sole representatives of this endemic genus in the Paleogene which are also found in rocks as young as the Pleistocene. The lucinid *Miltha* has been recorded from "Wangaloan" to Recent and the Paleocene record is seemingly the oldest.

A range of Eocene to Recent was given by Chavan *in* Moore (1969, p. N523) for kelliid *Kellia* and a "Wangaloan" species *K*.? *paleocenica* n. sp. compares well with described members of this genus.

The carditid *Purpurocardia* first appeared in "Wangaloan" rocks then disappeared until the Neogene.

The cardiid *Nemocardium* (*Pratulum*) has had a long history in Europe extending back into the Early Cretaceous (Keen *in* Moore, 1969, p. N589), but the group has not been recorded in rocks older than "Wangaloan" in New Zealand where it extends to the present.

Recent work has established the presence of the mactrid *Maorimactra* in "Wangaloan" rocks, extending the previous record of Altonian (upper Lower Miocene) to Recent (Beu and Maxwell, 1990, p. 35, Fig. 6c), and also a possible new genus herein assigned to *Mactra* s. l.

The cosmopolitan psammobiid *Gari* s. s. is first recorded in the New Zealand Cenozoic in "Wangaloan" rocks.

If not congeneric with Paleocene to Eocene venerid *Dosiniopsis*, presumed endemic monotypic genus *Marwickia* first appeared in the "Wangaloan". The venerid *Dosinia* (*Kereia*?) may be present in "Wangaloan" rocks, greatly extending the range. *Dosinia* (*Dosinobia*) is thought to be endemic to New Zealand, represented only by two species in the "Wangaloan".

Many new gastropod groups appeared during the "Wangaloan". Of 76 genera/subgenera recorded in the Paleocene of New Zealand, 67 (= c. 88%) appeared for the first time. Trochids are poorly represented in Paleocene rocks, represented solely by apparently short-lived *Conominolia* in New Zealand and Australia (T. A. Darragh, pers. commun., 1991), compared to several Late Cretaceous taxa in New Zealand.

The turbinid *Bolma* (*Ormastralium*) appeared during the "Wangaloan", represented by a few specimens collected from Raupo Creek.

The turritellid *Colposigma* is represented by eight recorded species in Paleogene rocks of the southern hemisphere, the

"Wangaloan" record being the oldest. Spirocolpus of the Turritellidae has been recorded from the "Wangaloan" (this work) to Waitakian (Lower Paleocene to Lower Miocene) of New Zealand and Late Eocene of Australia (cf. Beu and Maxwell, 1990). The shallow sinus of endemic monotypic turritellid Zeacolpus (Leptocolpus), recorded solely from the "Wangaloan" in great abundance from South Canterbury to South Otago, is distinct from younger species of Zeacolpus s. s. which have a deeper sinus.

Drepanocheilus (Tulochilus), one of the smallest members of the Aporrhaidae, is known from only a few examples in the "Wangaloan". A possible new genus of aporrhaid allied to Hemichenopus is recorded in New Zealand in Paleogene rocks from the "Wangaloan" to the Bortonian (Middle Eocene).

The struthiolariid Perissodonta made its first appearance in "Wangaloan" rocks of New Zealand, where it is represented by two species; the genus extends to the Recent in subantarctic waters.

Boshier (1960) believed that the endemic monotypic "Wangaloan" calyptraeid Sigapatella (Spirogalerus) gave rise to Sigapatella s. s.; movement of the exsert apex to a more central position would result in S. (Spirogalerus) having a comparable shell outline to Sigapatella s. s. Due to deficiencies in the fossil record the timing of this change, if it did indeed occur, is uncertain but probably took place during the Late Paleocene or Early Eocene. However, the possible occurrence of Sigapatella in the Late Cretaceous of New Zealand sheds some doubt on Boshier's hypothesis.

Several naticid groups first appeared in the "Wangaloan"; these include Globisinum ("Wangaloan" to Recent of New Zealand, also Eocene of Australia), *Magnatica* (*Spelaenacca*) ("Wangaloan" to Altonian, New Zealand), *Taniella* (*Pristinacca*) (sole record), *Amauropsona*? (possibly also in Haumurian of Northland), *Amauropsis* (sole record), *Polinices* s. s. ("Wangaloan" to Mangapanian (Upper Pliocene)), *P*. (*Polinella*) ("Wangaloan" to Waipipian (Upper Pliocene)), and *Eunaticina*? ("Wangaloan" to Recent?).

The cassids *Galeodea* s. s. and *Taieria* have their oldest records in the "Wangaloan".

One of the oldest records of ficid *Priscoficus* is from the "Wangaloan".

The eulimid *Melanella* is tentatively recognised from the "Wangaloan". Distinguishing species of this genus from pyramidellid *Odostomia* is not always clear-cut even when the material is well-preserved. The record of the eulimid *Niso* extended into the "Wangaloan"; elsewhere it is known in many regions from the Late Cretaceous to Recent in warm seas (Wenz, 1940).

The paleoaustral epitoniid *Acirsa* (*Notacirsa*) is recorded in the "Wangaloan" for the first time; this genus may also be present in Piripauan? or Haumurian rocks. *Acirsa* (*Plesioacirsa*) and *Amaea* s. s. are recognised herein in "Wangaloan" rocks for the first time and together form sole records of this Late Cretaceous to Recent group; elsewhere in the southern hemisphere *A*. (*Plesioacirsa*) is recorded from Eocene rocks of Antarctica.

Many buccinid genera first appeared in "Wangaloan" rocks greatly extending stratigraphic ranges; these include *Austrofusus*

s. s., A. (Nassicola), Buccinulum, Penion, Aeneator, Pseudofax, and Austrocominella. Of these taxa, Pseudofax was most widespread during the Paleocene with records in this country, Australia and Patagonia; it apparently became extinct in the Antarctic at the close of the Eocene.

The tudiclid Saulopsis n. gen. is first recorded in New Zealand for certain in "Wangaloan" rocks and ranged into the Waipawan or Heretaungan (Lower or lower Middle Eocene). Tudiclana also made its first apearance in "Wangaloan" rocks where it seemingly became extinct in the Late Paleocene in this country; elsewhere it ranged into the Late Eocene of Antarctica (Stilwell and Zinsmeister, 1992).

The turbinellid Columbarium was well-established in the southern hemisphere by Early Paleocene time with records in New Zealand ("Wangaloan" to upper Teurian) and Australia, possibly slightly earlier in Antarctica. Other turbinellids first occurring in "Wangaloan" rocks include Exilia, Fyfea (sole record) and Microfulgur (sole record).

The muricid Uttleya is tentatively recorded in the "Wangaloan".

The volutomitrid Volutomitra made its first appearance in the "Wangaloan", previously recorded from Eocene to Recent in New Zealand (Maxwell, 1992).

Recent work at Wangaloa has established the presence of the Volutidae in "Wangaloan" rocks; taxa include endemic Wangaluta n. gen. (sole record), Alcithoe s. l. (oldest record) and Fulgoraria? (sole record).

Diverse Turridae made their first appearance in the

"Wangaloan"; these taxa include Austrotoma, Marshallaria, Amuletum (first and last record), Campylacrum (sole record), Cosmasyrinx (Tholitoma), Hesperiturris (sole record), Zemacies, Inquisitor, Eothesbia (sole record), and Taioma (sole record in New Zealand).

Several cancellariids made their debut in "Wangaloan" and upper Teurian rocks, including Pristimerica (sole record; also recorded from the Eocene of Antarctica), Antepepta (sole record), Coptostomella (sole record) and possibly Kapuatriton (oldest record, Late Paleocene).

Species-level diversity of the Acteonidae was high during the Paleocene in New Zealand with 13 recorded species; only one species has been recorded in the Haumurian. Acteonids first recorded from the Paleocene include Acteon, Wangacteon (sole record), Crenilabium, Kaurueon n. gen., Ongleya ("Wangaloan" to upper Teurian), and Tornatellaea. Of ringiculids Superstes is first recorded from the "Wangaloan".

The cylichnid Priscaphander was thought to be endemic in the "Wangaloan", but has recently come to light in Patagonia (Griffin and Hünicken, 1994).

The architectonicid Wangaloa is first recorded from the "Wangaloan" (extends to the Miocene in New Zealand).

Endemic mathildid Eomathilda is recorded solely from the "Wangaloan"; Gegania also made its appearance at this time (also extends to the Miocene).

The pyramidellid Pyramidella may also be recorded in the "Wangaloan", but more material of the inferred new species is needed to confirm this identification.

Biogeographic elements and trends of Paleocene taxa

The endemic element in the New Zealand molluscan fauna was stronger during the Paleocene than at any other time during the Cenozoic with 10 of 35 bivalve taxa (c. 29%) and 26 of 76 gastropod taxa (c. 34%) assigned to this category (see Tables 7-8 for tabulations; Figure 53, histograms showing proportions of paleobiogeographic elements). Noteworthy endemics include the minute bivalve Limopsis (Limopsista), Maorimactra, possibly Purpurocardia, Marwickia, gastropods Zeacolpus (Leptocolpus), Drepanochilus (Tulochilus), Sigapatella (Spirogalerus), Magnatica (Spelaenacca), Austrofusus, Fyfea, Microfulgur, Alcithoe s. l., Wangaluta n. gen., Eothesbia, Antepepta, Coptostomella, Wangacteon, Kaurueon n. gen., Superstes and Eomathilda.

The paleoaustral element is marked for both bivalves and gastropods; 18 of 35 bivalves (c. 51%) and 49 of 76 gastropods (64.5%). Examples of paleoaustral molluscs include bivalves Electroma (also present in Australia and Antarctica), Lahillia (closely allied species in Australia, Antarctica and South America), Aphrodina (Tikia) (related species in Australia), gastropods Conominolia (possibly in Australia), Colposigma (widely distributed Austral taxon), Perissodonta (also present in Antarctica), Polinices (Polinella) (also present in Australia and South America), Penion (widely distributed Austral taxon), Austrocominella (also in Antarctica, South America and possibly Australia), Cosmasyrinx (Tholitoma) (also in Australia), Zemacies (widespread in southern hemisphere), Pristimerica (also in

Table 7: New Zealand Paleocene bivalve, gastropod and scaphopod genera/subgenera with respective biogeographic elements. Extinct taxa by the end of the Paleocene are noted. Acronyms used: E, endemic; P, paleoaustral; I, Indo-Pacific/Tethyan; C, cosmopolitan; Ex, extinct.

BIVALVIA	
Nuculidae	
Linucula	(P)
Varinucula?	(E)
Leionucula	(C)
Nuculanidae	
Jupiteria	(I)
Sareptidae	
Ledina	(I) (Ex)
Malletiidae	
Neilo	(C)
Spineilo	(P) (Ex)
Cucullaeidae	
Cucullaea (Cucullona)	(P) (Ex)
Cucullaea (Cucullastis)	(E) (Ex)
Limopsidae	
Limopsis (Limopsista)	(E) (Ex)
Glycymerididae	
Glycymerita	(I)
Mytilidae	
Septifer?	(C)
Pteriidae	
Electroma (Pterelectroma)	(P)
Isognomonidae	
Isognomon	(C)
Pectinidae	
Chlamys s.l.	(C)
Anomiidae	
Anomia	(I)
Gryphaeidae	
Pycnodonte (Notostrea?)	(E)
Ostreidae	
Ostrea	(C)
Lucinidae	
Pteromyrtea	(E)
Miltha	(I)
Myrtea	(I)
Thyasiridae	
Thyasira s.s.?	(I)
Thyasira (Conchocele)	(I)
Kelliidae	
Kellia?	(C)
Carditidae	
Purpurocardia	(E)
Cardiidae	
Nemocardium (Pratulum)	(I)
Lahillia	(P)
Mactridae	
Maorimactra	(E)
Mactra s.l.	(E?) (Ex?)
Psammobiidae	
Gari	(C)
Veneridae	
Aphrodina (Tikia)	(P) (Ex)
Marwickia	(E) (Ex)
Dosinia (Kereia?)	(E)
Dosinia (Dosinobia)	(P) Ex)
Hiatellidae	
Panopea	(I)
GASTROPODA	
Trochidae	
Conominolia	(P) (Ex)
Turbinidae	
Bolma (Ormastralium)	(I)
Potamididae	
Bittiscala	(E) (Ex)
Turritellidae	
Colposigma	(P)
Spirocolpus	(P)
Zeacolpus (Leptocolpus)	E) (Ex)
Aporrhaidae	
Drepanocheilus (Tulochilus)	(E) (Ex)
n. gen? aff. *Hemichenopus*	(E) (Ex)
Struthioptera	(P)
Struthiolariidae	
Conchothyra	(E) (Ex)
Perissodonta	(P)
Calyptraeidae	
Sigapatella (Spirogalerus)	(E) (Ex)
Naticidae	
Globisinum	(P)

Magnatica (Spelaenacca) ... (E)
Taniella (Pristinacca) ... (E) (Ex)
Amauropsona ... (E) (Ex)
Amauropsis ... (I?)
Euspira ... (C)
Polinices s.s. ... (I)
Polinices (Polinella) ... (P)
Eunaticina? ... (I)

Cassidae
Galeodea s.s. ... (I)
Taieria ... (P) (Ex)

Ficidae
Priscoficus ... (I)

Eulimidae
Melanella ... (I)
Niso ... (I)

Epitoniidae
Acirsa (Notacirsa) ... (P)
Acirsa (Plesioacirsa) ... (I)
Amaea s.s. ... (I)

Buccinidae
Austrofusus s.s. ... (E)
Austrofusus (Nassicola) ... (P)
Buccinulum ... (E)
Penion ... (P)
Aeneator ... (P)
Pseudofax ... (P)
Austrocominella ... (P)

Tudiclidae
Saulopsis n. gen. ... (I)
Tudiclana ... (P)

Turbinellidae
Columbarium ... (I)
Exilia ... (I)
Fyfea ... (E) (Ex)
Microfulgur ... (E) (Ex)

Muricidae
Uttleya? ... (E)

Volutomitridae
Volutomitra ... (C?)

Volutidae
Wangaluta n. gen. ... (E) (Ex)
Alcithoe s.l. ... (E) (Ex?)

Turridae
Austrotoma ... (P)
Marshallaria ... (P)
Amuletum ... (I) (Ex)
Campylacrum ... (E) (Ex)
Cosmasyrinx (Tholitoma) ... (P)
Hesperiturris ... (I)
Zemacies ... (P)
Inquisitor ... (I)
Eothesbia ... (E) (Ex)
Tomopleura ... (I)
Taioma ... (P?)

Cancellariidae
Pristimerica ... (P)
Antepepta ... (E) (Ex)
Coptostomella ... (E) (Ex)
Kapuitriton? ... (E)

Acteonidae
Acteon ... (C)
Wangacteon ... (E) (Ex)
Crenilabium ... (I)
Kaurueon n. gen. ... (E) Ex)
Ongleya ... (E?) (Ex)
Tornatellaea ... (C)

Ringiculidae
Superstes ... (E)

Cylichnidae
Cylichnania ... (P) Ex)
Priscaphander ... (P) (Ex)

Architectonicidae
Wangaloa ... (E)

Mathildidae
Eomathilda ... (E) (Ex)
Gegania ... (C)

Pyramidellidae
Pyramidella? ... (C)
Odostomia ... (C)

SCAPHOPODA
Antalis ... (C)
Fissidentalium ... (C)
Gadila ... (C)

Antarctica), and *Priscaphander* (also in Australia and South America).

The proportion of Indo-Pacific/Tethyan elements was weak during the Paleocene, at 10 of 35 bivalves (c. 28.5%) and about 19 of 76 gastropods (25%). These elements include *Jupiteria*, *Ledina*, *Glycymerita*, *Miltha*, *Nemocardium* (*Pratulum*), *Bolma* (*Ormastralium*), *Priscoficus*, *Niso*, *Acirsa* (*Plesioacirsa*), *Saulopsis* n. gen., *Columbarium*, *Amuletum*, *Hesperiturris*, *Tomopleura*, and *Crenilabium*.

The cosmopolitan component was quite weak during the Paleocene, compared to the Late Cretaceous, with 8 of 35 bivalves (c. 23%) and only 5 of 76 gastropods (c. 6.5%). Taxa included in this category are *Leionucula*, *Neilo*, *Isognomon*, *Ostrea*, *Gari*, *Euspira*, possibly *Volutomitra*, *Acteon*, *Tornatellaea*, *Gegania*, and *Odostomia*.

Some taxa are not easily placed in any of these biogeographic categories. An example of one of these taxa is the inferred paleoaustral genus *Taioma* Finlay and Marwick, 1937, which is remarkably similar to a coeval gastropod in Greenland.

Two of three scaphopods recorded from the "Wangaloan" appeared at this time; these are cosmopolitan Cretaceous to Recent dentaliid *Fissidentalium* and similarly widely distributed gadilid *Gadila*.

At species-level the "Wangaloan" fauna is almost completely endemic. *Cucullaea* (*Cucullona*) *inarata* Finlay and Marwick, 1937, from the "Wangaloan" may be conspecific with *C.* (*C.*) *psephea* Singleton, 1943, of the Pebble Point Formation of southeastern Australia (interpretation based on my study of material housed at the Museum of Victoria). General outlines and sculpture of these species are remarkably similar. Few disparities are recognised apart from slightly more curved umbones and slightly different duplivincular ligament morphology of more numerous successive chevrons in C. (C.) psephea. Darragh (in press) decided to separate these species with the proviso that a larger range of specimens may, indeed, reveal a conspecific relationship. Also, the uncommon species Taieria allani Finlay and Marwick, 1937, is possibly recorded from the Late Paleocene of Chatham Islands (Red Bluff Tuff), but the sole recorded specimen from the Red Bluff Tuff has 10 very strong tubercles in contrast to 14-16 tubercles present on most specimens of T. allani. Otherwise, these taxa cannot be distinguished.

As a result of this work endemic Paleocene macrofossils other than molluscs have been recovered from marine sediments in South Island, predominantly Otago. Of such specimens, Feldmann (1993) described the decapod Glyphea stilwelli (Figure 54, this work) from probable Abbotsford Formation or Steel Greensand at Mount Watkin in association with "Wangaloan" taxa Spineilo elongata, ?Miltha agilis, Bittiscala simplex, and Tudiclana simulator. Glyphea stilwelli, endemic to New Zealand, represents the only record of the genus in Cenozoic rocks. Stilwell et al. (1994) reported the presence of the "Wangaloan" isocrinid Metacrinus sp. from the Raupo Concretionary Sandstone Member of the Kauru Formation (Figures 55-57). Metacrinus sp. is probably endemic, but has affinities with species from the Late Cretaceous and Paleogene of Antarctica. Associated with Metacrinus sp. in the Kauru Formation are corals identified as *Oculina*? sp. (S. D. Cairns, pers. commun.), bryozoans (lunulitiform anascan (cf. Lunulitidae) and celleporiform ascophoran cheilostomes, Stilwell *et al*., 1994), rare brachiopods identified as *Terebratulina* cf. *suessi* (Hutton) (D. E. Lee, pers. commun.), a small robust decapod claw, cirriped fragments, echinoid fragments, and a reworked belemnite(?). In the Wangaloa Formation at Mitchells Rocks (see Figure 49) macrofossils associated with bivalves, gastropods and scaphopods include the nautiloid *Eutrephoceras*? sp. (recently discovered by A. Grebneff, University of Otago; sole record of the molluscan class Cephalopoda in the Paleocene of New Zealand; see Plate 84), teredinid-bored Araucariaceae logs (Lindqvist, 1986), fish otoliths, teleost vertebrae, many shark teeth, and a moderately large bone fragment of uncertain affinity (reptilian?). Most of these fossils require further work to establish whether or not they are endemic taxa.

The "Wangaloan" fauna bears little resemblance to faunas in the northern hemisphere except for the few cosmopolitan and Indo-Pacific/Tethyan elements named above. Paleocene macrofaunas in general are not globally extensive. According to Darragh (in press), Paleocene molluscan faunas fall into four broad groupings (revised here with added information):

1) an Early Paleocene boreal fauna found in northern Alaska, Europe from Denmark as far east as the Volga Basin in Ukraine, and possibly Tashkent (Ravn, 1933, 1939; Makarenko, 1970; Anderson, 1973, 1974; Kollmann and Peel, 1983; Marincovich, 1993) and in the Late Paleocene extending further south into the Anglo-Franco-Belgian Basin;

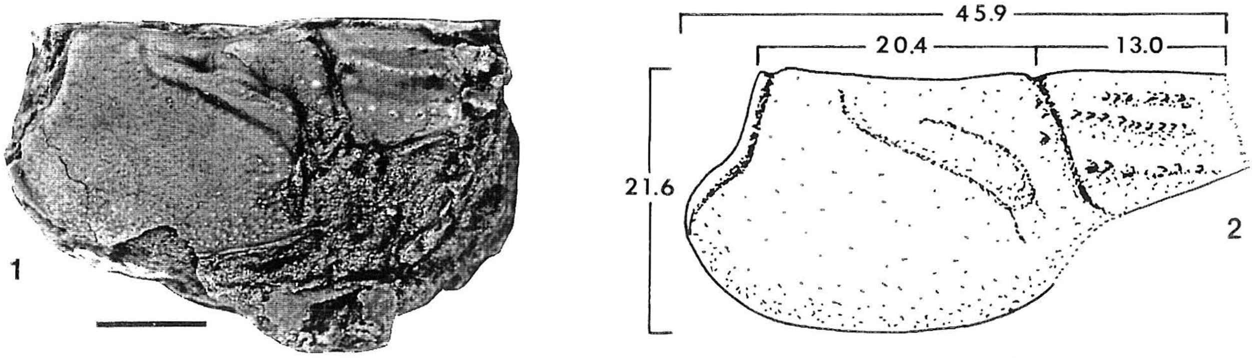


Figure 54. Glypheid decapod *Glyphea stilwelli* Feldmann, 1993, from Abbotsford Formation or Steel Greensand ("Wangaloan") of Mt. Watkin, North Otago. Left figure (right lateral view of the carapace of the holotype, OU 39532). Right figure (line drawing of the carapace of holotype showing measurements taken). Grid reference: I43/208130.

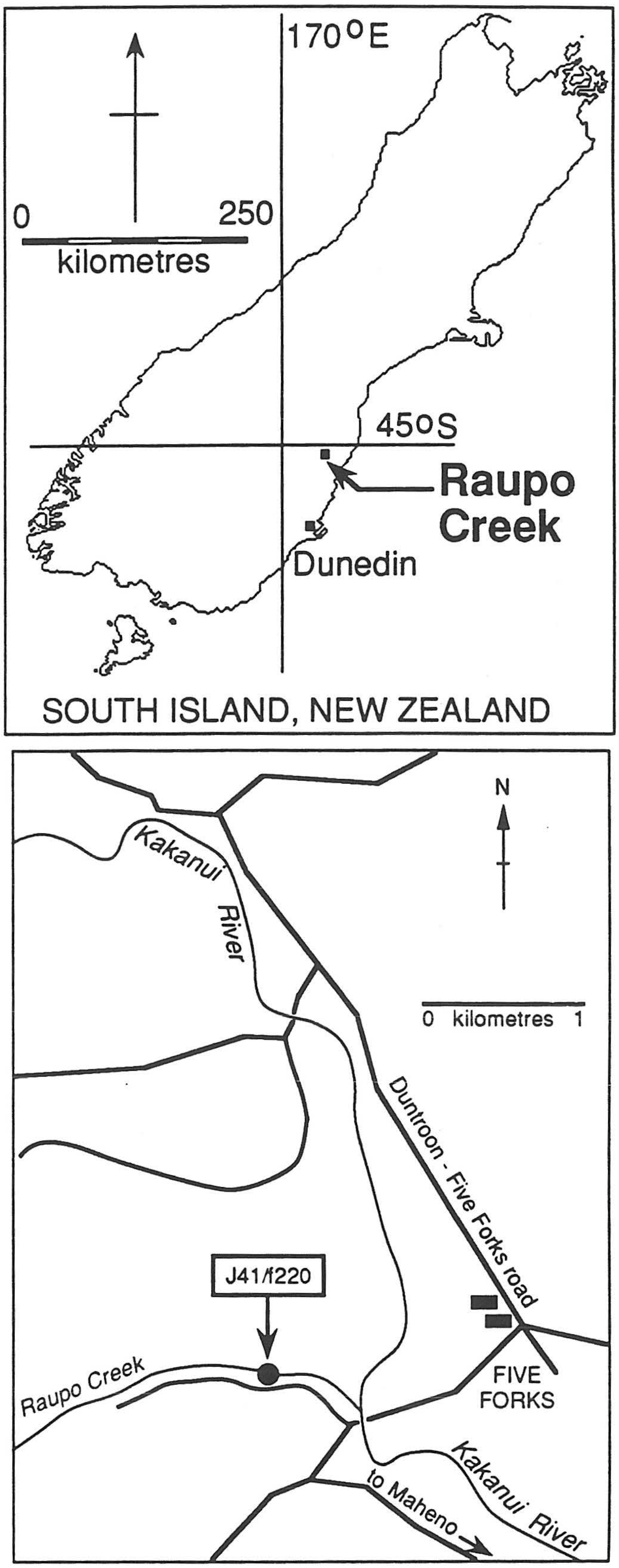


Figure 55. Location of crinoid locality at Raupo Creek, North Otago. Grid reference J41/327702 corresponds to fossil record number J41/f22

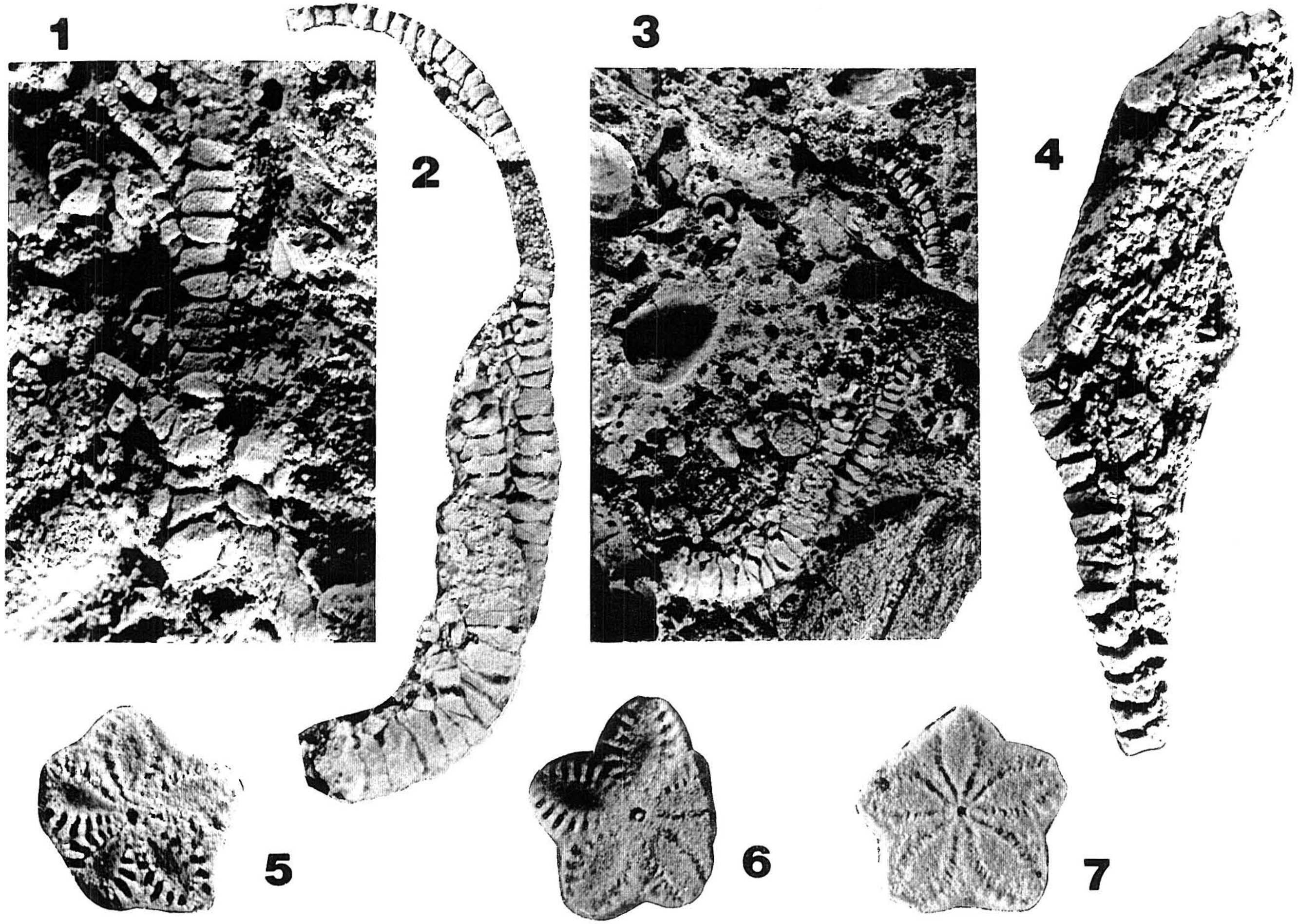


Figure 56. Metacrinus sp. of Stilwell et al. (1993). 1, partially articulated skeleton with some pinnules preserved, OU 40648, x 5; 2, partially bifurcating arm with ligamentary articulations preserved between some brachials (cryptosyzygies), OU 40647, x 2.5; 3, same specimen as 2 showing coarse sediment component, OU 40647, x 1.5; 4, partially articulated skeleton, OU 40649, x 5; 5-7, isolated columnals, 5, OU 40744, x 6; 6, OU 40745, x 6; 7 OU 40756, x 6.

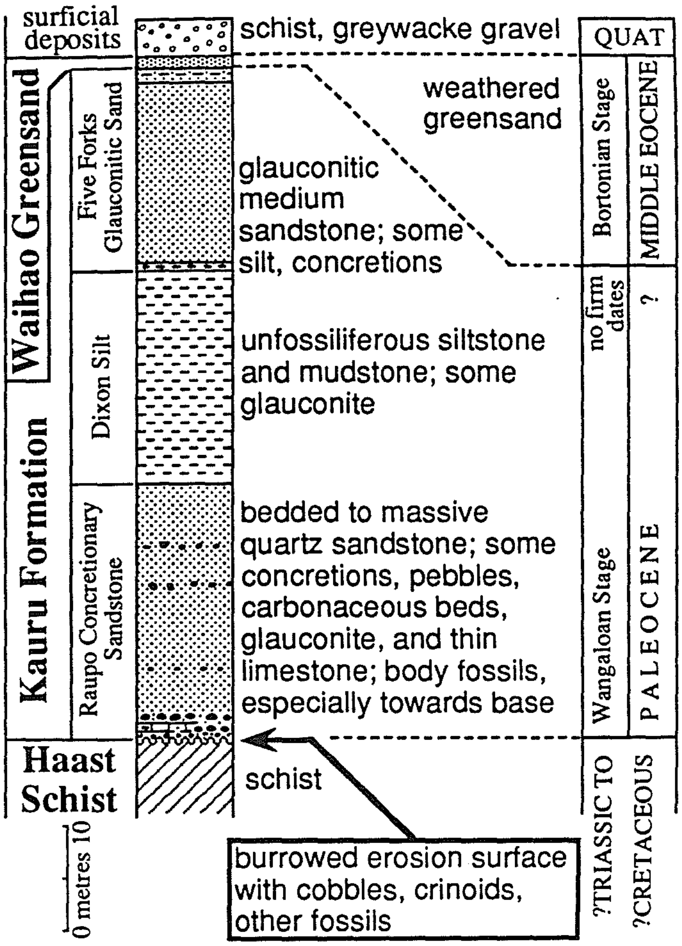


Figure 57. Raupo Creek stratigraphic column revised slightly from Gage (1957). Metacrinus sp. specimens and other fossils were collected from the basal 0.3 m of the Kauru formation (shown by arrow), resting unconformably on Haast Schist. Quat. = Quaternary.

2) a temperate to warm-temperate fauna in the Early Paleocene of Europe (Belgium, France) (Glibert and Van der Poel, 1973) and in America from New Jersey in the north as far south as Brazil (Stanton, 1920; Gardner, 1933; Toulmin, 1977; Zinsmeister, 1983);
3) an Early to Late Paleocene tropical to warm water Tethyan fauna reaching from central west Africa and north Africa eastwards as far as India and Burma (Adegoke, 1977); and
4) a southern hemisphere group of faunas from now isolated regions of Early to Late Paleocene age, including New Zealand (Finlay and Marwick, 1937; this work), Chatham Islands (Campbell *et al*., 1993), Australia (Singleton, 1943; Darragh, in press), Antarctica (Zinsmeister and Macellari, 1988), and southern South America, predominantly in Argentina (Leanza and Hugo, 1985; Olivero *et al*., 1990; Griffin and Hünicken, 1994).

Many of the "Wangaloan" taxa found in the northern hemisphere during the Paleocene are considered to be long-ranging taxa which were apparently well-established around the globe by the end of the Late Cretaceous or earliest Paleocene (e. g. *Leionucula*, *Ledina*, *Isognomon*, *Ostrea*, *Glycymerita*, *Priscoficus*, *Euspira*, *Amuletum*, *Gegania*, and *Odostomia*).

Paleogeography of the Gondwana Realm

It is well known that distributions of molluscs and other benthic marine organisms reflect preference/tolerance for temperature and salinity, substrate preference, larval dispersal capabilities and a host of other parameters. It follows that changes in climatic, oceanic and tectonic regimes associated with the breakup of the supercontinent Gondwana directly influenced distributions of the extant shallow, benthic biotas of the southern hemisphere.

The paleogeography of New Zealand relative to the Gondwana margin during the Cretaceous and Paleogene is fairly well constrained. Continental configurations for the southern hemisphere during this interval are based on geological/paleontological evidence, including sea-floor magnetic data; critical/useful information was reviewed in papers such as those of Zinsmeister (1979, 1982, 1987), Weaver et al. (1980), Coleman (1980), Kennett (1980), Knox (1980), Stevens (1980, 1985, 1989), Ziegler et al. (1983), Kamp (1986), Korsch and Wellman (1988), Elliot (1988), Skelton (1988), Bradshaw (1989), Clarke and Crame (1989), McGowran (1990, 1992), Mayes et al. (1990), White (1990), Grunow et al. (1991), Eastman (1991), Cooper and Tulloch (1992), Holdsworth and Nell (1992), Hovan and Rea (1992), Huber and Watkins (1992), Lawver et al. (1992), Specht et al. (1992), and Cooper and Millener (1993). During the Early Mesozoic the continents of the southern hemisphere were united into a single supercontinent Gondwana (usage of "Gondwanaland" has been abandoned by most workers), composed of India, Africa, Australasia (New Zealand, Australia, South Pacific islands), South America, and Antarctica. The Gondwana landmass as a whole had been considerably reduced in area due to fragmentation with loss of India and Africa by Cretaceous time when it was made up of Australia (also New Caledonia), Antarctica, South America, and the New Zealand region (including submerged continental crust beneath Lord Howe Rise, Norfolk Ridge, Chatham Rise and Chatham Islands, and Campbell Plateau) (see Figures 58-71). (Note: The

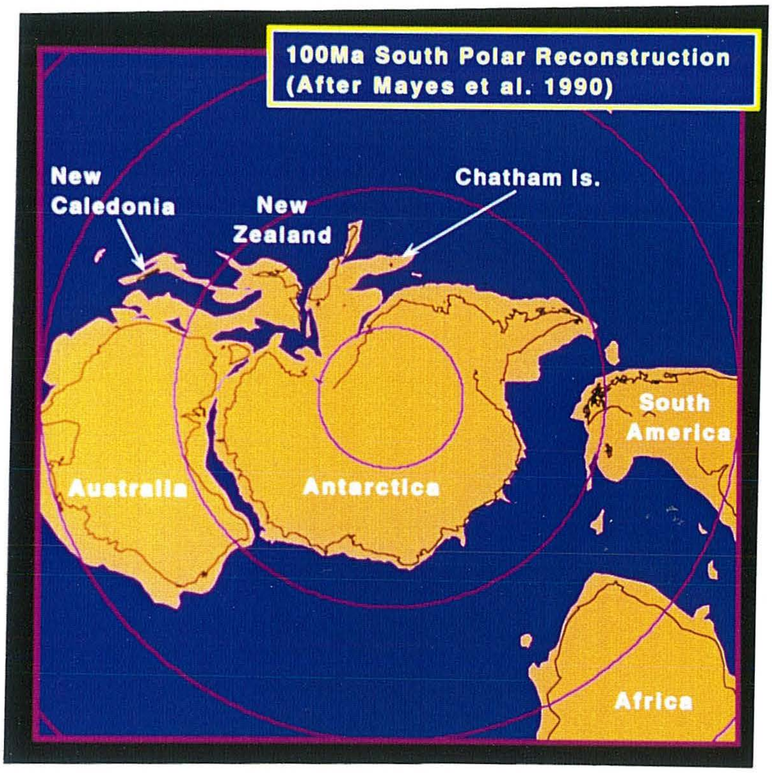


Figure 58. 100 Ma South Polar reconstruction of Gondwana Realm (after Mayes *et al.*, 1990).

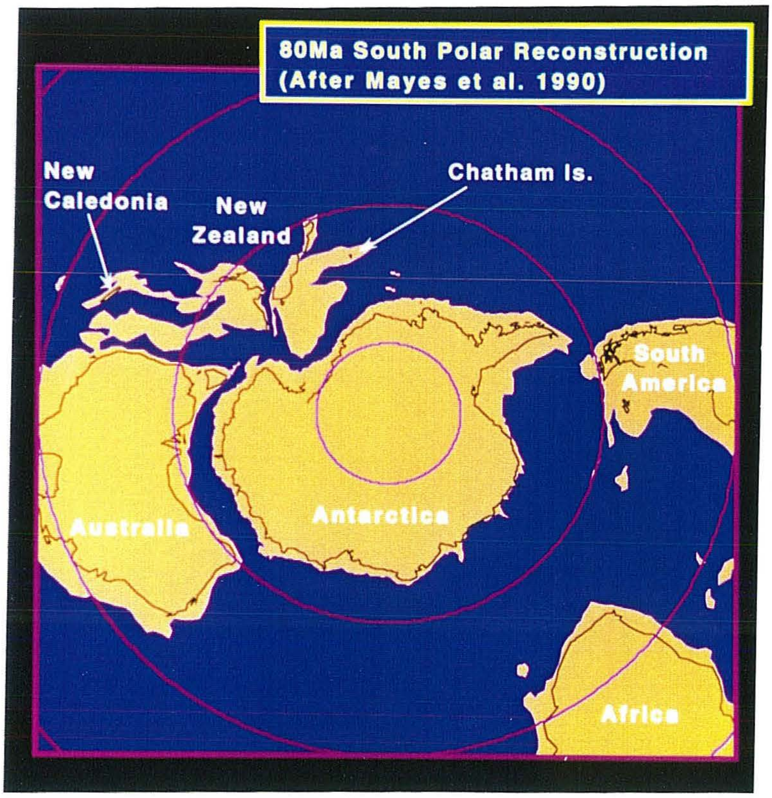


Figure 59. 80 Ma South Polar reconstruction of Gondwana Realm (after Mayes *et al.*, 1990).

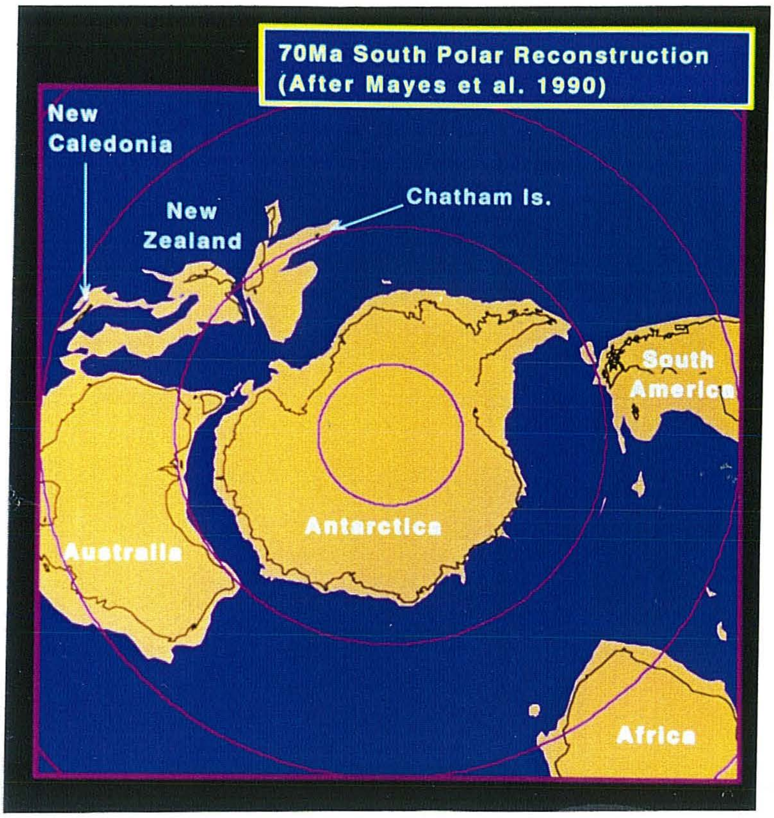


Figure 60. 70 Ma South Polar reconstruction of Gondwana Realm (after Mayes et al., 1990).

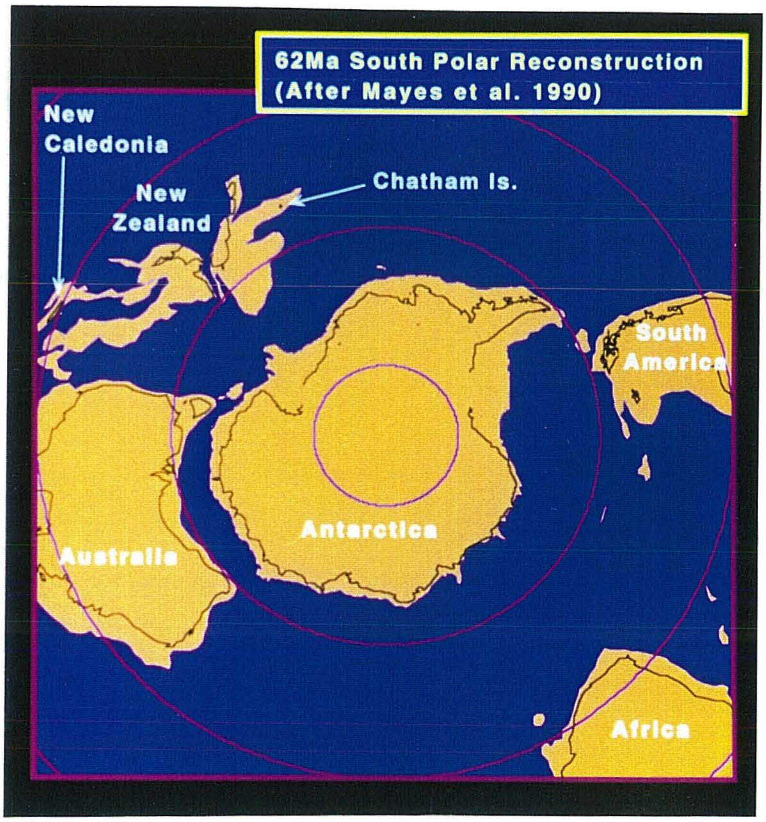


Figure 61. 62 Ma South Polar reconstruction of Gondwana Realm (after Mayes et al., 1990).

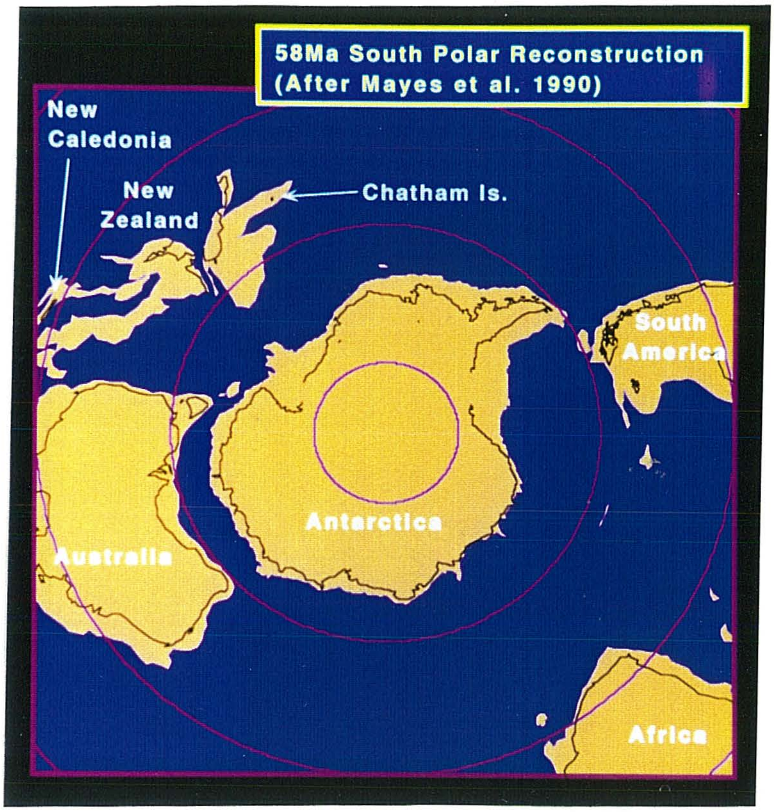


Figure 62. 58 Ma South Polar reconstruction of Gondwana Realm (after Mayes *et al.*, 1990).

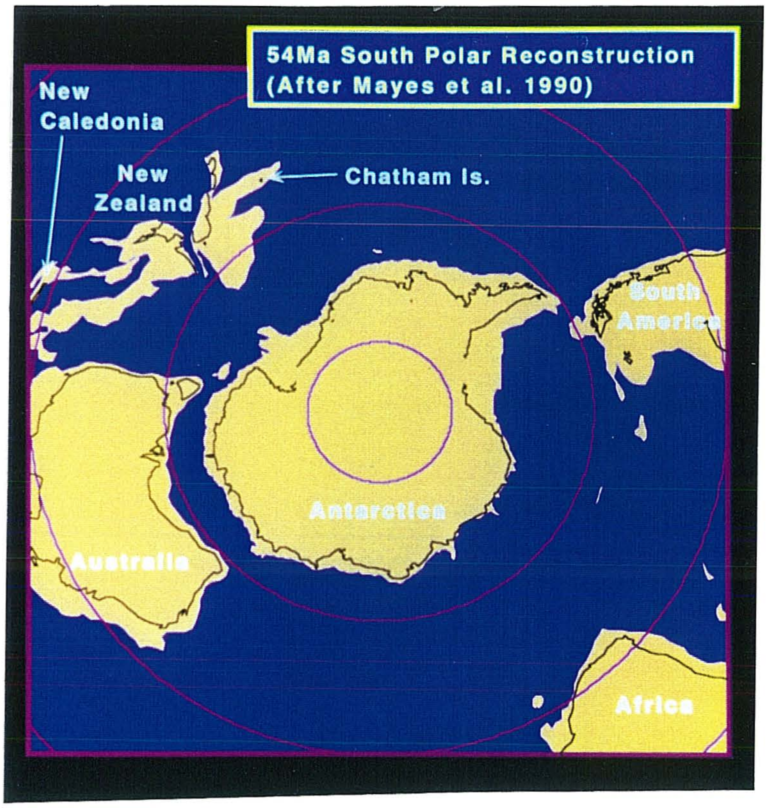


Figure 63. 54 Ma South Polar reconstruction of Gondwana Realm (after Mayes *et al.*, 1990).

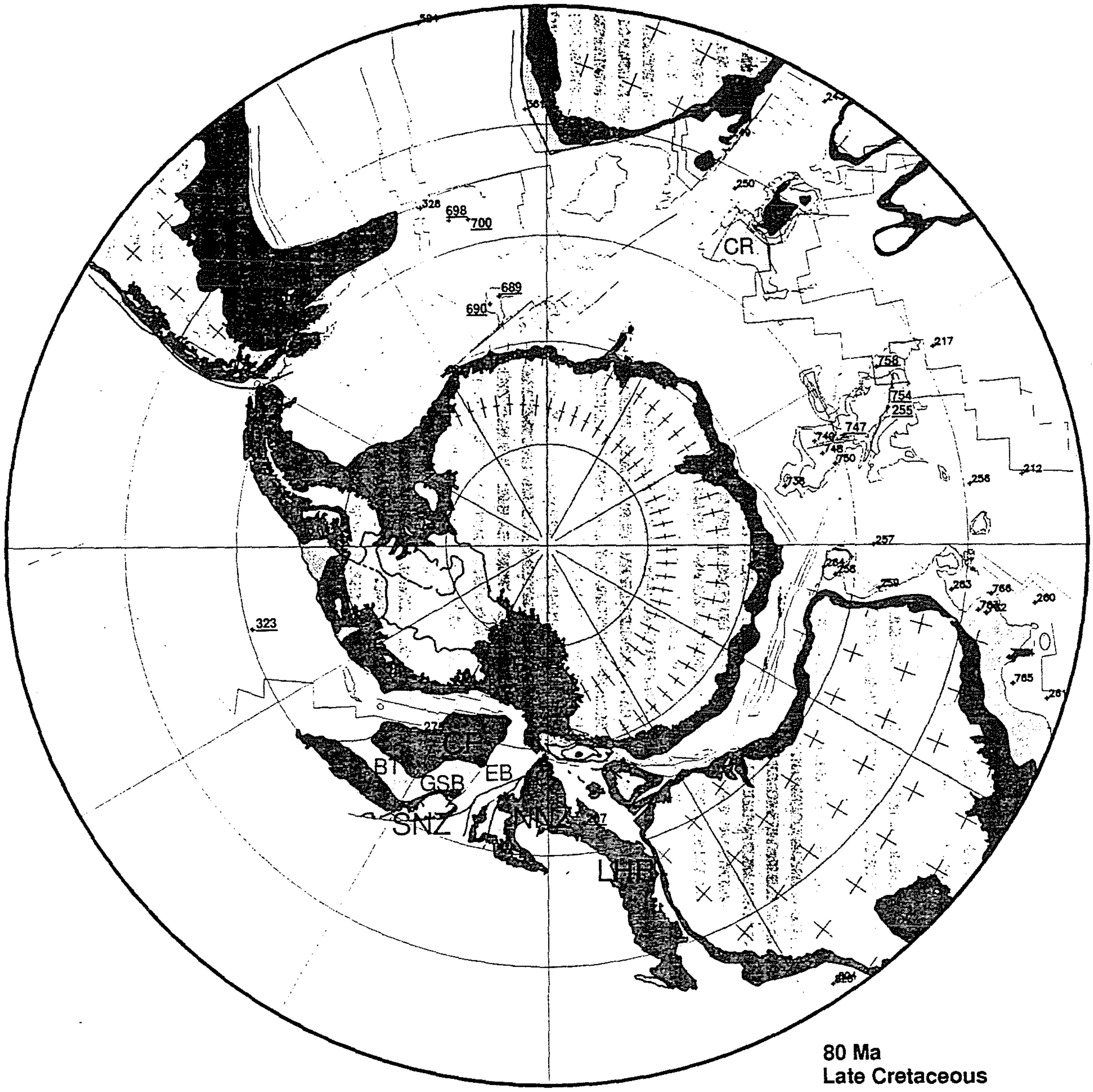


Figure 64. Paleogeographic reconstruction of southern Gondwana at 80 Ma. Reconstruction shows rifting of Campbell Plateau from Marie Byrd Land with the extension of the Pacific-Antarctic spreading center to the west and rifting in the Tasman Sea between Lord Howe Rise and eastern Australia. BT, Bounty Trough; CP, Campbell Plateau; CR, Conrad Rise; EB, Emerald Basin; GSB; LHR, Lord Howe Rise; NNZ, north New Zealand; RS, Ross Sea Embayment; SNZ, south New Zealand (from Lawver et al., 1992).

= Great South Basin

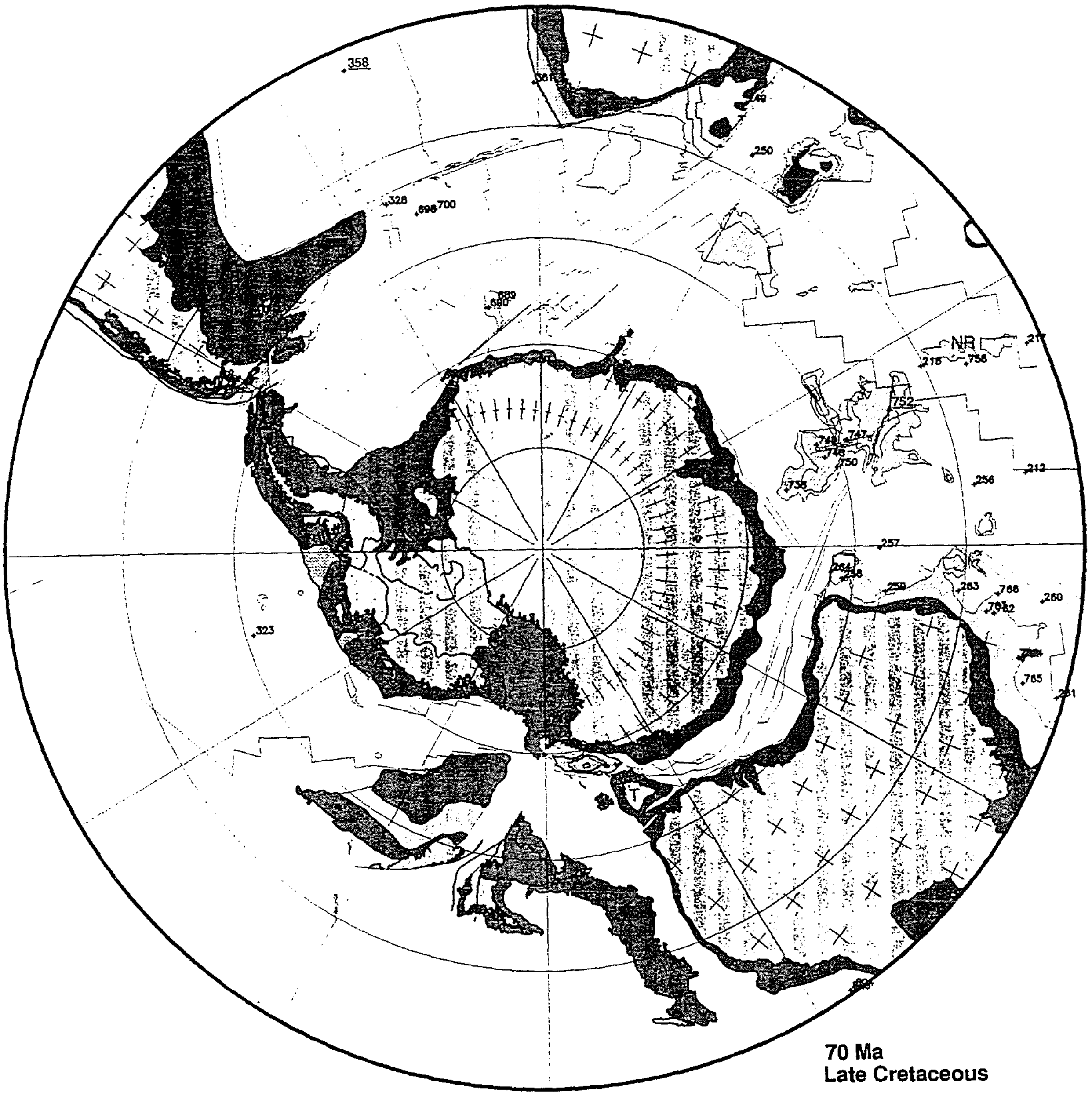


Figure 65. Paleogeographic reconstruction of southern Gondwana at 70 Ma. NR, Ninety Degree East Ridge; T, Tasmania (from Lawver et al., 1992).

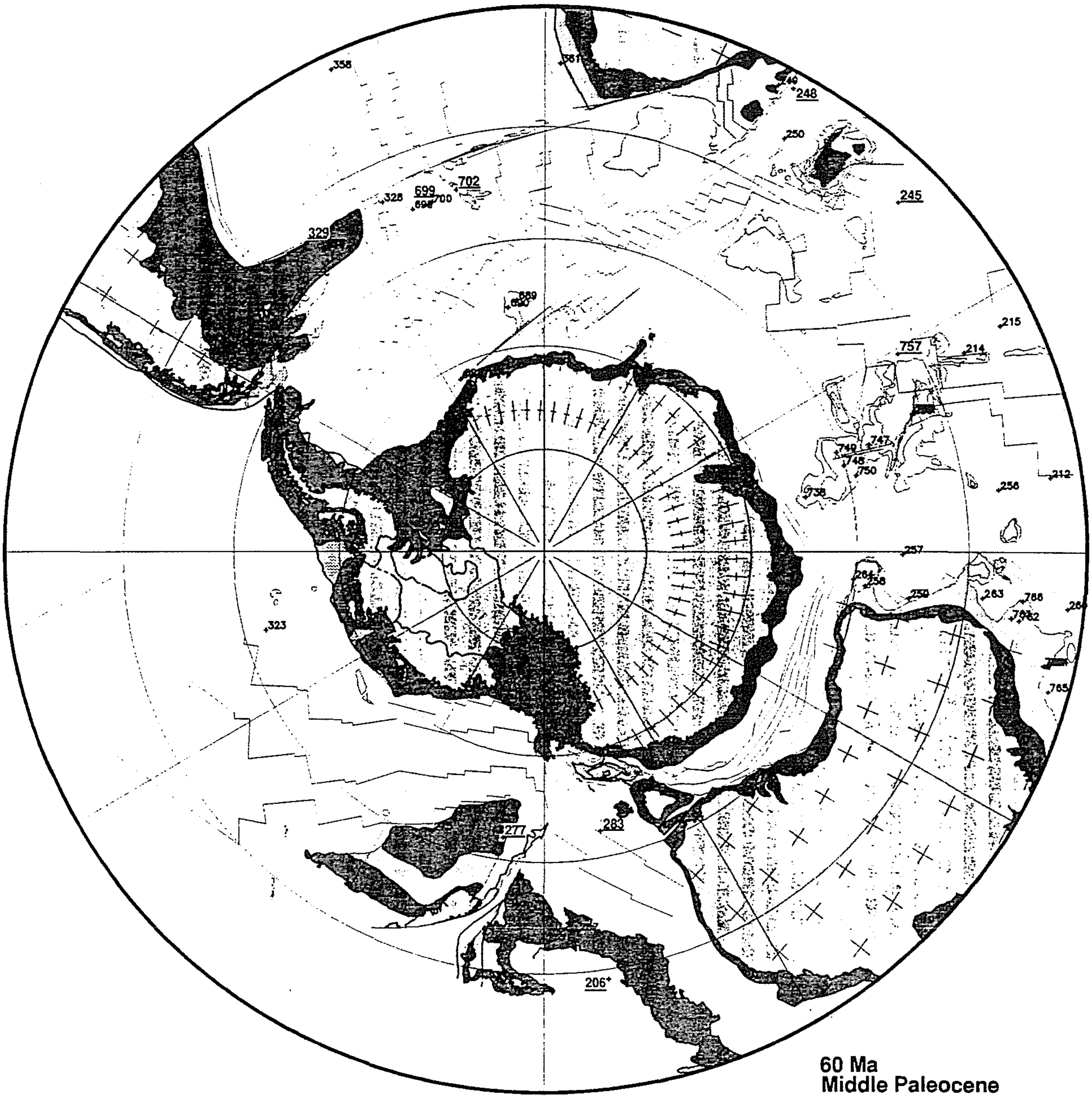


Figure 66. Paleogeographic reconstruction of southern Gondwana at 60 Ma (from Lawver et al, 1992).

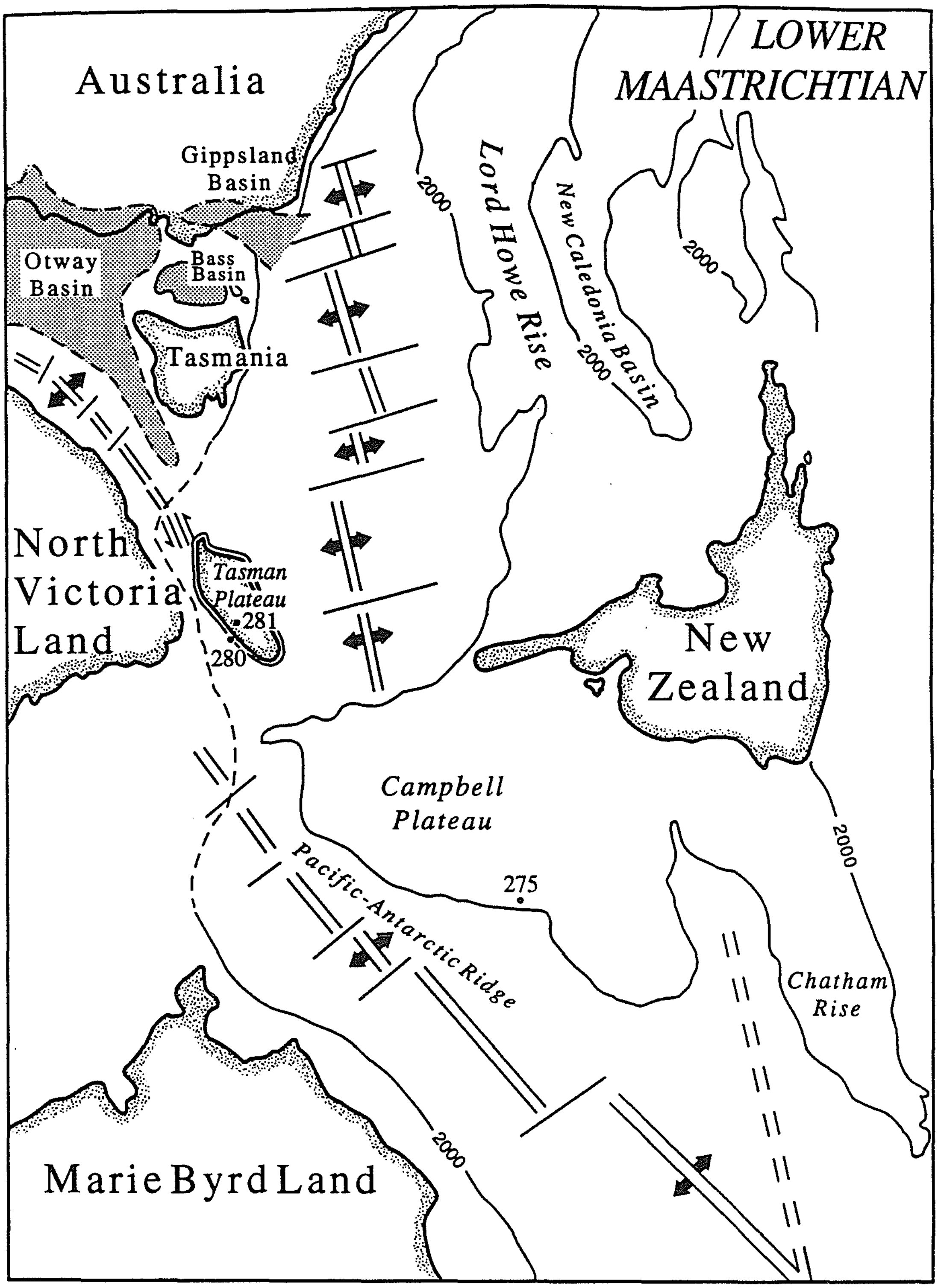


Figure 67. Early Maastrichtian (Anomaly 32) paleogeographic reconstruction of the southwest Pacific region showing the location of sedimentary basins in southeastern Australia and DSDP Leg 29 sites 280 and 281. Continental margins are taken to follow the 2000 m contour (from Huber, 1992).

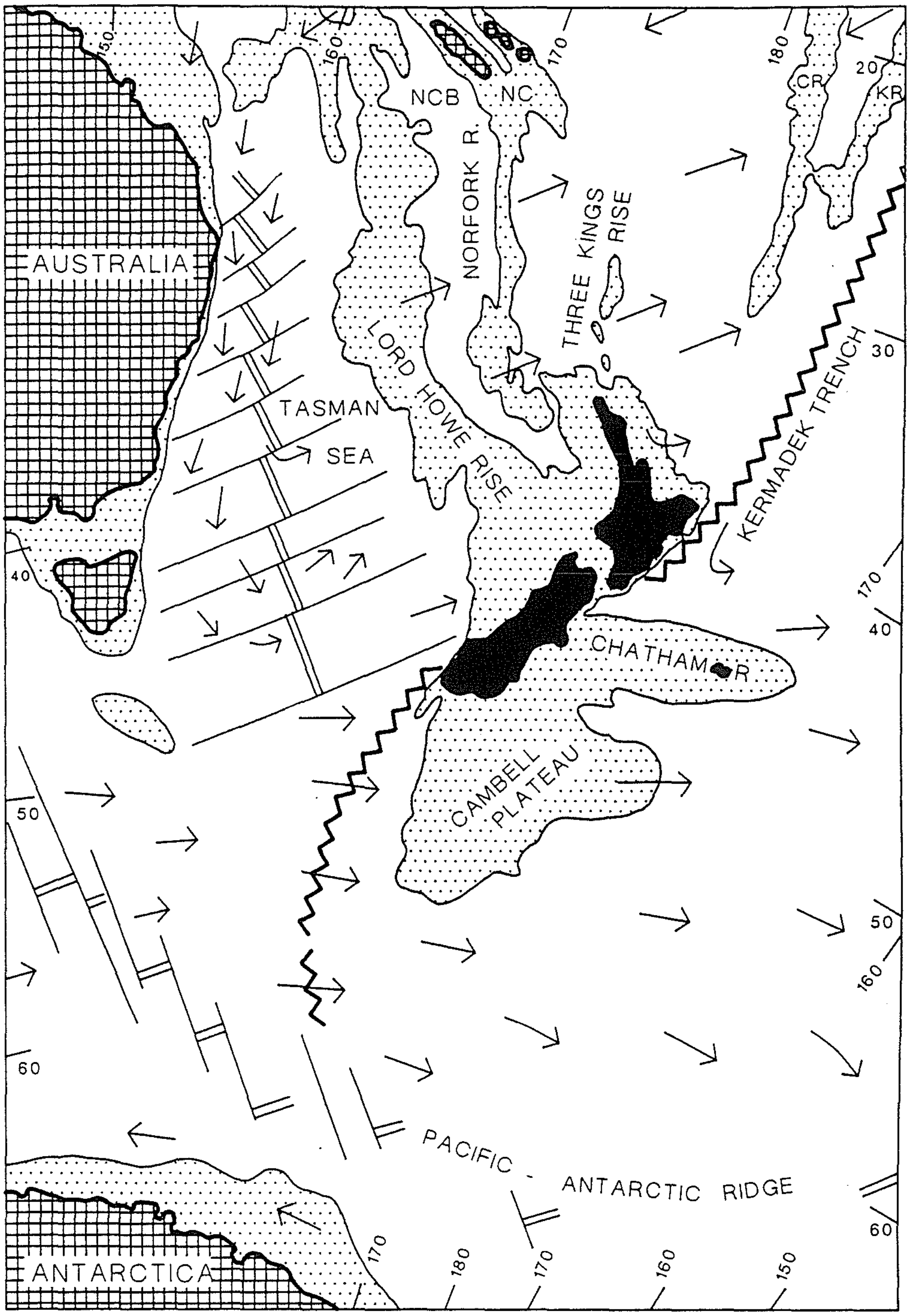


Figure 68. Location of New Zealand relative to Australia and Antarctica. The 2000 m isobath gives the approximate outline of continental crust (shaded); the sea-floor spreading centres in the Tasman Sea (extinct) and South Pacific Ocean (active), shown by double lines, with their associated transform faults, give the direction of plate movement in the New Zealand region. The present-day plate boundary through New Zealand is shown by the zig-zag line. The arrows indicate the direction of present-day surface water ocean currents. NC, New Caledonia; NCB, New Caledonia Basin; CR, Colville Ridge; KR, Kermadec Ridge (from Cooper and Millener, 1993).

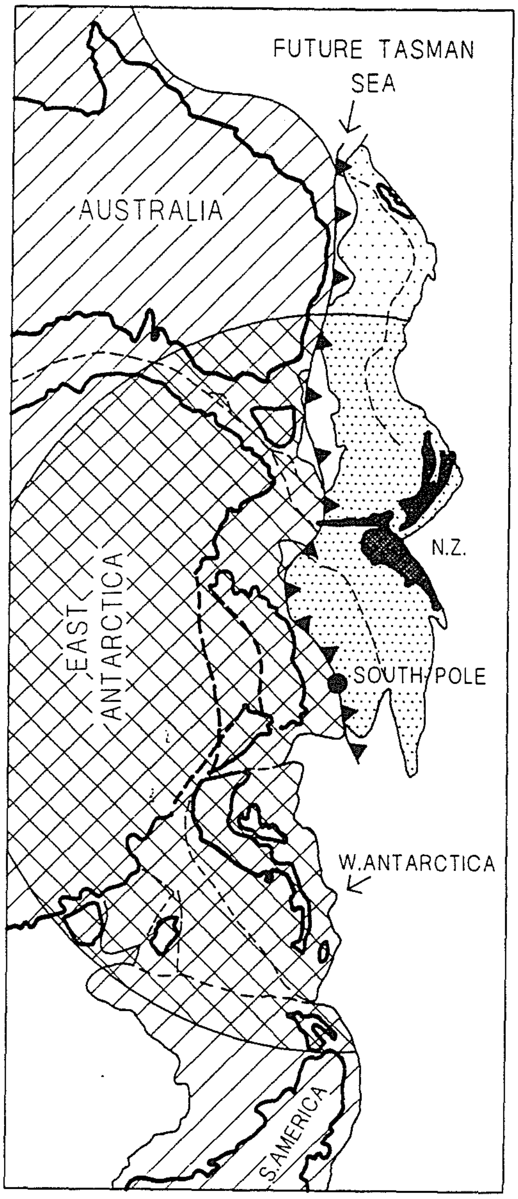


Figure 69. The New Zealand region (shaded), most of which was above sea-level, as part of Gondwana (cross-hatched) in the Late Cretaceou (90 Ma). The Antarctic circle (66°S) and the area affected by winter darkness are shown by the denser pattern (from Cooper and Millener, 1993).

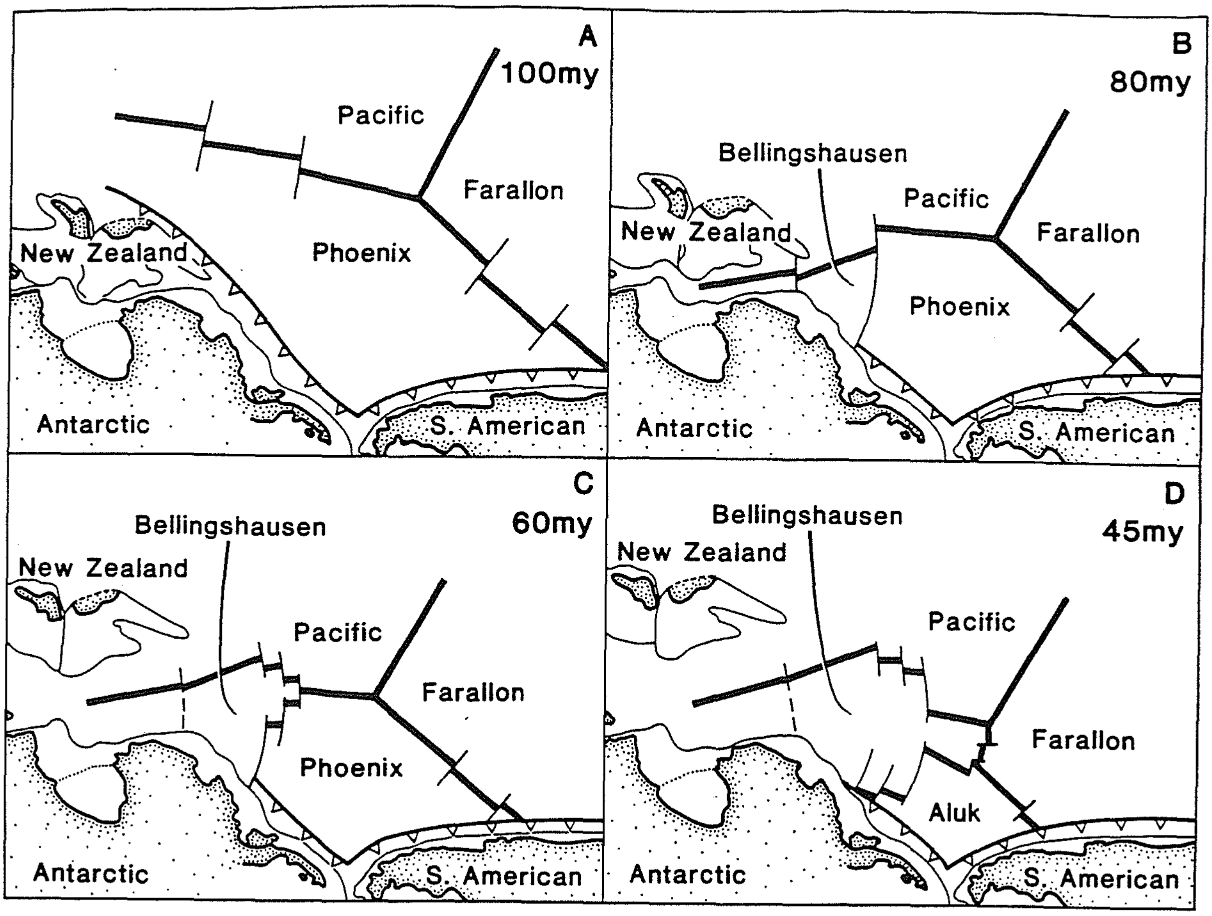


Figure 70. Evolution of the sea floor of the southeastern Pacific Ocean with lithospheric plates identified by name, with the exception that New Zealand is used only in a geographic sense (from Elliot, 1988).

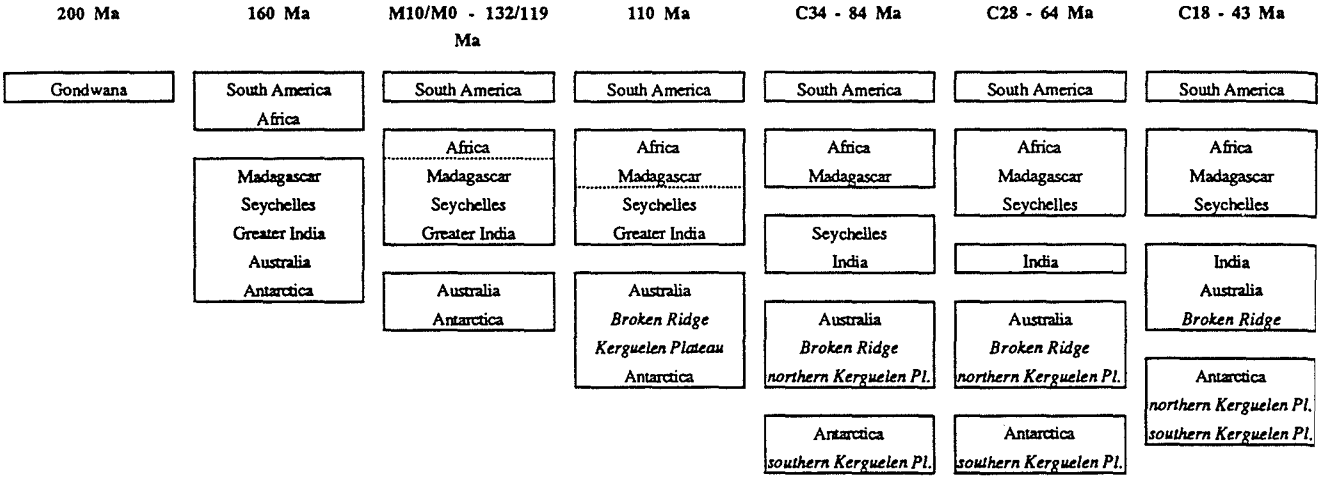


Figure 71. Circum-Antarctic seafloor spreading chronology and plate configurations. Seaways developed between the major boxed continental assemblages shown. Dotted lines indicate uncertain configurations. Italics indicate crustal blocks of dominantly oceanic affinity (from Lawver et al., 1992).

driving force behind the break-up of Gondwana is highly speculative, but a relatively new (if not somewhat radical!) hypothesis by Overbeck et al. (1993) of NASA suggests that geological evidence of extraterrestrial impacts during the Late Paleozoic could explain the reason for fragmentation of Gondwana. These authors argued mathematically that divergent forces alone of plate tectonics would not be sufficient to pull the plates apart.) The final break-up of the remaining continental "fragments" of Gondwana during the Late Cretaceous and early Paleogene is of paramount importance to our understanding of Late Mesozoic and early Cenozoic climates in the southern hemisphere, evolution of oceanic circulation patterns and resultant biogeographic changes.

For convenience (cf. Zinsmeister, 1987), the Gondwana landmass can be divided into an eastern sector (some workers prefer western) composed of East Antarctica, Australia-New Guinea-New Caledonia and New Zealand-Chatham Islands region and a western sector (some workers prefer eastern) consisting of West Antarctica (Marie Byrd and Ellsworth lands, Ellsworth and Whitmore mountains), Antarctic Peninsula and South America. The geological histories and relationship between the eastern and western sectors of Gondwana are still not clear (Zinsmeister, 1987, p. 200).

Tectonic history of New Zealand

The Cretaceous Period was a critical time for "Greater New Zealand" (see Stevens, 1989) in terms of tectonics, geography and biogeography as land links between New Zealand and the eastern Gondwana margin were severed by divergent plate motions/rifting along the western margin of New Zealand and along the western part of the Lord Howe Rise (Figures 67-70). During the Cretaceous the New Zealand region (and adjacent Gondwana margin) experienced two major tectonic regimes: 1) a well-established convergent margin which generated a complex of tectonostratigraphic terranes at or near the Gondwana margin throughout the Mesozoic, forming the eastern part of New Zealand; and 2) extension and rifting following collision during the Late Cretaceous which pulled the New Zealand block away from the Australian/Antarctic sector of Gondwana; divergence was facilitated by the westward propagation of the Pacific-Phoenix ridge, linking areas of incipient spreading south of Australia and in the Tasman Sea (see Elliot, 1988, Fig. 4 (Figure 70 herein); Bradshaw, 1989). Incipient rifting began during the late Neocomian, increasing during Aptian-Albian (late Early Cretaceous) times, leading to the development of new sea floor and fully marine conditions in the Tasman Sea and Southern Ocean and marked disruptions of land links by Campanian time (c. 85-80 Ma; probably closer to 84 Ma (anomaly 34)) (Weissel and Hayes, 1977; Coleman, 1980; Elliot, 1988; Korsch and Wellman, 1988; Stevens, 1989 (review); Cooper and Millener, 1993 (review)). Fracture patterns of the Southern Ocean floor indicate that the

Chatham Islands part of the New Zealand continent fitted into the Pine Island Bay region of Marie Byrd Land, Antarctica before fragmentation, as advocated by the South Pacific Rim International Tectonics Expedition; the South Pacific Rim project represents an international effort to understand the processes by which New Zealand split away from Antarctica approximately 85 Ma (Bradshaw et al., 1992). An unlikely paleogeographic reconstruction by Hovan and Rea (1992, p. 15, Fig. 1) depicted New Zealand at 60 Ma as being partially attached (more or less same outline as today) to southeastern Australia.

"Greater New Zealand" during the Late Cretaceous was characterised both by moderate relief and an amalgam of possibly as many as 13 tectonostratigraphic terranes which were sutured to the New Zealand margin of Gondwana (Cooper and Millener, 1993, p. 429). The shape of New Zealand during the Late Cretaceous was very different from its present form (Figure 67). Korsch and Wellman (1988, p. 443) stated that "there is virtually no direct geological control for change of shape, and the inferred change is so large that the New Zealand of Gondwana is almost unrecognizable in the New Zealand of today, and this in spite of the fact that slightly over half of New Zealand remains rigid, distortion being confined to the Alpine Fault Zone." During the mid Cretaceous the New Zealand region was situated in a high latitude position (c. 85° S) with the South Pole straddling the edge of the Campbell Plateau; plate movements during the Late Cretaceous moved New Zealand away from the South Pole, so that at this time it occupied a lower latitude position of c 65°-55° S (see review by Stevens, 1989, p. 149). The excellent marine Late

Cretaceous fossil record of New Zealand reflects a further effect of rifting away from the Gondwana margin. As New Zealand separated finally from the Gondwana margin, its crust was thinned to some 26 kilometres (as reviewed by Thornton, 1985, p. 111; further research is underway to establish thicknesses of continental crust, which vary from place-to-place, P. O. Koons, pers. commun.) and because of the resultant thermal subsidence the seas began to transgress over eastern New Zealand (Wilson, 1956). The widespread marine deposits present today from the tip of Northland to southeastern Otago attest to this subsidence and greater New Zealand's denudation during the latest Cretaceous. In general these Cretaceous-Cenozoic transgressive sediments are characterised first by sandstone, followed by carbonaceous siltstone, calcareous mudstone and ultimately limestone (Korsch and Wellman, 1988, p. 465).

"Greater New Zealand" was well-separated from the Gondwana margin (Antarctica-Australia) during the Paleocene, as evidenced by sea-floor spreading data and the highly provincial nature of the biotas. Spreading in the Tasman Sea ended during the Late Paleocene (c. 60 Ma) when it attained approximately its present width; spreading continued, however, widening the Southern Ocean south of New Zealand, between Antarctica and the southern edge of the Campbell Plateau (reviewed by Stevens, 1989, p. 151). During the Paleocene New Zealand was situated at a latitude of 50-45°S, in contrast to 65-55°S in the Late Cretaceous (Stevens, 1985, 1989). As will be discussed below, there is no evidence to support the statement of Stevens (1989, p. 155) that although the northwards component of New Zealand's movement brought it into regions influenced by warm temperate waters, cool-temperate conditions existed in this country at least until the Early Paleocene, as indicated by the "Wangaloan" fauna of "cool-water aspect."

Oceanic circulation patterns

Final fragmentation of the Gondwana supercontinent during the Late Cretaceous and early Tertiary played a significant role in interpreted changing oceanic circulation patterns around the rim of the southern circum-Pacific. Such events in turn influenced climate. To reconstruct accurately sea-surface gyres in the southern hemisphere for this interval, it is paramount that detailed information be available on relative positions of sea and land and on timing of tectonic events and opening/closing of marine seaways. These events are reasonably well-constrained apart from uncertainties about the complex Scotia Arc region and much of Antarctica which is masked by c. 97% ice cover. According to Zinsmeister (1982, p. 90) three major differences exist between the South Pacific of the Late Cretaceous and early Tertiary and that of the present day; these are:

"1) absence of southern connections with the Indian Ocean and very poor connections with the Atlantic;

2) land areas in the western South Pacific were in an extreme southern location with a broad seaway to the Indian Ocean to the north; and

3) the width of the Pacific was nearly half again as great as it is today."

Zinsmeister (1982, p. 90) hypothesised that, based on modelling circulation patterns in the North Pacific, the "southern Pacific was dominated by counterclockwise circulation with a western boundary current flowing southward along Australia and New Zealand similar to the present-day Kuroshio Current of the North Pacific." Zinsmeister believed that: 1) the southern circum-Pacific was for the most part isolated by prevailing oceanic circulation from other major oceans in the southern hemisphere; and 2) that the inferred oceanic circulation model for the southern hemisphere would have prevailed until the opening of the Southern Ocean between Antarctica and Australia and the Drake Passage which lead ultimately to the formation of the Circum-Polar Current about 38 Ma. Although rapid spreading between Australia and East Antarctica did not commence until the early Tertiary evidence from seismic studies indicates that separation occurred much earlier than previously thought in the Neocomian at c. 120 Ma (at least in the area from the Great Australian Bight to the Naturaliste Plateau) (Stag and Willcox, 1991).

Huber and Watkins (1992) summarised published and new data for the inferred Campanian-Maastrichtian oceanic circulation in the southern hemisphere as follows (Figures 72-74 herein); conclusions reached by these authors include:

1) early Campanian gyral circulation was weak and broadly latitudinal in the South Atlantic, poorly developed in the newly forming Indian Ocean, and very broad in the South Pacific;
2) by mid Campanian time sea-floor spreading had opened shallow marine seaways between the Campbell Plateau, Marie Byrd Land,

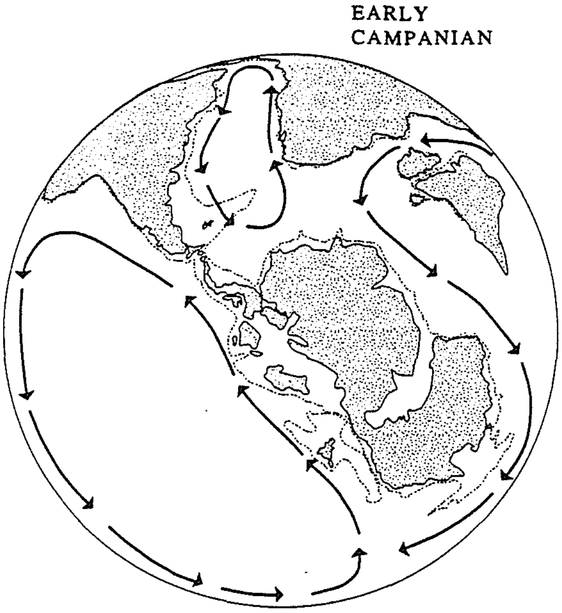


Figure 72. Southern hemisphere surface circulation inferred for the early Campanian (84 Ma) (from Huber, 1992).

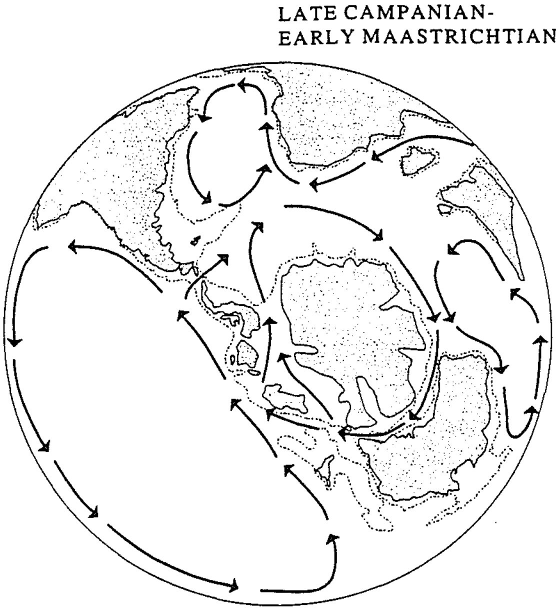


Figure 73. Southern hemisphere surface circulation inferred for the late Campanian and early Maastrichtian (79 Ma). Note that shallow marine gateways are open (contrary to being closed during the early Campanian) between New Zealand, Australia, Antarctica, and South America at a time of global eustatic sea-level, enabling circum-Antarctic flow of shallow surface waters (from Huber, 1992).

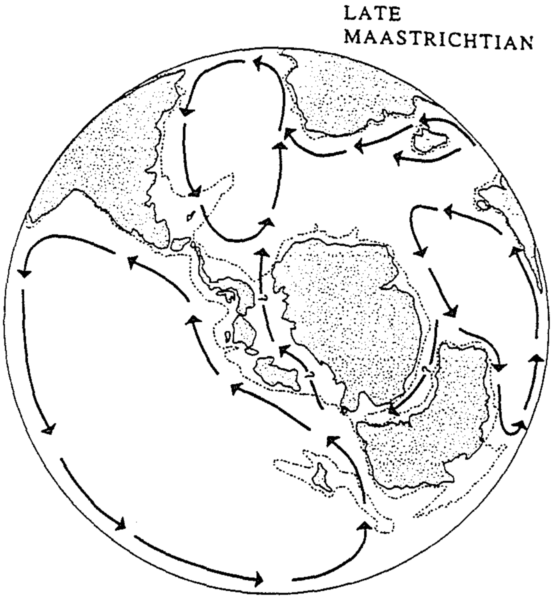


Figure 74. Southern hemisphere surface circulation inferred for the late Maastrichtian (70 Ma). Note that shallow seaways between Antarctica, Australia, and New Zealand continue to widen slowly, but uplift of a postulated South American-Antarctic Peninsula isthmus and a sea level fall have restricted surface communication between the South Atlantic and southwest Pacific Ocean Basins (from Huber, 1992).

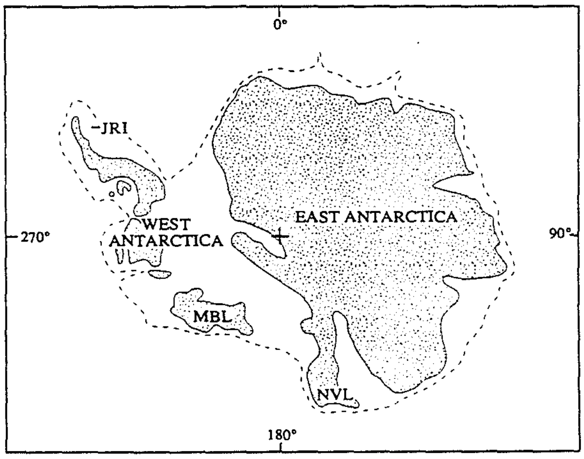


Figure 75. Paleogeographic map of East and West Antarctica showing areas inferred to have been flooded by shelf seas during maximum high-stands of sea-level during the Late Cretaceous (from Huber, 1992)

and the Tasman Sea, and between South America and Antarctica;

3) mid Campanian flooding of shelfal basins within Antarctica would have been at a maximum, forming a continuous migration route for shallow marine taxa that originated in different regions of the Gondwana Realm;

4) deep ocean passages developed in the southern hemisphere during the latest Cretaceous and the early Paleogene, resulting in slow widening of the Australian, Tasman, and South American-Antarctic gateways (Lawver _et al_., 1992); and

5) presence of microfossils of latest Cretaceous age in reworked glacial diamictites in the Transantarctic Mountains provides evidence of trans-Antarctic seaways (Figure 75, this work) and implies that open marine conditions existed ephemerally during the Late Cretaceous in sedimentary basins in or between East and West Antarctica. These basins could have originated during an extensional phase(s) of late Mesozoic rifting and graben downfaulting as a result of the fragmentation of the Gondwana continental "fragments" (see Bradshaw, 1991; Cooper _et al_., 1991; Storey, 1991).

If an Antarctic seaway existed during the Late Cretaceous and if the oceanic circulation models of Zinsmeister (1982) and Huber and Watkins (1992) are correct, molluscan larvae could have readily been dispersed along the shallow shelves via currents 1) moving from New Zealand-Chatham Islands to the margins of Marie Byrd Land-Antarctic Peninsula and through the shallow gateway between the Peninsula and southern South America and/or 2) originating from New Zealand-Chatham Islands and eventually moving northwards through the trans-Antarctic seaway to reach the

James Ross Basin, Antarctic Peninsula. Because part of West Antarctica was thought to be a series of volcanic islands during the Late Cretaceous (Zinmeister, 1987), larvae could have been readily dispersed through these areas, notwithstanding the probability of a transantarctic seaway. Strong similarities between the molluscan faunas of New Zealand and Antarctic Peninsula (discussed in detail below) suggest that there was strong communication between the shelf faunas of these areas. However, the large distance between New Zealand and Antarctic Peninsula during the Late Cretaceous (approximately same paleolatitude as Seymour Island, c. 90° of longitude difference or more) probably means that, for the most part, only planktotrophic and/or teleplanic larvae could have dispersed such great distances. I have assessed faunal similarity, based on published and new data, to determine that this faunal communication between New Zealand and western sector of the Gondwana Realm including the Antarctic Peninsula and southern South America was greatly reduced during the Paleocene when New Zealand had become increasingly isolated geographically and also oceanigraphically. That New Zealand was at its peak of isolation during the Paleocene is reflected in the highly endemic nature of the faunas. With the final fragmentation of East Antarctica from Australia and development of deep-sea conditions between these areas and the Drake Passage, the isolation of New Zealand would not have been as great and the marine faunas not as provincial.

It seems reasonable to assume that the advent of the

Circum-Polar Current would have decreased the isolation of faunas/floras around the southern rim of the Pacific. Indeed, correlation coefficient values calculated from published and unpublished molluscan data from the Late Eocene of New Zealand, Chatham Islands, Australia, Antarctica, and southern South America reveal an increased degree of similarity through the Eocene between these faunas suggesting, furthermore, increasing homogeneity and decreasing isolation of the faunas with the beginnings of the Circum-Polar Current (J.D.S., unpublished data).

Climate

Reorganization of the southern hemisphere continental plates played a large role in changing climate during the Late Cretaceous and Paleogene, which clearly further affected the composition of faunas and floras. It is generally agreed that the Cretaceous was a period of global warmth, "an extreme greenhouse world apparently warmer than our current Earth" (Kennett, 1984; Spicer and Corfield, 1992, p. 169), despite possible evidence that some glacial ice could have formed at this time (see review by Barron, 1994, p. 415). Warm temperatures were prevalent in both terrestrial and marine realms. In general the late Maastrichtian to middle Paleocene interval is characterised by cooling, high oxygen levels and vigorous circulation (Kaiho, 1991, pp. 81, 83). Furthermore, a high sea-level and low pole-to-pole temperature gradient existed during the Late Cretaceous (MacLeod, 1994, p. 141). The most useful means of deducing these marine paleotemperatures is by the oxygen isotope method, which is based empirically on the observation that the ratio of stable isotopes of oxygen (^{16}O and ^{18}O), when precipitated in carbonate from a surrounding solution, is dependent on temperature (Spicer and Corfield, 1992, p. 173). In general it is found that the proportion of light isotope of oxygen is greater in warm waters and more of the heavy isotope in cool waters. Fossils used in oxygen isotope work include molluscs, brachiopods, corals and foraminifera. Oxygen isotopes corroborate evidence from fossils to reveal declining sea-surface temperatures during the Late Cretaceous and shallower latitudinal temperature gradients at this time, reflecting a probable decline in atmospheric carbon dioxide due to enhanced productivity in surface waters; for example, low-latitude Pacific paleotemperatures indicate a cooling from equatorial sea-surface temperatures of about 27°C in the Albian to 21°C in the Maastrichtian (Savin, 1977; Spicer and Corfield, 1992, p. 177). Clarke and Crame (1989) summarised the broad surface and bottom temperatures in the Southern Ocean as 15-20°C in the Cretaceous to between +2°C and -1.8°C today. In the New Zealand region Campanian-Maastrichtian temperatures declined from 22.0° during post-Albian time to approximate mean annual temperatures on the order of 14.3° at the end of the Maastrichtian, based on analysis of belemnites (Clayton and Stevens, 1968). High-latitude floras corroborate findings of a warm, moist and equable Cretaceous (Barron, 1984; Askin, 1989), although the climate of the Antarctic Peninsula appears to have been of a warm/cool-temperate type during the Cretaceous and early Tertiary (Francis, 1986; Askin, 1992).

There are rather few Late Cretaceous marine paleotemperature determinations for the high southern latitudes. Pirrie and Marshall (1990, pp. 31, 34) and Ditchfield et al. (1994), utilising macrofossils from the James Ross Basin, recognised a cooling trend in the Antarctic Peninsula between Santonian-Campanian and Maastrichtian time which probably paralleled the cooling trend observed in warm lower latitudes; for example, these authors reported that shelf seawater temperatures of 9-14°C characterised the Late Cretaceous of a paleolatitude of 60°S. Crame (1993, p. 165, Fig. 1) reported similar paleotemperatures of 12-14°C for Antarctica during the Late Cretaceous. Climatic conditions in the Weddell Sea sector of Antarctica were considered to be temperate to cool subtropical during the Late Cretaceous, as evidenced by ODP Leg 113; a marked warming event began about 0.5 Ma before the K-T boundary, followed by significant cooling (Kennett and Barker (1990; see also Huber and Watkins, 1992). Savin (1977, p. 331) found that the "magnitude of the temperature drop identified near the boundary [K-T] is small compared to the drop from Santonian through Maastrichtian time or that near the Eocene-Oligocene boundary."

This gradual drop in temperature across the K-T boundary could partially explain the significant number of genus-level mollusc taxa in New Zealand that crossed this boundary and survived the end Cretaceous mass extinction. Many taxa probably adapted to the gradual temperature decline. Furthermore, many of the survivors of the end Cretaceous extinction event had ancestors that seemingly evolved at the end of the Cretaceous, when sea-surface temperatures were already on the decline. Many New Zealand taxa have close relatives in inferred low-mid [= Indo-Pacific/Tethyan = warm] latitudes in the Cretaceous. I assume that New Zealand taxa were also warm-adapted. Support for warm sea-surface temperatures in the New Zealand region during the Late Cretaceous is provided by the large proportion of inferred warm-water taxa of Indo-Pacific or Tethyan affinities or at present living in warm waters; these include bivalves *Jupiteria*, *Cucullaea*, *Indogrammatodon*, *Glycymerita*, *Lycettia*, *Pinna*, *Aequipecten*, *Chlamys* (*Lyriochlamys*), *Anomia*, *Acesta* (*Plicacesta*), *Planospirites*, *Pseudoperna*, *Pterotrigonia* (*Ptilotrigonia*), *Iotrigonia*, *Myrtea*, *Thyasira* (*Conchocele*), *Eriphyla*, *Anthonya*, *Cymbophora*, *Mya*, *Panopea*, *Clavipholas*, and *Pholadidea* (*Hatasia*); gastropods include *Perotrochus*, *Chelotia*, *Patelloida*, *Cellana*, *Turbo*, *Amberleya*, *Calliomphalus*, *Chrystostoma*, *Damesia*, *Neritopsis* (*Hayamiella*), *Bathraspira*, *Rhabdocolpus*, *Perissoptera*, *Arrhoges* (*Latiala*), *Sigapatella*, *Cerithioderma* (*Trichotropis*), *Opalia*, *Cryptorhytis*, *Sycostoma*, *Saulopsis* n. gen., *Pseudoperissolax*, *Perissitys*, *Tornatellaea*, and *Eriptycha* (see systematics sections for further details of distributions and references for taxa named above). New Zealand Late Cretaceous cosmopolitan, endemic and paleoaustral elements were probably also adapted to the inferred warm-temperate (at least 15°C or greater) conditions in this region. I could find no evidence for latitudinal differences in faunas in the New Zealand latest Cretaceous that might relate to temperature belts.

The Paleocene Epoch was characterised by significant cooling high-latitude temperatures and development of greater latitudinal thermal contrast (Kennett, 1983), compared to the Cretaceous when there was seemingly a larger increase in the ability of the oceans to transport heat to the poles thus accentuating global warmth. Through the efforts of ocean drilling, it has been demostrated that the Cenozoic marine biotic evolution of the Southern Ocean is associated with the development of Antarctic climatic and water mass evolution. Evidence supports a warming trend in southern hemisphere sea-surface temperatures during the Late Paleocene to early Middle Eocene to a climax of as much as 20°C or slightly more in the Weddell Sea and other subantarctic areas and New Zealand at the Paleocene-Eocene boundary (Beu and Maxwell, 1968, p. 72, Fig. 4; Shackleton and Kennett, 1975, p. 747, see Fig. 2; Kennett and Barker, 1990, p. 937; Hornibrook, 1993, Fig. 1; Crame, 1993, Fig. 1).

A possible problem arises, however, when comparing inferred temperature values for the latest Maastrichtian with those of the Early Paleocene in New Zealand. As stated previously, Clayton and Stevens (1968) arrived at a temperature value of 14.3°C for the close of the Maastrichtian, but Hornibrook (1993) indicated values of about 20°C for the earliest Paleocene. This c. 5°C temperature inconsistency has not been explained in the literature; a sudden increase of temperature at the K-T boundary of this magnitude is probably unlikely.

Data from oxygen isotope values indicate a warming of deep waters (4-5°C) starting in the Late Paleocene (Hovan and Rea, 1992, p. 18). Indeed, eventually the northern component of movement for New Zealand during the Tertiary brought it to within proximity to regions influenced by warm-temperate oceanic currents; however, cool-temperate oceanic conditions may have existed until the Early Paleocene (Zinsmeister, 1979, 1982; Stevens, 1989, p. 155). Conversely, Beu (1966, p. 180; see other listed taxa in Fleming, 1967) commented that the presence of pteriid, cucullaeid and lucinid (e. g. *Miltha*) bivalves along with ficid and tudiclid (e. g. *Tudiclana*) gastropods with warm-water affinities in the "Wangaloan" fauna suggest a subtropical climate. Generally, apart for the presence of *Perissodonta* and Aporrhaidae (former genus extant in polar waters; latter genus restricted to temperate and subpolar regions--living relatives probably reduced remants) in the "Wangaloan" fauna, there is nothing to indicate a particularly cool climate (Beu, ibid; cf. Beu and Maxwell, 1990, p. 77). The presence of the long-ranging inarticulate brachiopod *Lingula* in the Paleocene of New Zealand is also consistent with a climate that was warmer than it is at present (Lee and Campbell, 1987). (Note: Adams *et al*., 1990, p. 290 advocated continued "use of the terms "tropical" and "subtropical" to indicate regions of the present-day global oceans approximately coincident with the areas within the tropics, and characterised by mean sea-surface temperatures within the range 20-25°C (subtropical), and >25° (tropical)..."). Inferred warm-water taxa recorded in the New Zealand Paleocene include bivalves *Jupiteria*, *Ledina*, *Glycymerita*, *Anomia*, *Miltha*, *Myrtea*, *Thyasira* (*Conchocele*), *Nemocardium* (*Pratulum*), and *Panopea*; gastropods include *Bolma* (*Ormastralium*), *Bittiscala*?, *Amauropsis*?, *Eunaticina*?, *Galeodea* s. s., *Priscoficus*, *Melanella*, *Niso*, *Acirsa* (*Plesioacirsa*), *Amaea* s. s., *Saulopsis* n. gen., Columbarium, Exilia, Amuletum, Hesperiturris, Inquisitor, Tomopleura, and Crenilabium; and nautiloid Eutrephoceras (refer to systematics section for further details). As with the Cretaceous taxa, cosmopolitan, endemic and paleoaustral elements were most likely preadapted to the inferred warm conditions during the "Wangaloan". The abundance of evidence from this thesis and published data points to subtropical marine conditions during the Paleocene in New Zealand.

Given the interpreted oceanic circulation and paleogeographic models presented above coupled with a reduced latitudinal sea-surface temperature gradient in the southern hemisphere during the Late Cretaceous, similarity of biotas around the rim of the southern circum-Pacific might be expected. Such conditions would have favoured biotic homogeneity during this interval. The inferred extensive shallow shelves during this interval probably also played a significant role in observed patterns of similarity.

Paleobiogeographic history of Austral molluscs

Similarities of the faunas

Similarities of Late Cretaceous to early Tertiary molluscan faunas of New Zealand, Australia, New Caledonia, Antarctica and southern South America have been noted by many workers (e. g. Wilckens, 1911, 1922; Benson, 1923; von Ihering, 1924; Marshall, 1926; Spath, 1953; Howarth, 1966; Henderson, 1970; Zinsmeister, 1976, 1979, 1982; Freneix and Grant-Mackie, 1978; Knox, 1980; Stevens, 1977, 1980, 1989; Harasewych, 1987; Clarke and Crame, 1989; Crame, 1992; Stilwell and Zinsmeister, 1992; Stilwell, 1991, 1994a-b). Concomitant with the regional isolation of continental "fragments" around the southern circum-Pacific rim during the Late Cretaceous, many new groups appeared for the first time. Furthermore, this distinctiveness of the biota of the southern hemisphere has been discussed at length or commented on by many workers (e. g. Darwin, 1859; Hutton, 1872, 1896; von Ihering, 1892, 1907, 1925; Steinmann and Wilckens, 1908; Wilckens, 1910, 1922, 1924; Marshall, 1926; Finlay and Marwick, 1937; Howarth, 1966; Fleming, 1962, 1963a-b, 1975, 1979; Henderson, 1970; Zinsmeister, 1976, 1977, 1979, 1982; Askin, 1989; Clarke and Crame, 1989; Doyle and Howlett, 1989).

As a result of intense study of the unique character of southern hemisphere biotas during the Late Cretaceous and early Tertiary, several biogeographic reviews have been presented to the scientific community. Such papers include those on Cretaceous ammonites (Henderson, 1970; Macellari, 1985), Cretaceous bivalves (Kauffman, 1973), Late Cretaceous and early Tertiary bivalves and gastropods (Zinsmeister, 1979, 1982; Stilwell, 1991, 1994a), Late Cretaceous and early Tertiary floras (Askin, 1989), and Late Cretaceous foraminifera (Huber and Watkins, 1992). One of these works, that of Kauffman (1973), requires a detailed review.

Kauffman (1973), based on using the geographic distribution of Cretaceous Bivalvia, erected the Austral Province for the high latitudinal region of the southern hemisphere including the southern extent of South America, New Zealand, Australia, New Caledonia, New Guinea, southern India, and other smaller, poorly studied islands of this area (Chatham Islands could be included in this latter category). Antarctica was curiously not mentioned in his summary of the Austral Province apart from a large "?" in Fig. 2; perhaps Kauffman was unaware of the early monograph of Late Cretaceous molluscs of Antarctic Peninsula by Wilckens (1910), which could have demonstrated the strong affinities of the Antarctic fauna with New Zealand, New Caledonia and South America. Kauffman divided the Austral Province into two subprovinces, Australian and New Zealand, based on the percentage of Early Cretaceous endemic taxa in Australia (15.6-19.3%) and supposed endemism (15.1-15.7%) of New Zealand Late Cretaceous taxa which reflected the small country's tectonic isolation and Cenomanian transgression. He was unable to explain the lack of shared taxa between Australia and New Zealand during the Late Cretaceous when these landmasses were in close proximity. This disparity may result from the paucity of Australian Upper Cretaceous macrofossiliferous deposits reflecting a change in tectonic regime from Early to Late Cretaceous time when very little of Australia was flooded by the sea due to regression (cf. Brown *et al*., 1968). Late Cretaceous Australian molluscs are poorly known, probably because marine sediments are limited surface outcrops in Perth and Carnarvon Basins of Western Australia (Darragh and Kendrick, 1991, p. 8; in press). The close similarity of New Zealand and southeastern Australia Paleocene molluscs suggest that, although notably wanting in Australia, similarities of southeastern Australian Late Cretaceous molluscs would probably have matched those of New Zealand and New Caledonia during the Campanian?-Maastrichtian.

As Kauffman rightly pointed out, no endemic genera have been recorded in New Zealand prior to the Cenomanian flooding. Taxa that he noted as characteristic endemic genera warrant comment, namely *Chlamys* (*Mixtipecten*), *Electroma* s. s., *Megaxinus* (*Pteromyrtea*), *Myrtea* s. s., *Lahillia* (*Lahilleona*), *Marwickia*, *Dosinobia*, and *Cyclorismina*. Firstly, *Mixtipecten* cannot now be considered as endemic because it occurs in the Maastrichtian of Chile (Stinnesbeck, 1986). Despite the fact that *Electroma* s. s., *Pteromyrtea*, *Marwickia* and *Dosinobia* are New Zealand Paleocene genera and have not been recorded from the Late Cretaceous, *Pteromyrtea* is the only one that is currently considered endemic. *Electroma* has recently been reported from Antarctica (Stilwell and Zinsmeister, 1992), South America (Griffin, 1991) and southeastern Australia (Darragh, in press). *Dosinia* (*Dosinobia*) has recently been recorded from the Paleocene of southeastern Australia (Darragh, in press). *Marwickia* may be congeneric with *Dosiniopsis* Conrad, 1864. Zinsmeister (1984) has shown that *L*. (*Lahilleona*) is synonymous with *Lahillia* s. s. *Cyclorismina* has been reported from New Caledonia (Freneix, 1980) and an early Tertiary survivor may be present in Antarctica (Zinsmeister, 1984). As will be discussed more fully below, the endemic component in Late Cretaceous New Zealand molluscs was much lower at c. 8%, compared to the c. 15-16% cited by Kauffman (1973). These faunas are considered here to be much more cosmopolitan than previously thought. As a result it is proposed that the New Zealand Subprovince of Kauffmann (1973) be abandoned.

Weddellian Biotic Province hypothesis

As some of the southern continents parted at the close of the Cretaceous, the Austral Province is thought to have lost its identity and split up into smaller faunal provinces. Zinsmeister (1979) proposed the Weddellian Province as one of these smaller provinces that became recognizable by the Late Cretaceous; this province included the region south of the northeastern coast of Australia and New Zealand extending westward to include continental shelf areas along Antarctica and southern South America (Figure 76 herein). The faunal/floral assemblages of the Weddellian Province have received a great deal of attention in the literature and the concept of the Province generally has been supported (e. g. see Zinsmeister and Camacho, 1980; Zinsmeister, 1984; Harasewych, 1987; Manceñido and Griffin, 1988; Beu and Dell, 1989; Askin, 1989; Case, 1989; Stevens, 1989; del Rio, 1990; Kennett and Barker, 1990; Olivero _et al_., 1990; Darragh and Kendrick, 1991; Crame, 1992; Stilwell and Zinsmeister, 1992; Stilwell, 1991, 1994a-b). Zinsmeister's concept of the Weddellian Province has changed slightly for New Caledonia and Chatham Islands can also be included in the Weddellian Province, based on bivalve and gastropod data from Freneix (1980), Stilwell (1994a-b) and Campbell _et al_. (1993) (Figure 77 herein). Also, western Australia can be excluded from the Weddellian Province as the molluscan faunas of this region bear little resemblance to those of New Zealand, Antarctica and South America (cf. Darragh and Kendrick, 1991; in press). Except for the exceptional record of Late Cretaceous to Paleogene faunas/floras of the James Ross

Basin, Antarctic Peninsula, limited data are available apart from sparse microfossils in glacial erratics in the Transantarctic Mountains to establish whether other parts of West (e. g. Marie Byrd Land) and East Antarctica could be included in the Weddellian Province. According to Zinsmeister (1982, p. 94) the Weddellian Province would have existed as long as this region was physically isolated from other ocean basins of the globe.

Test of the Weddellian Province hypothesis and summary

The Weddellian Province was based on a qualitative assessment of similarities of molluscan faunas around the southern circum-Pacific, including taxa such as Lahillia, Struthioptera, Taioma, and Struthiolariidae (see Zinsmeister, 1982, Text-fig. 6, Tab. 1-3). Because paleobiogeography is moving from a purely qualitative to a more quantitative phase (see authoritative accounts and examples by Campbell and Valentine, 1977; Shea, 1987; Smith, 1989; Leal and Bouchet, 1991), it is desirable to define and diagnose biotic provinces quantitatively rather than depend on an "eye-ball" approach to establish provinces, based on the distribution of a few taxa. Quantification of paleobiogeographic patterns should yield a more explicit understanding of processes shaping the biosphere. Further, research has shown that species-level biogeographic patterns also can be recognised at genus- and family-levels (Campbell and Valentine, 1977; Smith, 1989). A critic of paleobiogeographic studies might argue that work of this kind should not be undertaken if the faunas are poorly known or if faunas described many years ago have not had recent revision for, in such cases, an element of bias is inevitable. Conversely, I contend that it is paramount, notwithstanding deficiencies in knowledge and fossil record, to have a starting point that can be built upon with future work. Well-known faunas are being revised across the globe, and with ongoing advances in knowledge paleobiogeographic patterns are becoming clearer. To dismiss paleobiogeographic studies because of inherent weaknesses as has been done in the past by some paleontologists and neontologists is, in my opinion, a defeatist attitude and gets us nowhere in our better understanding processes shaping the biosphere.

It is well accepted that probability of fossil collection failure decreases with increasing taxonomic rank (Smith, 1989, p. 263). Thus, in paleobiogeographic studies the genus is usually the fundamental unit as the fossil record for species is patchy.

The most useful means of gauging similarity amongst different faunas is by using binary correlation coefficients based on presence/absence data of genera. Workers using binary coefficients must recognise some limitations, although these are not unsurmountable; these include: 1) modern and fossil communities contain relatively few species that are abundant/common and a greater number that are rare--binary coefficients ignore this skew; and 2) sampling must be thorough because collection failure creates bias against taxa that are not as abundant (Smith, 1989, p. 263). Several binary correlation coefficients are available (see Brown and Gibson, 1983, p. 239; Smith, 1989, p. 265). I have chosen to use the Simpson, Dice and Simple Matching coefficients because they most closely approximate a binomial distribution, based on Monte Carlo

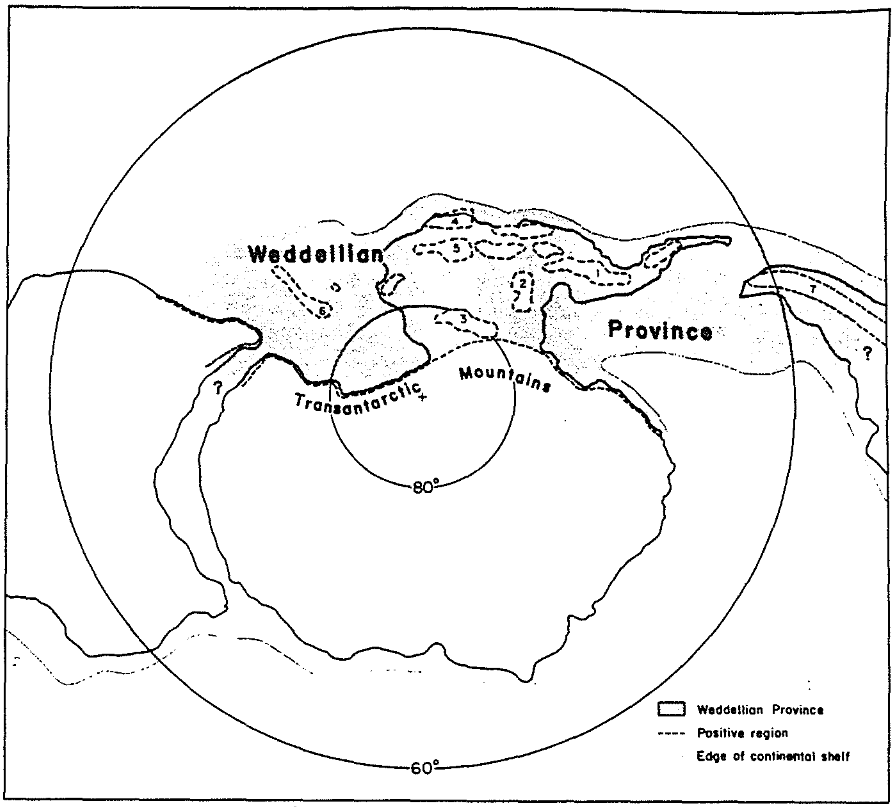
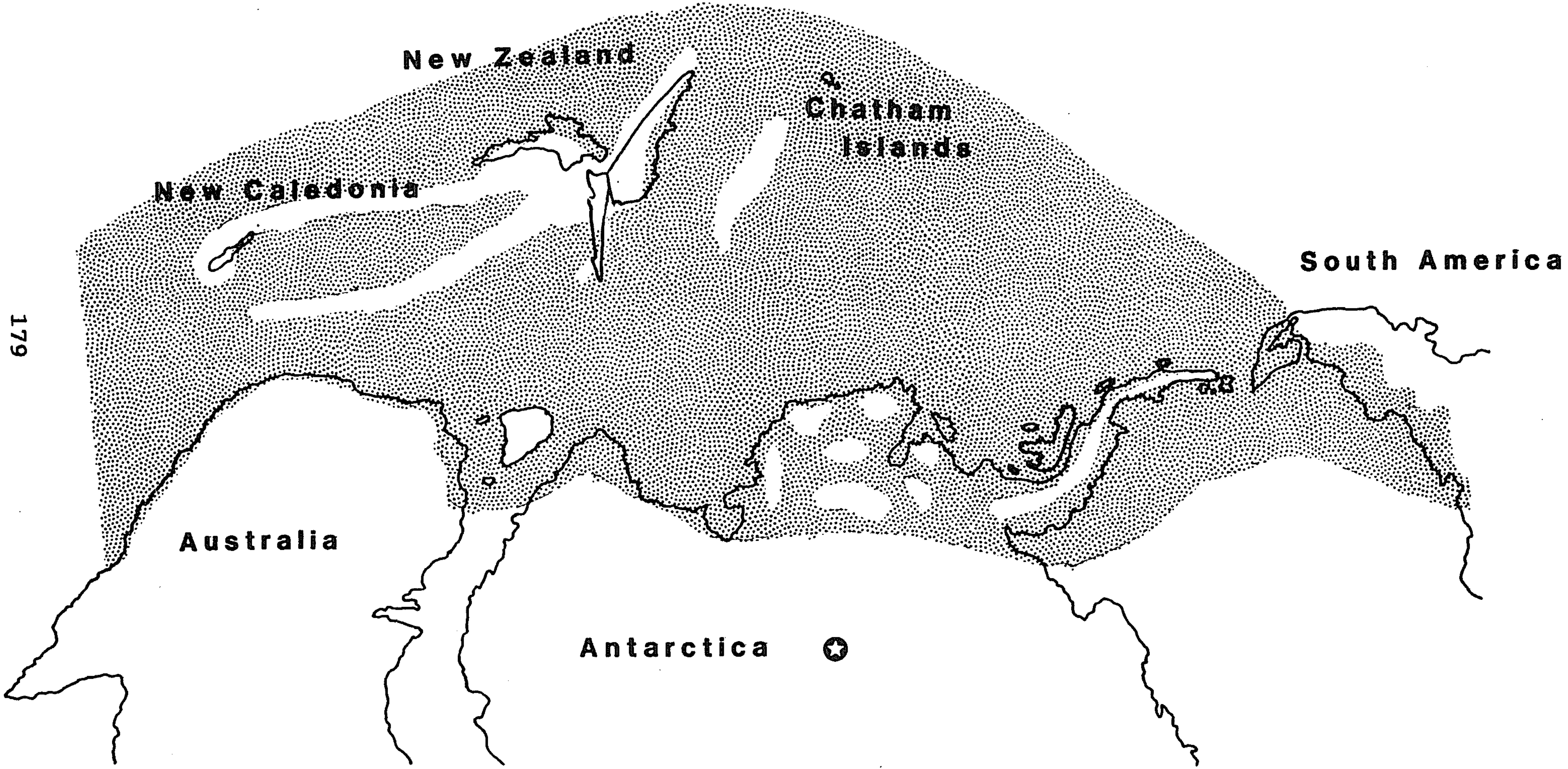


Figure 76. Paleogeography of the Weddellian Province (shaded area) during the Late Cretaceous (80 Ma) before the final separation of New Zealand and Australia from Antarctica. Regions enclosed with dashed lines indicate probable land areas during the latest Cretaceous and earliest Tertiary: 1, Antarctic Peninsula; 2, Ellsworth Mountains; 3, Whitmore Mountains; 4, Thurston Island; 5, Marie Byrd Land; 6, New Zealand; 7, South America (from Zinsmeister, 1979).



Late Cretaceous Gondwana and Weddellian Province (shaded)

Figure 77. Late Cretaceous Weddellian Province revised from Zinsmeister (1979) and Stevens (1989).

computer simulations; the Jaccard Coefficient, although used by many authors (e. g. Macellari, 1985; Maxwell, 1992; Stilwell and Zinsmeister, 1992), has been shown empirically to be unreliable (Smith, 1989, p. 265).

Few comprehensive quantitative studies of southern hemisphere Late Cretaceous-early Tertiary faunas have been accomplished. Macellari (1985) published a paleobiogeographic study on Austral Cretaceous ammonites. The first comprehensive attempt at testing Zinsmeister's Weddellian Biotic Province hypothesis was by Stilwell (1991), based on distributions of Austral Late Cretaceous-early Tertiary bivalves, gastropods and scaphopods. Here data matrices were compiled for coeval Campanian to Eocene molluscan shelf faunas (605 genus-group taxa) of New Zealand, Australia, Antarctica, and southern South America. Similarities were assessed by the use of simple binary similarity coefficients (coefficients used in the study were Simpson and Dice). This preliminary study was not based on a revised systematic study, but based mostly on previously published and a few unpublished faunal lists. I have now revised the entire known latest Cretaceous to Paleocene molluscan fauna of New Zealand (see systematic paleontology chapter below) and am well-acquainted with faunas around the southern circum-Pacific. A major concern regarding comprehensive and quantitative paleobiogeographic studies such as the current one is the so-called monographic effect, in which one has to rely partly or wholly on identifications of fossils made by someone else, possibly introducing a bias into the study. Of particular importance, different workers may assign different names to the same fossil. A case in point is my 1991 visit to the Museum of Victoria to study Paleocene molluscs of southeastern Australia. Some of the labelled identifications differed from that which I would have assigned for congeneric taxa of New Zealand and Antarctica, but this comes down to opinion. At least if a single author has studied the entire fauna using a consistent approach to taxonomy, the chance of bias in the data base is less. Ideally, an author of a paleobiogeographic study should be well-versed in all molluscan groups of all areas studied, but this is usually unrealistic. Because I have researched Late Cretaceous-early Paleogene molluscan faunas of Antarctica, New Zealand, Chatham Islands, and Australia, I am in a prime position to quantitatively assess faunal similarities between these areas with reduced or minimal bias caused by monographic effects.

Data matrices of similarity coefficient values of Late Cretaceous to Paleocene molluscs were compiled using shelf faunas of New Zealand, Chatham Islands, Australia, New Caledonia, Antarctica, and South America (see Tables 9-10). Calculations of 135 binary coefficient values were obtained utilizing every possible combination of Late Cretaceous and Paleocene faunas. Binary similarity coefficients used in this study are Simpson (SI), Dice (DI) and Simple Matching (SM). Graphs of these plotted Simpson values are shown in Figures 78-79. Bivalves and gastropods were separated in the analysis. "Bivalves are primarily infaunal filter and deposit feeders while gastropods, primarily epifaunal, have radiated into a wide variety of habitat and feeding types. With this large variation in mode of life, gastropods have become more diverse (and generally more specialized) than bivalves...Because their diversity and compositional changes are not perfectly matched, the patterns of diversity between these two classes are different in detail." (Campbell and Valentine, 1977, p. 53). Of note, because the focus of this project is changes in composition in faunas across the K-T boundary, inclusion of the Eocene in the quantitative study as was done by Stilwell (1991) is beyond the scope of this work, especially since the Early to early Middle Eocene molluscan faunas of New Zealand and East Antarctica require further revision and attention. I propose to publish a future paper on the paleobiogeography of these faunas.

Before I present the paleobiogeographic analysis of Late Cretaceous to Paleocene molluscan faunas around the rim of the southern circum-Pacific, it is appropriate to give a short review of the occurrence of fossil molluscs in the various Gondwana "fragments". As stated previously, I have found that New Zealand has the most diverse and well-documented molluscan assemblages across the K-T boundary. In contrast, Seymour Island has the most complete stratigraphic record of well sampled/successive horizons of molluscs across the K-T boundary even though species-level diversity is relatively low. Elsewhere around the rim of the southern circum-Pacific many molluscan assemblages have been recorded:

<u>Chatham Islands</u>--Mostly undescribed Late Cretaceous and Paleocene faunas are present in the Chathams c. 900 km east of Christchurch, New Zealand (see Figures 1, 80). The Chatham Islands faunas/floras are for the most part unexploited and are

Table 9: Data matrix of similarity coefficient values: Bivalvia

		New Zealand		Antarctica		Australia		South America		New Caledonia		Chatham Islands	
		a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
New Zealand	1			21	4	6	10	24	5	25	-	16	3
	2			68	36	33	36	49	28	71	-	76	18
	3			38	17	12	32	38	6	44	-	32	6
	4			57	53	52	55	57	51	58	-	55	51
Antarctica	1					5	4	15	3	18	-	7	1
	2					28	36	48	27	58	-	33	9
	3					20	21	38	21	55	-	27	7
	4					53	53	57	53	63	-	54	51
Australia	1							4	3	5	-	3	1
	2							22	16	29	-	18	6
	3							14	13	23	-	16	4
	4							52	52	53	-	52	51
South America	1									15	-	12	0
	2									43	-	57	0
	3									36	-	34	50
	4									56	-	56	50
New Caledonia	1												-
	2											48	-
	3											36	-
	4											56	-
Chatham Islands	1												
	2												
	3												
	4												

a = Campanian - Maastrichtian
b = Paleocene
1 = Genera in common
2 = Simpson Similarity Coefficient ($Si = \frac{C}{N_1}$)
3 = Dice Similarity Coefficient ($Di = \frac{2C}{N_1+N_2}$)
4 = Simple Matching Coefficient ($SM = \frac{C + A}{N_1 + N_2 - C + A}$)
C = Number of taxa in common in two localities
A = Number of taxa absent in both localities
N_1 = Total number of taxa in first locality (with fewest taxa)
N_2 = Total number of taxa in second locality (with most taxa)

Table 10: Data matrix of similarity coefficient values: Gastropoda

		New Zealand		Antarctica		Australia		South America		New Caledonia		Chatham Islands	
		a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
New Zealand	1			4	2	0	10	7	7	1	-	2	5
	2			20	18	0	91	21	54	50	-	100	23
	3			12	5	0	23	22	16	4	-	8	10
	4			52	51	50	53	52	52	51	-	51	51
Antarctica	1					2	0	5	2	-	-	0	0
	2					14	0	28	11	-	-	0	0
	3					12	0	19	17	-	-	0	0
	4					52	50	53	52	-	-	50	50
Australia	1							2	4	-	-	0	1
	2							14	36	-	-	0	9
	3							2	33	-	-	0	9
	4							51	56	-	-	50	51
South America	1									-	-	1	1
	2									-	-	50	8
	3									-	-	6	6
	4									-	-	51	51
New Caledonia	1											2	-
	2											100	-
	3											80	-
	4											75	-
Chatham Islands	1												
	2												
	3												
	4												

a = Campanian - Maastrichtian
b = Paleocene
1 = Genera in common
2 = Simpson Similarity Coefficient ($Si = \frac{C}{N}$)
3 = Dice Similarity Coefficient ($Di = \frac{2C}{N_1+N_2}$)
4 = Simple Matching Coefficient ($SM = \frac{C+A}{N_1+N_2-C+A}$)
C = Number of taxa in common in two localities
A = Number of taxa absent in both localities
N_1 = Total number of taxa in first locality (with fewest taxa)
N_2 = Total number of taxa in second locality (with most taxa)

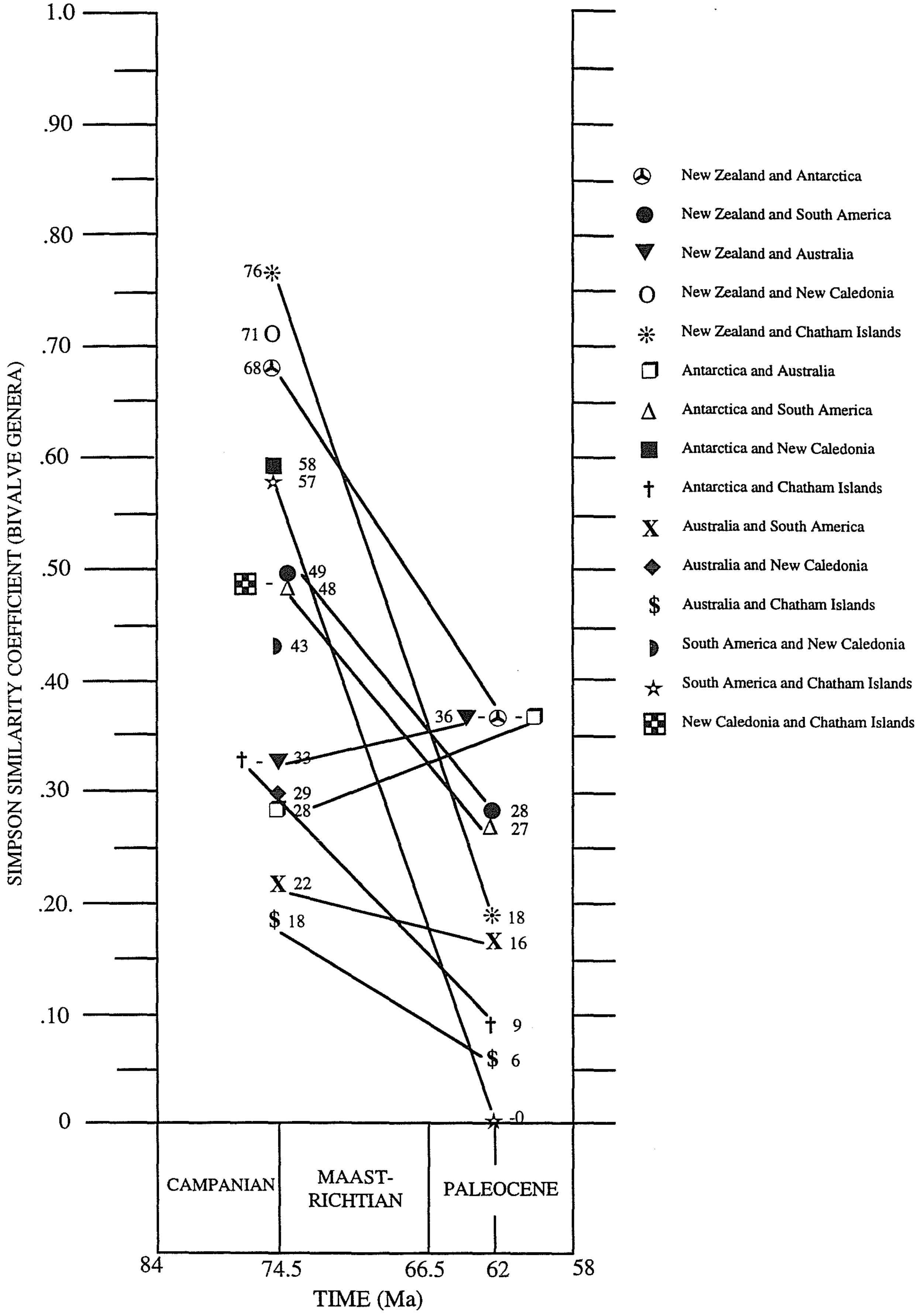


Figure 78. Graph of bivalve Simpson similarity coefficient values plotted against time.

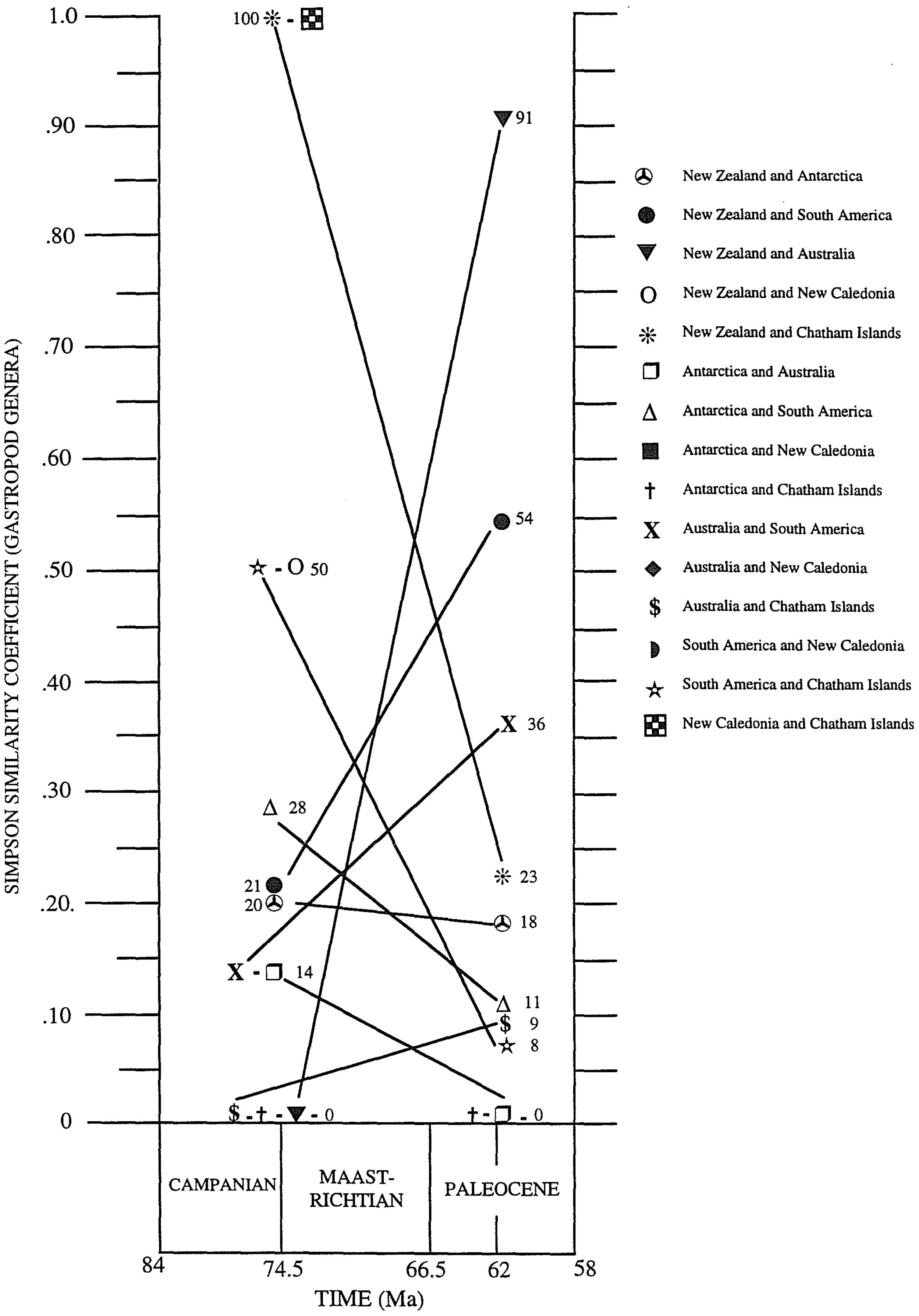


Figure 79. Graph of gastropod Simpson similarity coefficient values plotted against time.

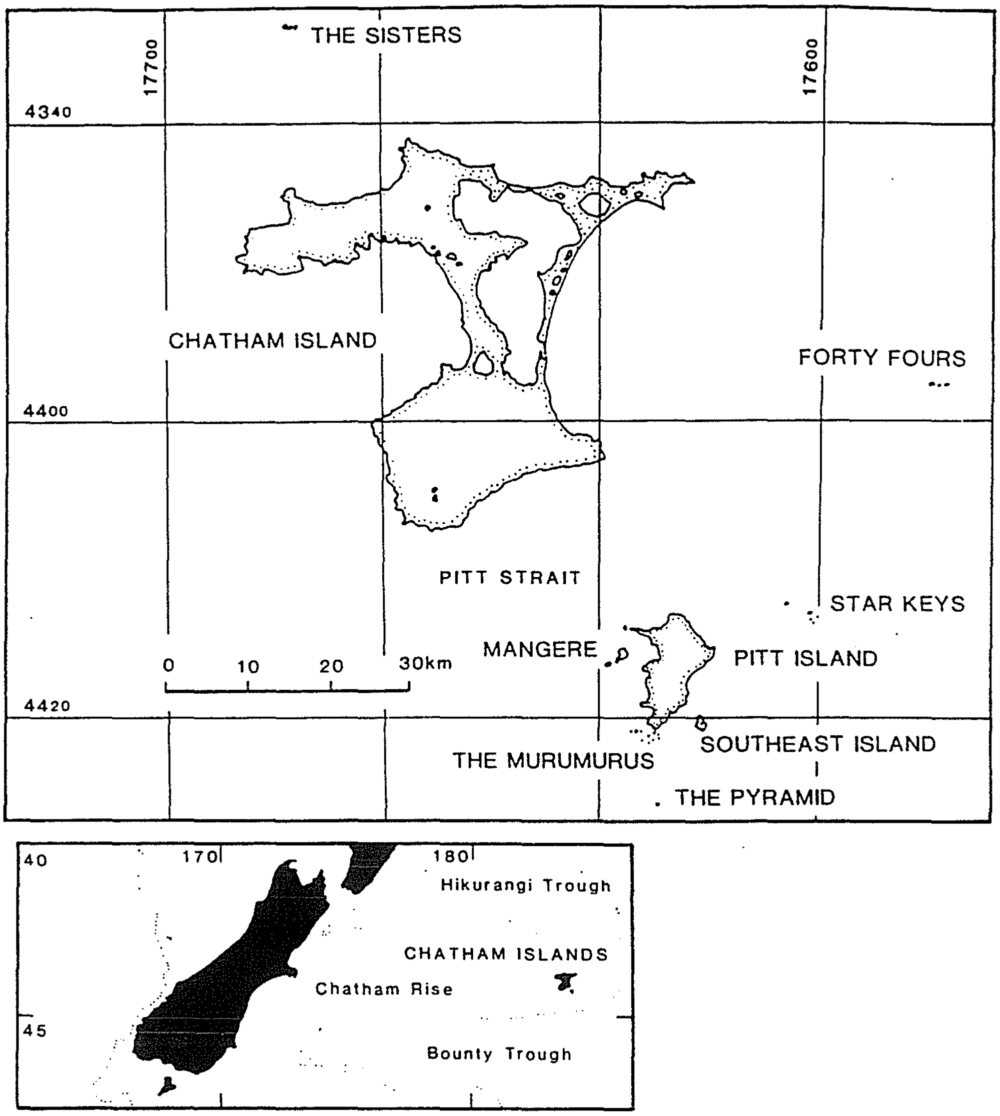


Figure 80. Location map of Chatham Islands, southwest Pacific.

yielding important new data. Cretaceous fossils include wood, coelenterates, bryozoans, brachiopods, bivalves, gastropods, scaphopods, nautiloids, ammonoids, belemnoids, annelids, echinoderms, and chordates. A possible therapod dinosaur has recently come to light, but this poorly preserved bone alternatively may represent a plesiosaur rib (R. E. Fordyce, pers. commun., 1993). The Late Cretaceous fossils are mainly from the Kahuitara Tuff which crops out predominantly on Pitt Island. See faunal lists in Campbell _et_ _al_. (1993, Tab. 4.3). Recently, _Protodolium_ _pittensis_ was described by Stilwell (1994b) from the Kahuitara Tuff. Paleocene molluscs from Chatham Islands are probably mid to Late Paleocene in age (Beu and Maxwell, 1990) and are found on both the main Chatham and Pitt islands. Identified Paleocene fossils from the Red Bluff Tuff include possible Porifera of uncertain affinity, coelenterates, brachiopods, bivalves, gastropods, nautiloids, polyplacophorans, cirripeds, echinoderms (see faunal lists in Campbell _et_ _al_., 1993, Tab. 4.11), and a turtle (R. E. Fordyce, pers. commun., 1994).

New _Caledonia_--Many fossil localities have been studied in New Caledonia, spanning nearly the length of the island, especially in the south (see Figures 81-82). Late Cretaceous fossils, including ammonites, bivalves and rare gastropods have been collected in the â Charbons Formation. Suzanne Freneix, Muséum National d'Histoire Naturelle, Paris, has long been involved in studies on the moderately rich bivalve fauna which is comprised of c. 44 species (see Freneix, 1958, 1960, 1980, 1981; Freneix and Grant-Mackie, 1978). Gastropods are sparse and include

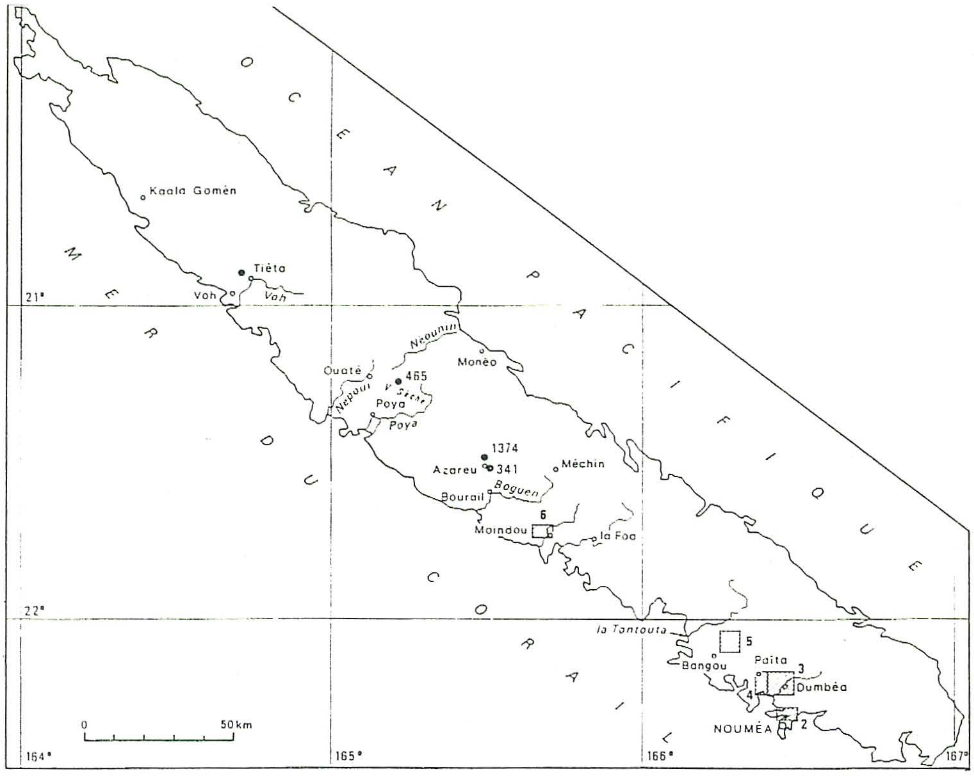


Figure 81. Map of Late Cretaceous fossil localities, New Caledonia (from Freneix, 1980).

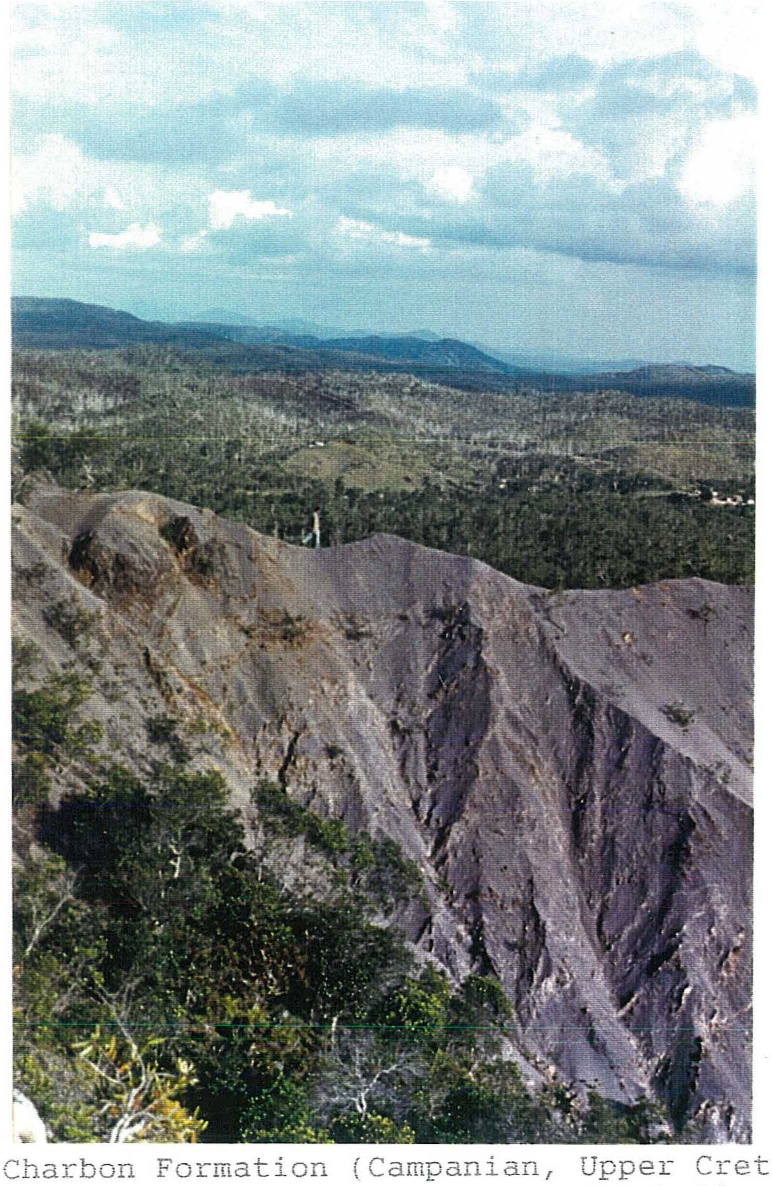


Figure 82. Charbon Formation (Campanian, Upper Cretaceous), New Caledonia. Photograph courtesy of J. D. Campbell.

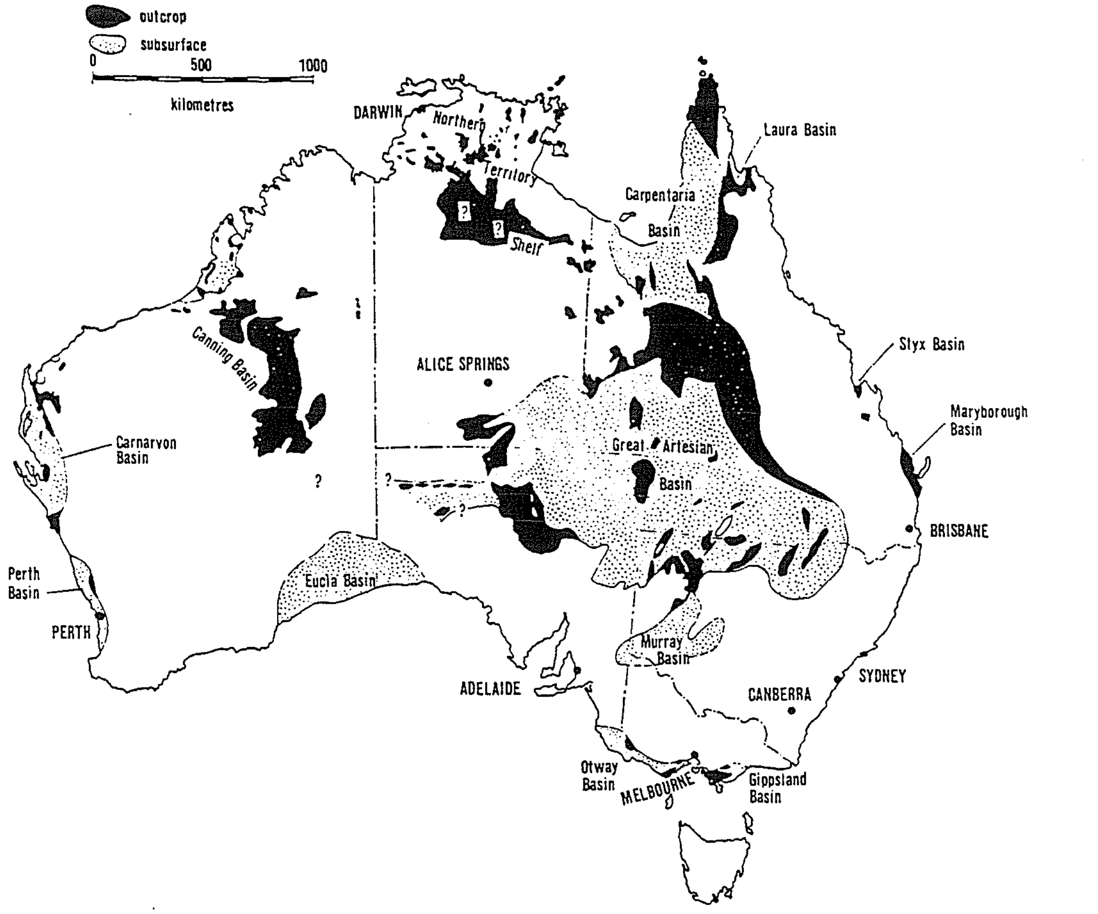


Figure 83. Distribution of Cretaceous strata in Australia (from Brown et al., 1968).

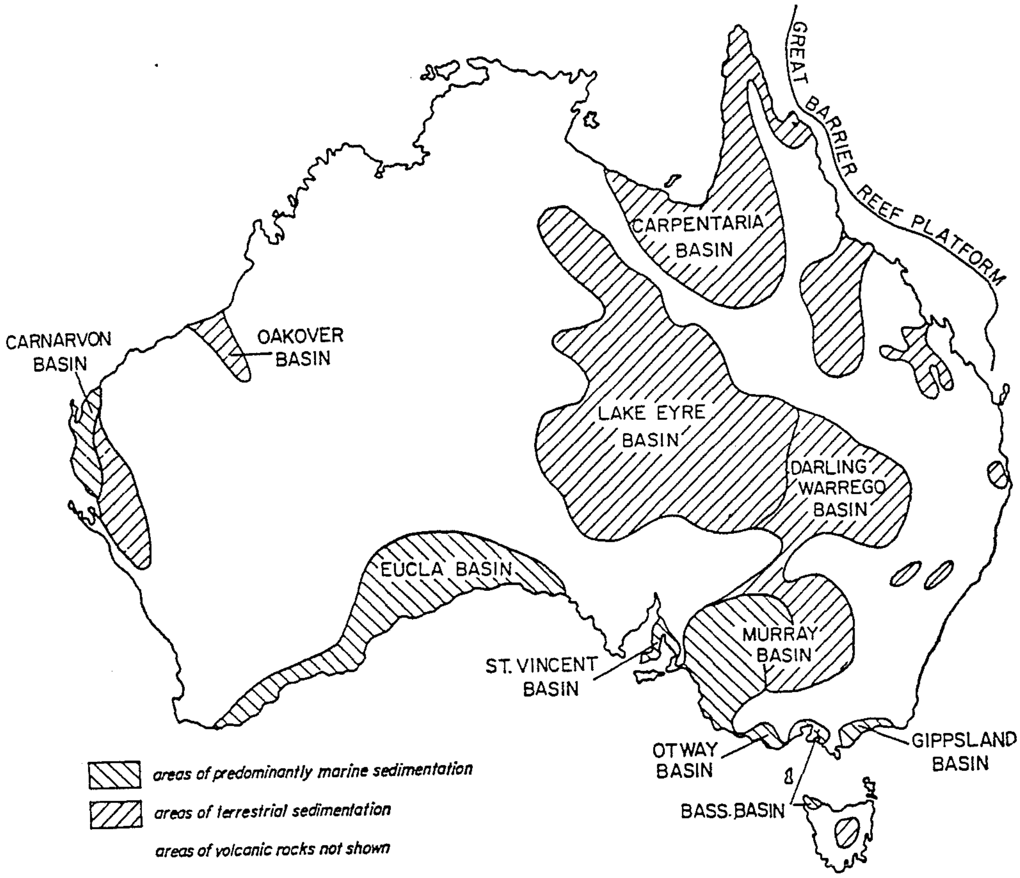


Figure 84. Distribution of Tertiary sedimentary basins in Australia (from Brown et al., 1968).

Pygulifera glypta Avias and Rey, 1958, and *Protodolium* cf. *P. speighti* (Trechmann, 1917) (Stilwell, 1994b, p. 2). Gastropods tentatively assignable to Aporrhaidae are also present (J.D.S., unpublished data). No Paleocene molluscs have been reported from New Caledonia.

Australia--Latest Cretaceous molluscs are restricted to the Perth and Carnarvon Basins in Western Australia (Darragh and Kendrick, 1991) (Figure 83); these fossils from the Miria Formation bear little resemblance to other coeval faunas around the rim of the southern circum-Pacific apart from a few taxa. It seems unlikely that this fauna is part of the Weddellian Biotic Province. Paleocene molluscs are mainly restricted to the Carnarvon and Perth Basins in Western Australia and in the southeastern part of Australia in the Otway Basin (Douglas and Ferguson, eds., 1976; Darragh, in press) (Figure 84). The most diverse assemblage of Paleocene molluscs is the Early to mid Paleocene assemblage from the Pebble Point Formation and slightly younger Late Paleocene molluscs from the overlying Dilwyn Formation. Thirty-two species of bivalves have been recorded from the Pebble Point Formation (Darragh, in press), greatly increasing the known fauna from three taxa of Singleton (1943). A significant gastropod fauna is also present in the Pebble Point Formation (T. A. Darragh, pers. commun., 1991; J.D.S., pers. obs., 1991). A single scaphopod was also described by Singleton (1943). The Dilwyn Formation has a small, mostly undescribed fauna (J.D.S., pers. obs.).

Antarctica.--A highly fossiliferous and relatively complete sequence of well-exposed Upper Cretaceous to lower Tertiary rocks

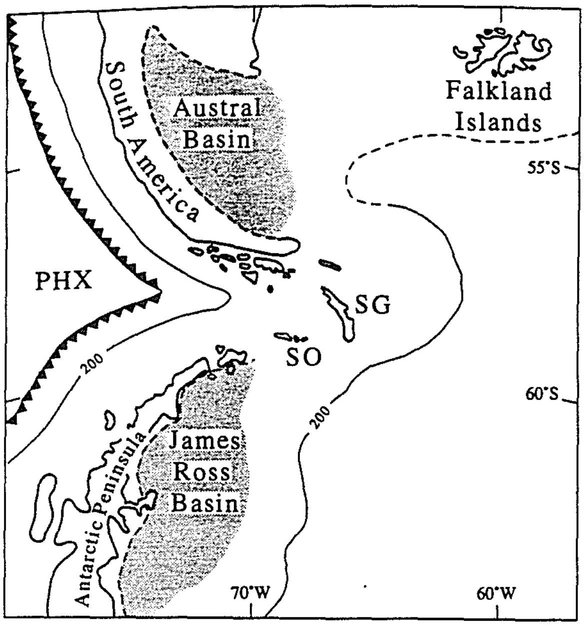


Figure 85. Late Campanian paleogeographic reconstruction of the Antarctic Peninsula-southern South America region prior to the opening of the Drake Passage and the Scotia Sea. Locations of the Austral and James Ross Basins are indicated (from Huber, 1992).

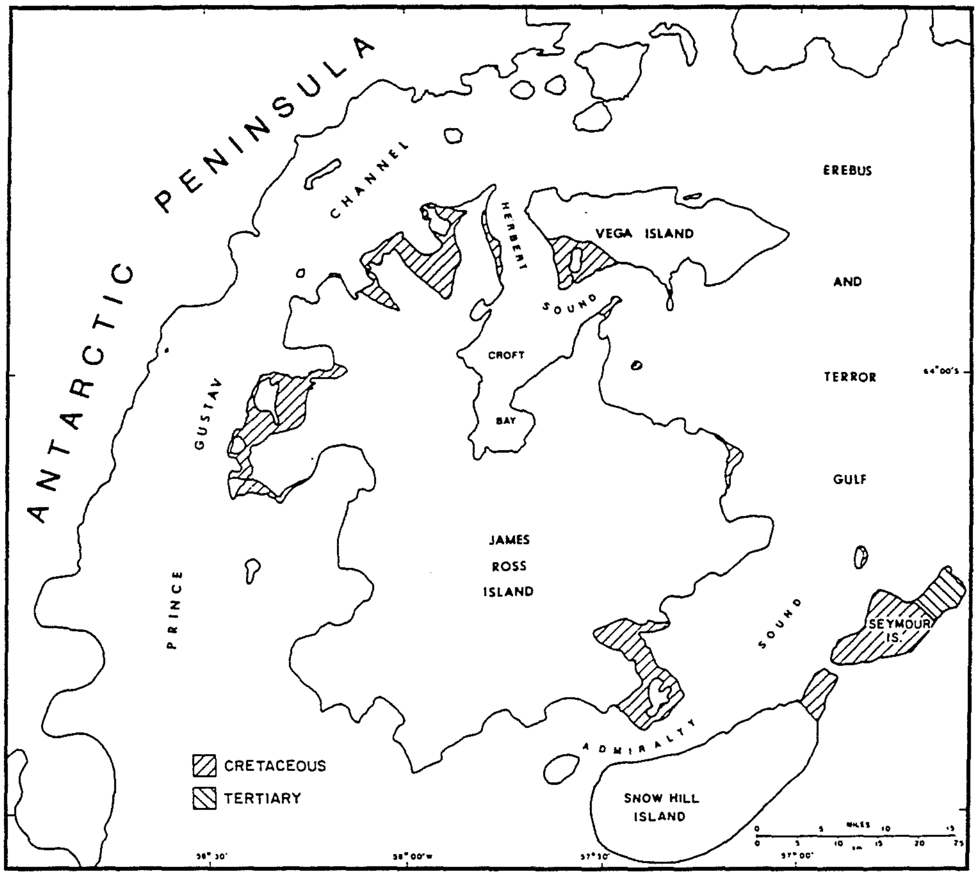


Figure 86. Distribution of Cretaceous and Tertiary rocks in the James Ross Island region of Antarctic Peninsula.

Figure 87. Concretions as surface lag in uppermost Cretaceous to lowermost Tertiary Lopez de Bertodano Formation (Maastrichtian at this locality), Seymour Island, Antarctic Peninsula. Seymour Island contains the richest record of macrofossils of this age in Antarctica.

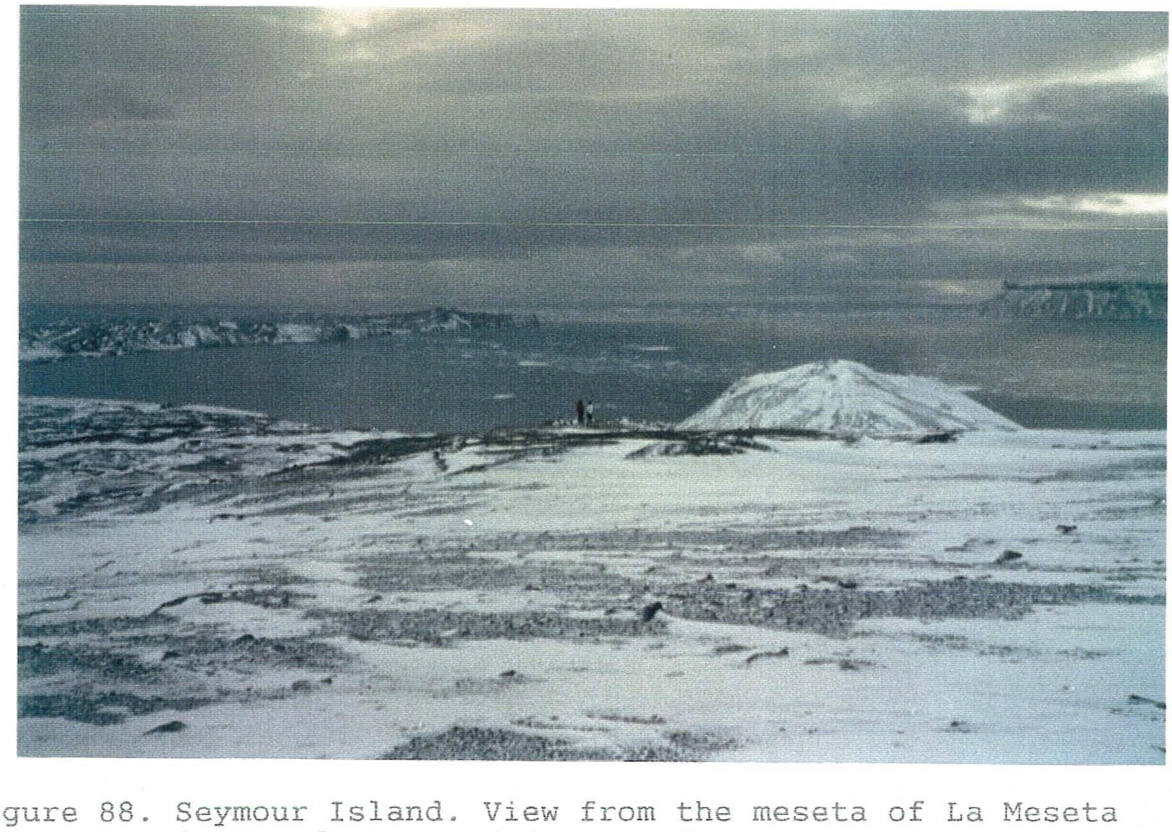


Figure 88. Seymour Island. View from the meseta of La Meseta Formation in the foreground (lower? Eocene to lowermost? Oligocene), Lopez de Bertodano Bay, Bodman Point (Lopez de Bertodano Formation), and Cockburn Island in background at extreme right.

Figure 89. Ula Point, James Ross Island, Antarctic Peninsula. Lopez de Bertodano Formation.

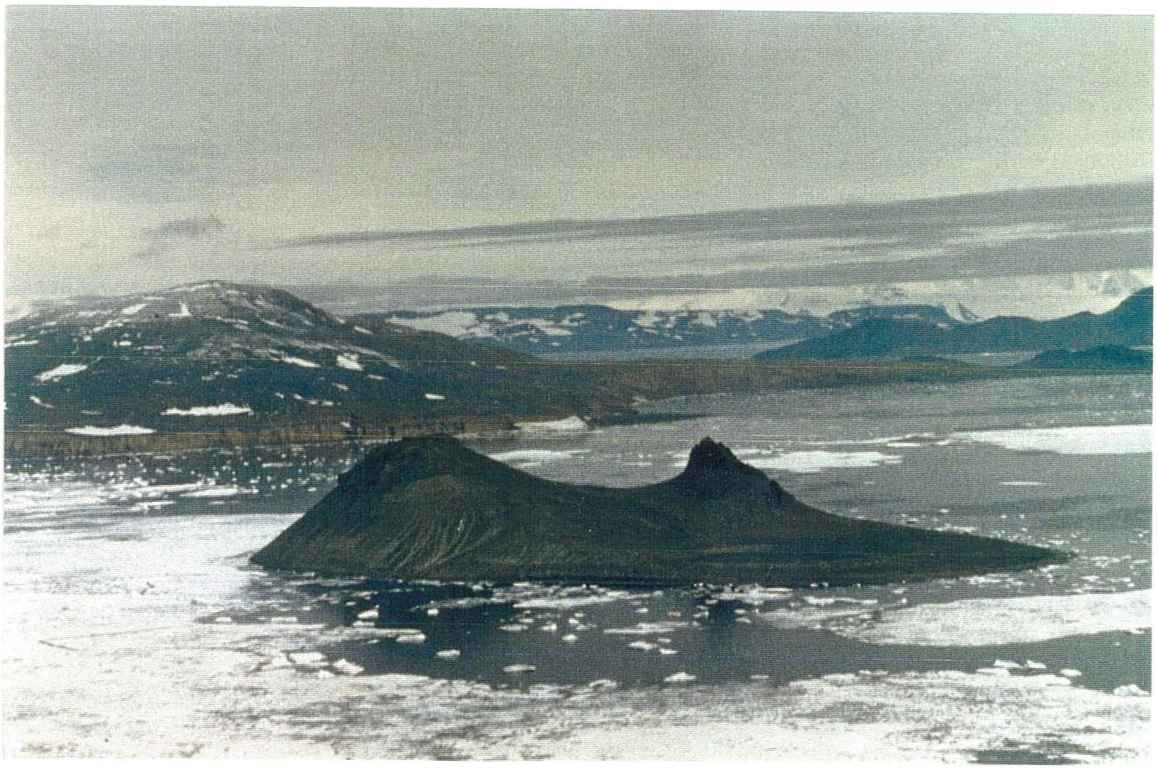


Figure 90. Humps Island, Antarctic Peninsula. Lopez de Bertodano Formation capped and cut by Miocene volcanic rocks of the James Ross Island group.

is present in the James Ross Basin of Antarctic Peninsula (Figures 85-86). Macrofossils of Late Cretaceous age have not been recorded elsewhere in Antarctica. Fossils, dominated by molluscs and various microfossils including forams and dinoflagellates, of latest Cretaceous age have been reported from Seymour Island (Wilckens, 1910; Medina and del Valle, 1985; Zinsmeister and Macellari, 1988) (Figures 87-88), Cockburn Island (Wilckens, 1910; Stilwell and Zinsmeister, 1987a; Askin et al., 1991), Snow Hill Island (Wilckens, 1910; Medina and del Valle, 1985), James Ross Island (Wilckens, 1910; del Valle and Medina, 1980; Stilwell and Zinsmeister, 1987b) (Figure 89), Vega Island (del Valle and Medina, 1980), and Humps Island (Stilwell and Zinsmeister, 1987c) (Figure 90). Most macroinvertebrate groups are represented in these rocks and vertebrates including sharks, marine reptiles and dinosaurs have been reported. The Lopez de Bertodano Formation spans the K-T boundary from upper Campanian to lower Danian time; the Danian is only exposed on Seymour Island. The Sobral Formation, also Paleocene in age, is exposed solely on Seymour Island and has a rather depauperate molluscan fauna of mostly undescribed taxa apart from a few bivalves (Zinsmeister and Macellari, 1988) and scaphopods (Medina and del Valle, 1985).

South America--Latest Cretaceous molluscs are known from many areas in southern South America including the Austral or Magallanes Basin, Chubut or San Jorge Basin and also localities in Central Chile (Wilckens, 1905; Stinnesbeck, 1986; Riccardi, 1988; Olivero et al., 1990; Griffin and Hünicken, 1994) (Figures 85. 91-92). See extensive faunal list in Riccardi (1988, p. 49,

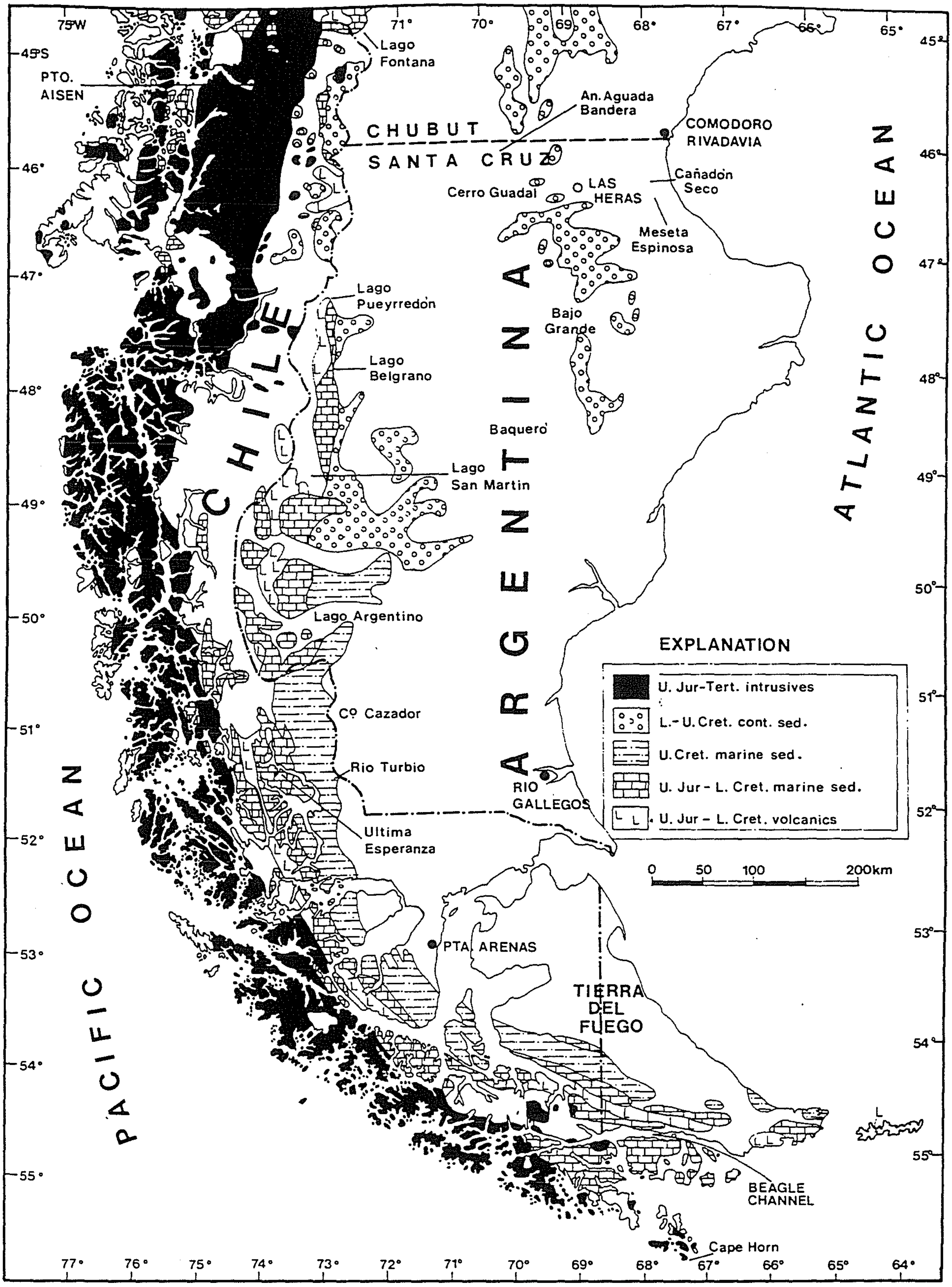


Figure 91. Geologic map of southern South America (from Riccardi, 1988

Figure 92. Beagle Channel, Tierra del Fuego. Jurassic to Tertiary intrusives and marine rocks.

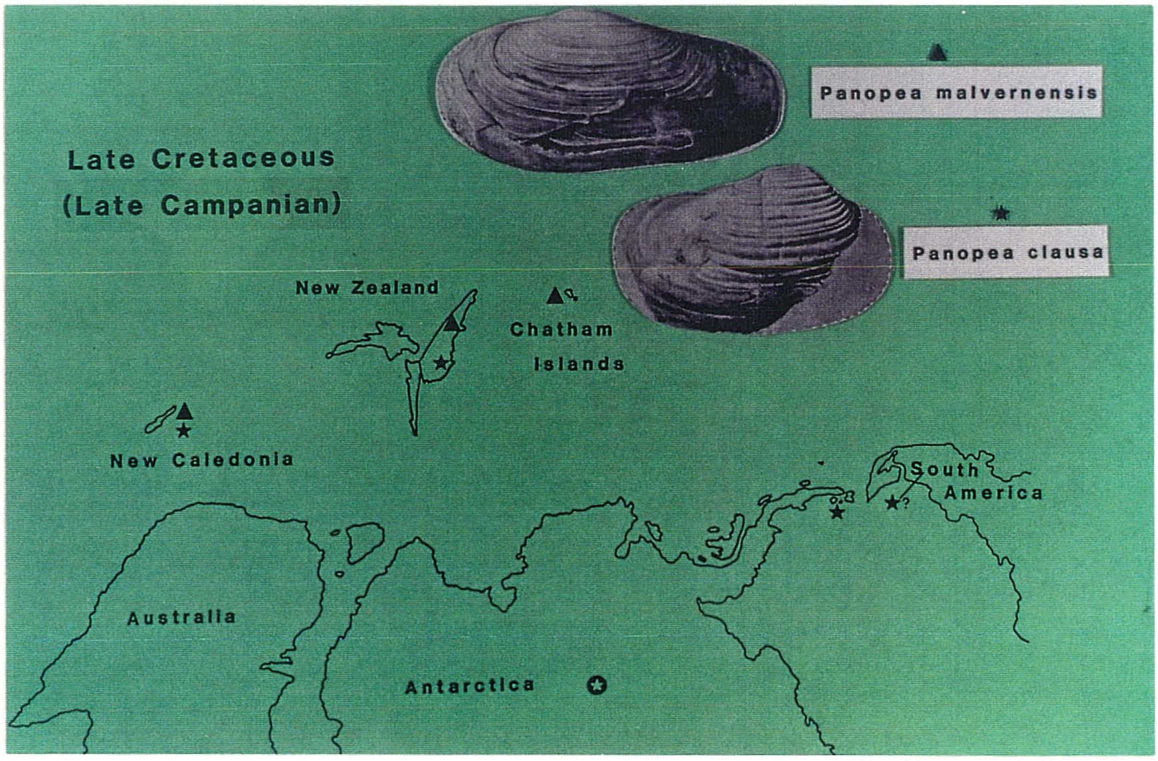


Figure 93. Distribution of Panopea malvernensis Woods, 1917 and P. clausa Wilckens, 1910 during the Late Campanian.

Tab. 7). Paleocene fossils are poorly known in southern South America, but have been noted from the vicinity of Rio Turbio and Sierra Dorotea in Santa Cruz, Argentina in the Cerro Cazedor and Cero Dorotea formations; Chubut, Argentina in the Lefipan Formation; and La Pampa Province in the Roca Formation (see Stanton, 1901; von Ihering, 1903; Feruglio, 1937; Peterson, 1946; Camacho, 1957; Leanza and Hugo, 1985; Manceñido and Griffin, 1988; Camacho and Zinsmeister, 1989; Medina et al., 1990; Griffin and Hünicken, 1994).

Quantitative analysis of latest Cretaceous to Paleocene molluscan faunas around the rim of the southern circum-Pacific indicate that faunal ties between those faunas extending from New Caledonia in the eastern sector to southern South America were indeed strong, compared to diminished similarities in the Paleocene apart from the eastern sector (see Tables 9-10, Figures 78-79; only key trends presented herein). As stated by Stilwell (1994a) in an unpublished abstract, molluscan ties were particularly marked, as reflected in similarity coefficient values, between those faunas of New Zealand, Chatham Islands and New Caledonia during the latest Cretaceous, compared to Antarctica and South America which still indicate strong similarity to a lesser degree. The SI value of 0.70 corresponds to 25 bivalve genera/subgenera common to New Zealand and New Caledonia. Stated another way, 25 latest Cretaceous New Caledonian taxa of a total of 36 (c. 70%) are common between New Caledonia and New Zealand. Smaller values of 0.44 for the DI and 0.64 for the SM coefficients were computed for the New Zealand-New Caledonia faunal combination. The smaller value of 0.44 for

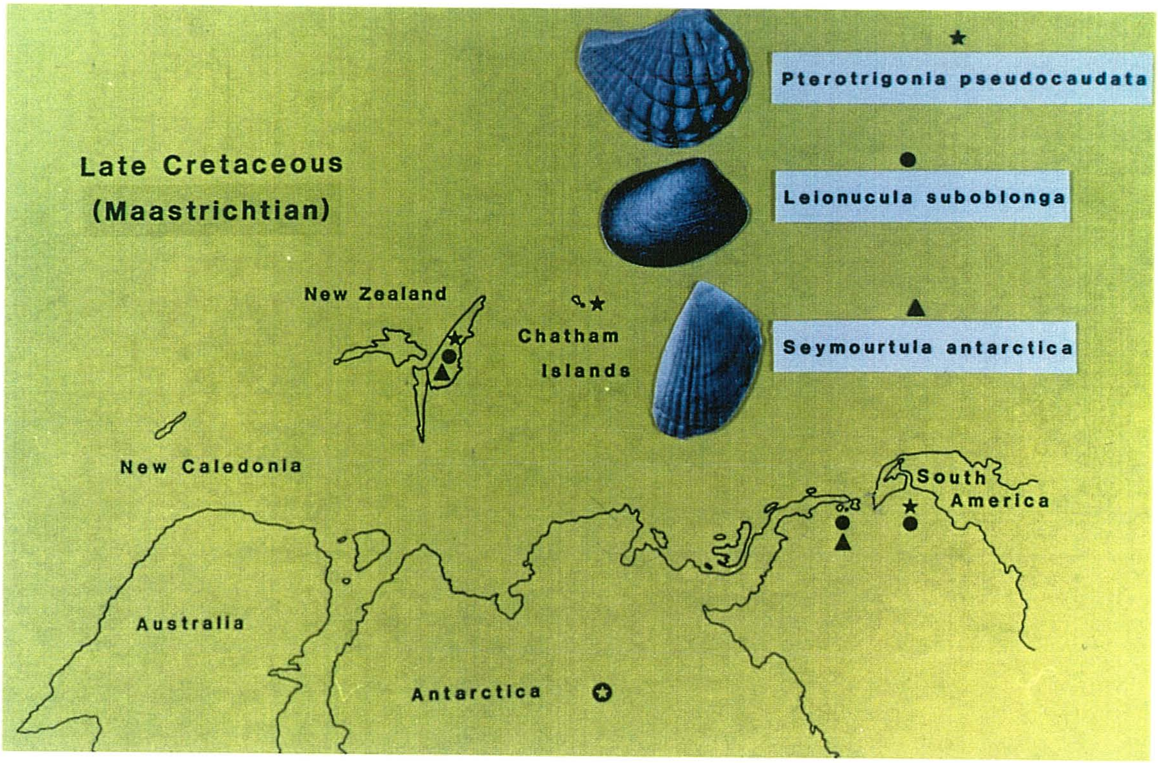


Figure 94. Distribution of Pterotrigonia pseudocaudata (Hector, 1886), Leionucula suboblonga (Wilckens, 1905) and Seymourtula antarctica (Wilckens, 1910) during the Maastrichtian.

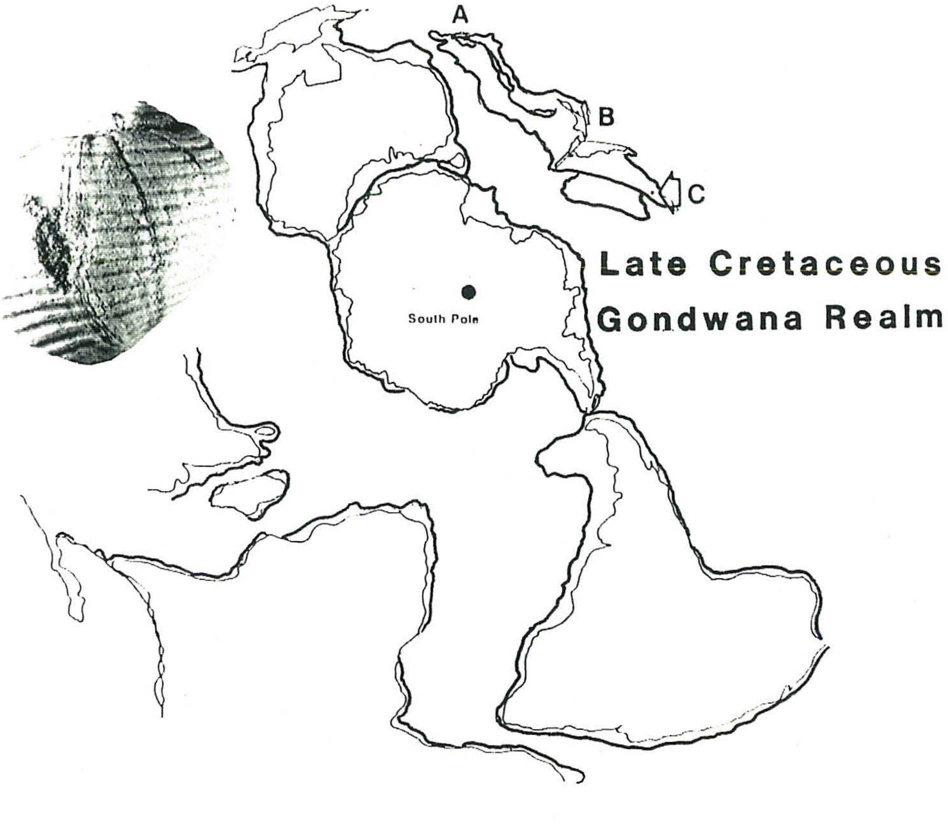


Figure 95. Distribution of Protodolium during the latest Cretaceous. A, New Caledonia; B, New Zealand; C, Chatham Islands.

the DI coefficient reflects the disparity of the fossil record between that of New Caledonia (36 recorded taxa) and New Zealand (79 taxa), rather than significant differences in similarity of the faunas. At species-level a few species are found to be common, including Leionucula suboblonga (Wilckens, 1905), Panopea malvernensis Woods, 1917, P. clausa Wilckens, 1910, and possibly Protodolium speighti (Trechmann, 1917) (Figures 93-95).

There is little correlation between the faunas of New Zealand and western Australia; only 6 of 18 taxa are common to New Zealand and Australia, an SI of 0.33. As would be expected, strong similarities are also found between New Zealand and Chatham Islands during the latest Cretaceous. Out of 21 recorded bivalve genera/subgenera in the Chathams, 16 are also present in New Zealand, resulting in an SI index of 0.76. Two gastropod genera, Protodolium and Struthioptera, and I expect others, are common to New Zealand and the Chathams. Several taxa at species-level are in common, including Pinna sp., Entolium membranaceum (Nilsson, 1827), Mixtipecten amuriensis (Woods, 1917), Limea (Pseudolimea) woodsi (Suter, 1921), Pacitrigonia hanetiana (d'Orbigny, 1842), Pterotrigonia (P.) pseudocaudata (Hector, 1886), P. (Ptilotrigonia) ultima Fleming, 1987, possibly Eselaevitronia n. sp.?, Panopea malvernensis Woods, 1917, Struthioptera novoseelandica (Wilckens, 1922), and Dentalium (Laevidentalium) morganianum (Wilckens, 1922). Many other taxa are probably conspecific, but further work is needed.

Strong links are inferred between the bivalve faunas of New Zealand and Antarctica; 21 of 31 taxa in Antarctica (SI of 0.68) are found to be common to New Zealand and Antarctica. A low index of 0.20 was calculated for gastropods of these two regions (4 out of 20 taxa). A slightly lower SI index of 0.49 was computed for the 24 of 49 bivalve taxa of New Zealand and southern South America probably reflecting greater distance and decreased shelfal communication across the Scotia Arc region of the proto-Drake Passage during the latest Cretaceous. An index of 0.21, remarkably parallel to correlations of New Zealand and Antarctica gastropods, was calculated for New Zealand and South America gastropods, based on 7 taxa common to both regions out of a total of 34 taxa from South America. Faunal links between Western Australia and other regions in the southern hemisphere are generally weak apart from the widespread taxa Panopea, Chlamys (Lyriochlamys), Inoceramidae, Trigonia s. s., Limea (Pseudolimea), Oistotrigonia, Entolium, Neithea and Pholadomya. Darragh and Kendrick (1991, p. 11) stated that the genus-level endemism of the Cretaceous Australian Subprovince of Kauffman (1973) was up to 20% and at species-level 70%, consistent with Australia's marked isolation throughout the Late Cretaceous from regions other than Antarctica. Part of this observed pattern is plausibly the result of the poor Late Cretaceous record in Australia. As indicated in Tables 9-10, bivalve faunas other than those of New Zealand reveal strong faunal links during the Late Cretaceous, but as might be expected gastropod similarities are weaker (see Campbell and Valentine, 1977). Antarctica and New Caledonia have a strong SI index of 0.58 and the the SI index of Antarctica and South America is weaker than expected at 0.48, especially given the inferred close proximity during the latest

Cretaceous. I interpret these similarities to be: coefficient values ≥0.75 (very strong); 0.75-0.50 (strong); <0.5-0.25 (moderate); and <0.25 (weak). As faunal relationships can be deemed significant if the index is above 0.5 (Smith, 1989), there is clear quantitative support for Zinsmeister's concept of a Weddellian Province, at least for the Late Cretaceous including Campanian to Maastrichtian time. Pre-Campanian patterns are consistent with Kauffman's concept of an Austral Province. As will be shown below there were marked changes in composition across the K-T boundary. Furthermore, there is insufficient evidence to support the existence of the Weddellian Province earlier than Campanian time apart from the weak evidence of Struthioptera in the early Late Cretaceous of New Zealand.

Evidence here supports the geographic reduction of the Weddellian Province during the Paleocene to a small region in the eastern sector of the Gondwana Realm, including southeastern Australia, New Zealand and possibly Chatham Islands. Strong faunal ties existed between the coeval bivalve and gastropod faunas of the Pebble Point Formation in southeastern Australia and the Wangaloa, Kauru, Abbotsford, and Steel Greensand formations of South Island, New Zealand. Ten out of 28 bivalve taxa in Australia (SI = 0.36) are common to New Zealand and Australia based on data in Darragh (in press), whereas as 10 out of 11 gastropod taxa (SI = 0.91) are common to New Zealand and Australia (based on unpublished data courtesy of T. A. Darragh of Museum of Victoria). Paleocene faunas of New Zealand and Australia differ greatly from coeval faunas of Antarctica and southern South America. Griffin and Hünicken (1994) attributed this disparity to incomplete knowledge of the fossil record and paucity of modern comprehensive revisions of Late Cretaceous and early Tertiary faunas. This statement may be true for the Late Cretaceous as I have suggested, but is probably not true for the Paleocene as, of the many taxa recorded from South America and Antarctica, few are known from New Zealand and Australia. Of these taxa reported from South America, *Cucullaea*, *Ostrea*, *Chlamys*, *Dosinia*, *Aphrodina* (*Tikia*), *Panopea*, *Polinices* (*Polinella*), *Pseudofax*, doubtfully *Taioma*, doubtfully *Fyfea*, *Zemacies*, *Tornatellaea*, and *Priscaphander*, are also present at least in New Zealand. Although the paucity of preserved facies in the Paleocene of Antarctica provides little insight into paleobiogeographic patterns, I contend that the faunas of southern South America and Antarctica belonged most likely to a different province or subprovince during this interval.

SURVIVORSHIP/EXTINCTION PATTERNS ACROSS THE K-T BOUNDARY

Mass extinction events such as the catastrophic elimination of life, both plant and animal, at the Permian-Triassic and Cretaceous-Tertiary boundaries have excited scientists and the media since the 19th century. Most paleontologists, if asked about the sorts of plants and animals that became extinct and how many extinctions can be gleaned from the fossil record, could provide details on **The Big Five**--Ordovician, Devonian, Permian, Triassic and Cretaceous. Although the Permian-Triassic boundary was the most catastrophic in terms of extinction at c. 95% (Sepkoski, 1994), the K-T has received more publicity and scientific attention especially since this extinction event saw the end of the great multimillion year reign of the dinosaurs and a host of other organisms such as marine reptiles (e. g. all plesiosaurs, mosasaurs, ichthyosaurs), some mammals, many bivalves (e. g. all Inoceramidae, all Radiolitidae (rudists), most Gryphaeidae), some gastropods (e. g. many genera of Aporrhaidae, some Ringiculidae), all ammonites and belemnites, many planktic foraminifera, and the loss of many angiosperms. Approximately 77% of all marine species died out at the end of the Cretaceous (Sepkoski, 1994). This great biotic revolution saw the end of an eventful Mesozoic Era in terms of faunal succession, but resulted in a world more familiar to us today who inhabit the Cenozoic Era.

Many credible hypotheses have been proposed to explain the K-T boundary extinctions, but as Zinsmeister _et_ _al_. (1989, p. 731) pointed out, these arguments "...failed to provide a convincing explanation for the apparent synchroneity of extinctions of both marine and terrestrial life." With the 1978 discovery of significant iridium enrichment in a 66 Ma rock layer in Gubbio, Italy, by a team from the University of California and Lawrence Berkeley Laboratory, much energy and funding has been expended in confirming a link between events recorded in this layer and the demise of the dinosaurs and other organisms at the close of the Cretaceous. As a result of the 1978 discovery of anomalously high concentrations of iridium at K-T boundary sections in Italy, Denmark and New Zealand, Alvarez _et_ _al_. (1980) proposed that the high levels of iridium reflected global fallout from an asteroid impact, which created a vast dust cloud that encircled the Earth. The "asteroid hypothesis" of Alvarez _et_ _al_. contended that the dust cloud produced long-term darkness for months or years which severely inhibited photosynthesis, affecting the base of the food chain and disrupting both terrestrial and marine ecosystems. These authors believed that the asteroid impact could have led to the mass extinction. After the publishing of this paper, which incidentally triggered a surge of research (geology, geophysics, astrophysics) towards a better understanding of the terminal Cretaceous event, it is/was not uncommon to see depictions of dying/starving dinosaurs in darkened, cold and barren landscapes in popular magazines. The K-T boundary extinction event has also initiated highly charged debates at scientific symposia on the subject. The race was on to gather data and evidence to support or reject the "asteroid hypothesis" and to look for other causal mechanisms to explain the K-T boundary extinctions. (Of note, recent work by Tredoux et al. (1989) has established that iridium, a platinum-group element, may not be as useful as previously conceived to identify unambiguously extraterrestrial impacts in the geological record; furthermore, a mantle-derived source of platinum-group elements should be seriously considered as well, based on new chemostratigraphic data).

Although many workers have provided data from a variety of disciplines to support extra-terrestrially induced extinction for the K-T boundary (see list in Zinsmeister et al., 1989), some researchers have challenged the "asteroid hypothesis" (e. g. Clemens et al., 1981; Officer and Drake, 1983; Officer et al., 1987). For example, Officer et al. (1987, p. 143) advocated that the K-T interval was marked by a period of intense volcanism and that there is evidence that the "causative agent [for the extinction] was not extraterrestrial but intrinsic to this planet." Others have presented convincing evidence that the supposed mass extinction event was not instantaneous, but occurred over a significant time interval (Ward et al., 1986; Zinsmeister et al., 1987; Zinsmeister et al., 1989; MacLeod and Orr, 1993; MacLeod, 1994). (Note: I will address only a few key points here, as there is an enormous amount of literature on the subject.)

Research on the Inoceramidae, for example, has demonstrated that only 2-3 million years prior to the K-T boundary during mid Maastrichtian time, virtually all recorded species of this cosmopolitan, biostratigraphically important family disappeared from the fossil record (MacLeod, 1994). Zinsmeister et al.

(1989) published an important account of faunal changes across an expanded K-T boundary section in the high southern latitudes of Seymour Island, Antarctic Peninsula. On Seymour Island there is no single extinction horizon and placement of the K-T boundary is not clear-cut because commonly used boundary indicators (e. g. ammonites, planktic foraminifera, dinocysts, and the iridium layer) disappear at different horizons within a 30 m interval. The lack of a sole extinction horizon on Seymour Island argues against a sudden catastrophic event that caused the supposed massive extinction pulse. Or, if there was a catastrophic event at the K-T boundary, its effects were apparently not as strong in the high southern latitudes. Also, several taxa made their first appearances during the K-T interval on Seymour Island (Zinsmeister et al., 1989, p. 736, Fig. 6). These authors proposed that changes in the chemistry of the oceans or climate could have caused the faunal turnover.

One researcher studying faunal changes at the K-T boundary presented evidence both for and against the impact scenario and went so far as to state philosophically, "Depending on my mood, I can support either of the two advocacy statements. So much depends on how one selects and arranges the data." (Raup, 1989, p. 178). Until the last few years there has been little information on possible K-T boundary impact sites to further support the "asteroid hypothesis". Sharpton et al. (1992) provided evidence that the 200-km-diameter Chicxulub structure in northern Yucatán, Mexico, is a prime candidate for the K-T boundary impact crater. Robin et al. (1993) cited further evidence for multiple impacts, stating that they have data to support a 2 km K-T impact site in the Pacific Ocean. This is difficult to reconcile with the record of a 10 km asteroid impact on the Yukatan Peninsula, approximately 10,000 km away from Site 577 on the flank of the Shatsky Rise. Given the abundance of evidence, I concur with Gallagher (1993, p. 75) who proposed that "a combination of gradual climatic changes coupled with a sudden event like a bolide impact caused a protracted period of mass extinctions with suppression of full biomass productivity lasting well into the Paleocene."

K-T boundary stratigraphic record in New Zealand molluscs

Little information on the macrofaunal turnover at the K-T boundary in New Zealand has been available until now. Published data on biotic changes across the K-T boundary in New Zealand have been predominantly microfossil (e. g. foraminifera, dinoflagellate, radiolaria). Strong (1977), for example, showed that, based on study of Cretaceous microassemblages, there is no apparent decrease in either abundance or diversity at the boundary at Woodside Creek, northeastern Marlborough. Other K-T boundary sections in this country include Needles Point, Chancet Rocks, and Flaxbourne River, northeastern Marlborough (Strong, 1977; Alvarez et al., 1980, Brooks et al., 1986; Strong et al., 1987); Waipara, North Canterbury (Brooks et al., 1986; Wilson, 1987); probably Wangaloa, southeastern Otago (Stilwell, 1993) (Figure 96); possibly Mount Watkin, North Otago (Figure 97); Fairfield Quarry, Dunedin, Otago (MacMillan, 1993) (Figure 98); Te Hoe River area, Tawanui and Te Uri, southern Hawke's Bay (Wilson and Moore, 1988; Wilson and Morgans, 1989; Crouch, 1993) (see Figure 99 for locality map of New Zealand K-T boundary sections). The paucity of information on macrofaunal changes across the K-T boundary in New Zealand stems from the observation that no single section(s) has been recorded with latest Cretaceous to earliest Paleocene macrofossils in sequence. All Paleocene macrofossil assemblages are either conformably or unconformably underlain by Mesozoic metamorphic rocks (e. g. Haast Schist), nonmarine or paralic sediments (e. g. Taratu Formation), or unfossiliferous Upper Cretaceous marine sediments. As a consequence, the observed macrofaunal changes across the K-T boundary are based on many composite South Island sections. Important changes in the composition of the faunas can, nevertheless, be deduced from these sections. Unfortunately, there is no fossil record of the critical period immediately following the supposed mass extinction to gauge the existence or extent of faunal rebound directly following the extinction. A catastrophic extinction should be manifested by a low diversity "disaster fauna" of local survivors following the event with a later increase in diversity as allochthonous survivors migrate into an area (Hansen, 1988, p. 37). Is this inferred short-term period of adjustment, which probably occurred on an ecological time scale of one year to a millenium, visible in the geologic record? In a study of the effects of stratigraphic completeness on interpretations of extinction rates across the K-T boundary, Dingus (1984, p. 420) observed that the biostratigraphic resolution of the best known K-T boundary sections could not distinguish events lasting 100 years or less from events as long as 100,000 years. Therefore, in most stratigraphic sections,

Figure 96. Uppermost Cretaceous paralic sandstones of the Wangaloa Formation near the K-T boundary, which is as yet unlocated. South of Mitchells Rocks. Grid reference: H46/c.725295.

Figure 97. Uppermost Cretaceous? rocks of Abbotsford? Formation, Mount Watkin, North Otago. Paleocene fossils have been collected in greensands overlying the deposits shown in the photograph. Grid reference: I43/c.208130.

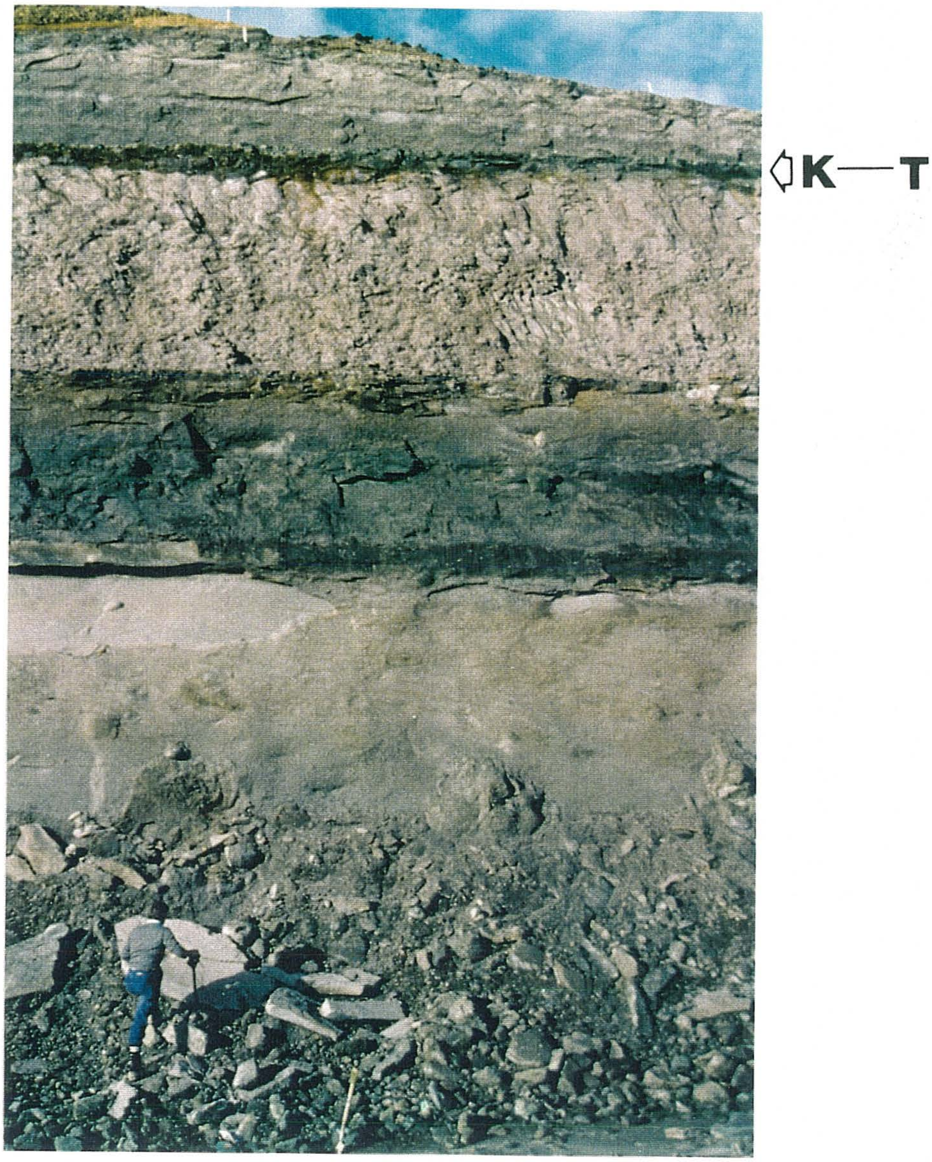


Figure 98. K-T boundary section at Fairfield Quarry. Approximate level of boundary indicated by solid line at top of photograph. Grid reference: I44/085762.

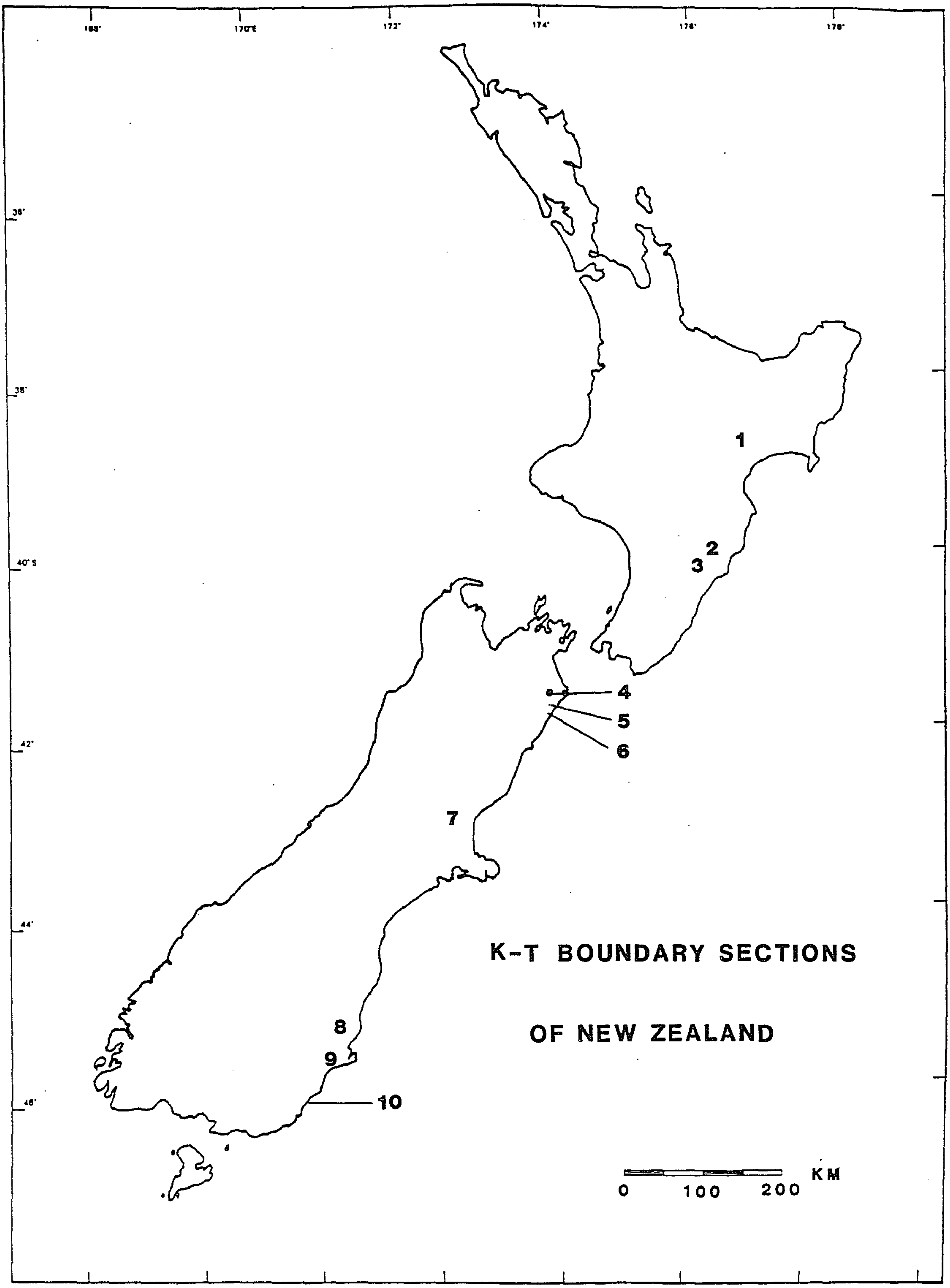


Figure 99. Location map of K-T boundary sections of New Zealand: 1, Te Hoe River; 2, Te Uri Stream; 3, Tawanui Stream; 4, Flaxbourne River (west), Chancet Rocks (east on coast); 5, Needles Point; 6, Woodside Creek; 7, Waipara; 8, Mt. Watkin; 9, Fairfield Quarry; 10, Wangaloa.

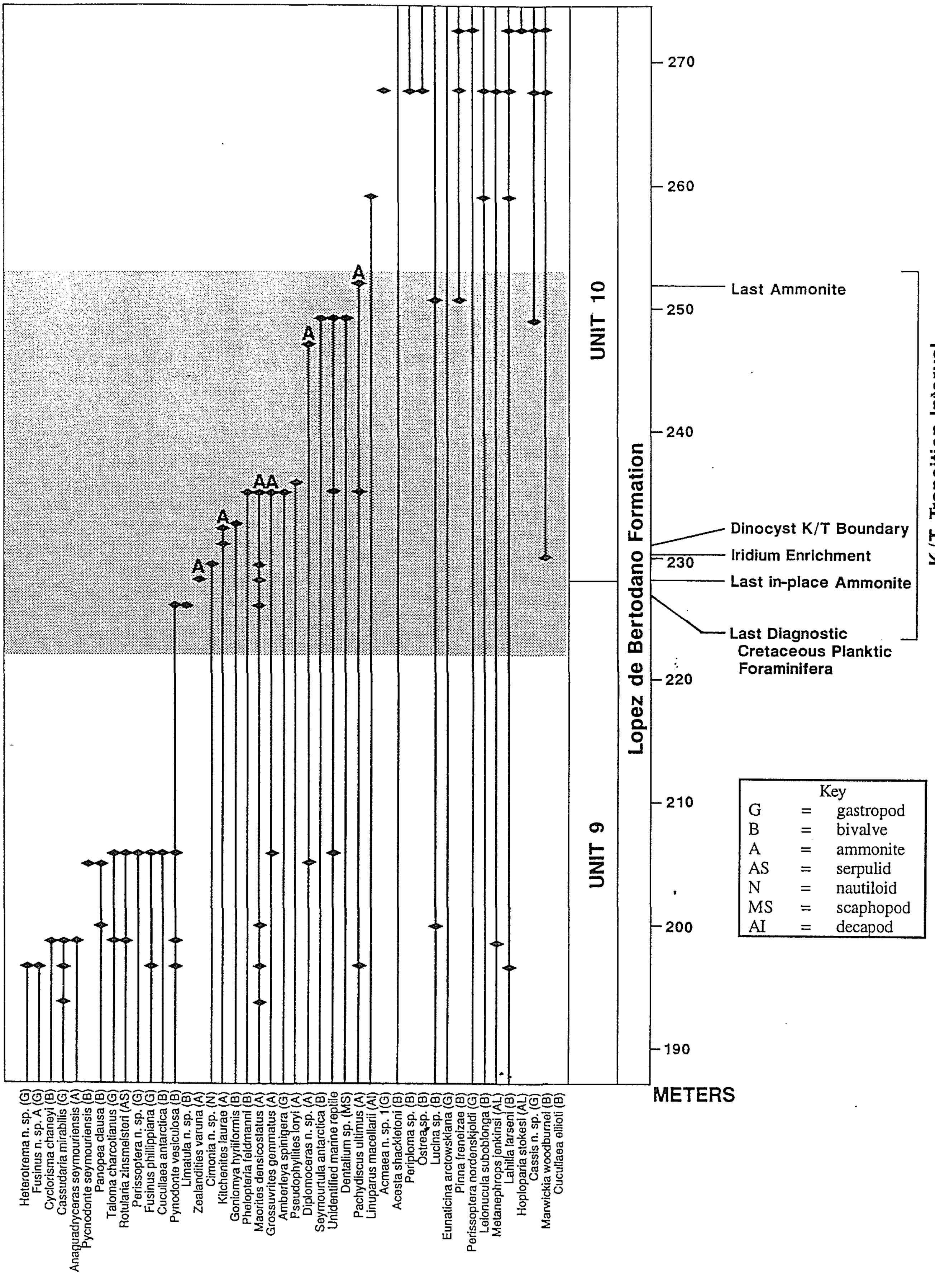


Figure 100. K-T transition interval on Seymour Island, Antarctic Peninsula. Plot across the 30 m interval illustrating the disappearance of macrofossils and the stratigraphic positions of the iridium enrichment horizon, dinocyst K-T boundary, last in situ ammonite, disappearance of Cretaceous planktic foraminifera, and last occurrence of ammonites (from Zinsmeister et al., 1989).

regardless if there was an extinction or not, we will probably not be able to resolve macrofaunal changes of such short duration. What can be resolved, as will be demonstrated herein, is the extent of the inferred initial radiation phase shortly following the supposed extinction event in the Paleocene.

Study of composite sections in New Zealand suggests that a gap occurs in the fossil record between youngest Maastrichtian and oldest Paleocene macrofossil assemblages. As a clue, no Maastrichtian mollusc species are known to have survived into the Danian, whereas in the well-documented coeval sequence in the Antarctic Peninsula and elsewhere in the world, several species crossed the K-T boundary (Figure 100). For New Zealand macrofossil-bearing strata, the hiatus between the Maastrichtian and Danian record may be substantial (perhaps as much as 5 million years or less), especially since the oldest Danian assemblages have been recently dated as late Early Paleocene on microfossil evidence. The seemingly cryptogenic appearance of many new genus- and species-level taxa in the Early Paleocene in New Zealand may be more apparent than real.

Extinction and survivorship in New Zealand molluscs

In the literature it is apparent that workers studying biotic changes across the K-T boundary have focused primarily on the extinction of taxa rather the survivors and the appearance of new groups (Zinsmeister et al., 1989, p. 735). In this study I present evidence on both extinction and survivorship patterns of New Zealand molluscs by looking at stratigraphic appearances and disappearances. I also present information on the inferred paleoecology of various taxa to gain a better understanding of the observed marked faunal changes across the boundary. Many aspects of taxonomy relevant to this section are covered in the systematics section.

Molluscs recorded at the K-T boundary interval in New Zealand can be conveniently assigned to six categories; these are:

1) genera/subgenera that became extinct in New Zealand and elsewhere at the end of the Cretaceous;
2) genera/subgenera that survived the K-T boundary extinction and are present in Paleocene rocks;
3) Lazarus taxa that crossed the boundary and reappeared sometime during the Tertiary, but not recorded in the Paleocene;
4) genera/subgenera that became extinct sometime during the Paleocene;
5) species that became extinct at the end of the Cretaceous; and
6) species that survived the K-T boundary extinctions (see Table 4).

Mollusc genera/subgenera believed to have become extinct at the close of the Cretaceous in New Zealand and other regions of the globe include Nucula s. l., Neilo (Neiloides), Austrocucullaea, Nordenskjoeldia, Indogrammatodon, Lycettia, Inoperna, Inoceramus, Entolium, Camptonectes, Chlamys (Lyriochlamys), Mixtipecten, Neithea, Seymourtula, Acesta (Plicacesta), Planospirites, Pseudoperna, most Trigoniidae (all new Zealand groups) (Pterotrigonia s. s., P. (Ptilotrigonia), Pacitrigonia, Oistotrigonia, Iotrigonia, Eselaevitrigonia, Trigonia), Eriphyla, ?Dozyia, Anthonya, Cardium (Bucardium?), *Austrocardium*, *Schedocardia*?, *Aenona*?, *Gari* s. l.?, *Surobula*, *Brookula* (*Paleobrookula* n. subgen.), *Amberleya*, *Kaiparomphalus* n. gen., *Procancellaria*, *Damesia*, *Protodolium*, *Neritopsis* (*Hayamiella*?), "*Zygopleura*", "*Loxonema*", *Bathraspira*, *Rhabdocolpus*, *Costacolpus*, *Perissoptera*, *Arrhoges* (*Latiala*), "*Cryptorhytis*", *Eriptycha*, and "*Aplustrum*". A few predominantly Cretaceous groups, such as *Tancredia*, have been discovered recently in Paleocene rocks. Families that were particularly hard hit by the extinction event include Nuculanidae, Cucullaeidae, Mytilidae, Inoceramidae, Pectinidae, Limidae, Trigoniidae, Trochidae, Neritopsidae, and Aporrhaidae. In summary, about 31 of 79 bivalve genera/subgenera (c. 39%) and approximately 17 of 47 gastropod taxa (c. 36%) became extinct in the New Zealand region and elsewhere around the globe. This corresponds to 48 of 128 taxa (c. 38%) of the total molluscan pool. Of inferred habits, about 39% of these bivalve taxa were probably epifaunal suspension feeders, approximately 50% were infaunal suspension feeders, and about 10% were infaunal deposit feeders (see Figure 101). A large proportion of gastropods (c. 65%) that became extinct were probably epifaunal herbivores and browsers (e. g. *Brookula* (*Paleobrookula* n. gen.), *Amberleya*, *Kaiparomphalus* n. gen., *Procancellaria*, *Damesia*, *Protodolium*, *Neritopsis* (*Hayamiella*?), *Bathraspira*, *Rhabdocolpus*). Few carnivores became extinct (e. g. *Eriptycha*). These patterns could reflect diminished productivity at the base of the food chain, greatly affecting those groups with herbivorous requirements and to a lesser extent groups higher in the food chain such as carnivores and scavengers. Another point to consider, as in the possible extinction of *Eriptycha*, is that some genus-group taxa may have evolved into Paleocene groups, but phylogenetic studies of molluscan taxa of this vintage in New Zealand have scarcely been attempted and documented. In the case of *Eriptycha*, an inferred carnivore, some evidence indicates that this genus evolved sometime over the K-T boundary into *Superstes*, present in the Paleocene. I consider that a host of factors are probably intertwined with the demise of several molluscan groups: the general decrease in temperature across the K-T boundary interval, changes in oceanic circulation patterns as a result of the break-up of Gondwana, nutrient differences, possible substrate changes, collection failure, and non-preservation probably all play a role in the observed patterns.

Of genera/subgenera studied herein, those that survived the end Cretaceous marine revolution into the Paleocene include *Linucula*, *Leionucula*, *Jupiteria*, *Neilo*?, *Cucullaea* (*Cucullastis*), *Glycymerita*, *Septifer*?, *Isognomon*, *Anomia*, *Myrtea*, *Thyasira* (*Conchocele*), *Lahillia*, *Gari* s. l.?, *Aphrodina* (*Tikia*), *Panopea*, *Bittiscala*, *Struthioptera*, *Conchothyra*, *Amauropsona*?, *Euspira*, *Acirsa* (*Notacirsa*), *Saulopsis* n. gen., *Tornatellaea*, *Cylichnania*, *Odostomia*?, and *Antalis* (see Figures 102-103). As many as 15 of 79 bivalves (c. 19%) and as many as 10 of 47 gastropods (c. 21%) are present in the Paleocene. One scaphopod, *Antalis*, crossed the boundary. In total, 26 of 128 genera/subgenera (c. 20%) survived the extinction event. Of these surviving genera/subgenera a large proportion of bivalves (c. 47%) are interpreted as shallow to variably deep, infaunal suspension

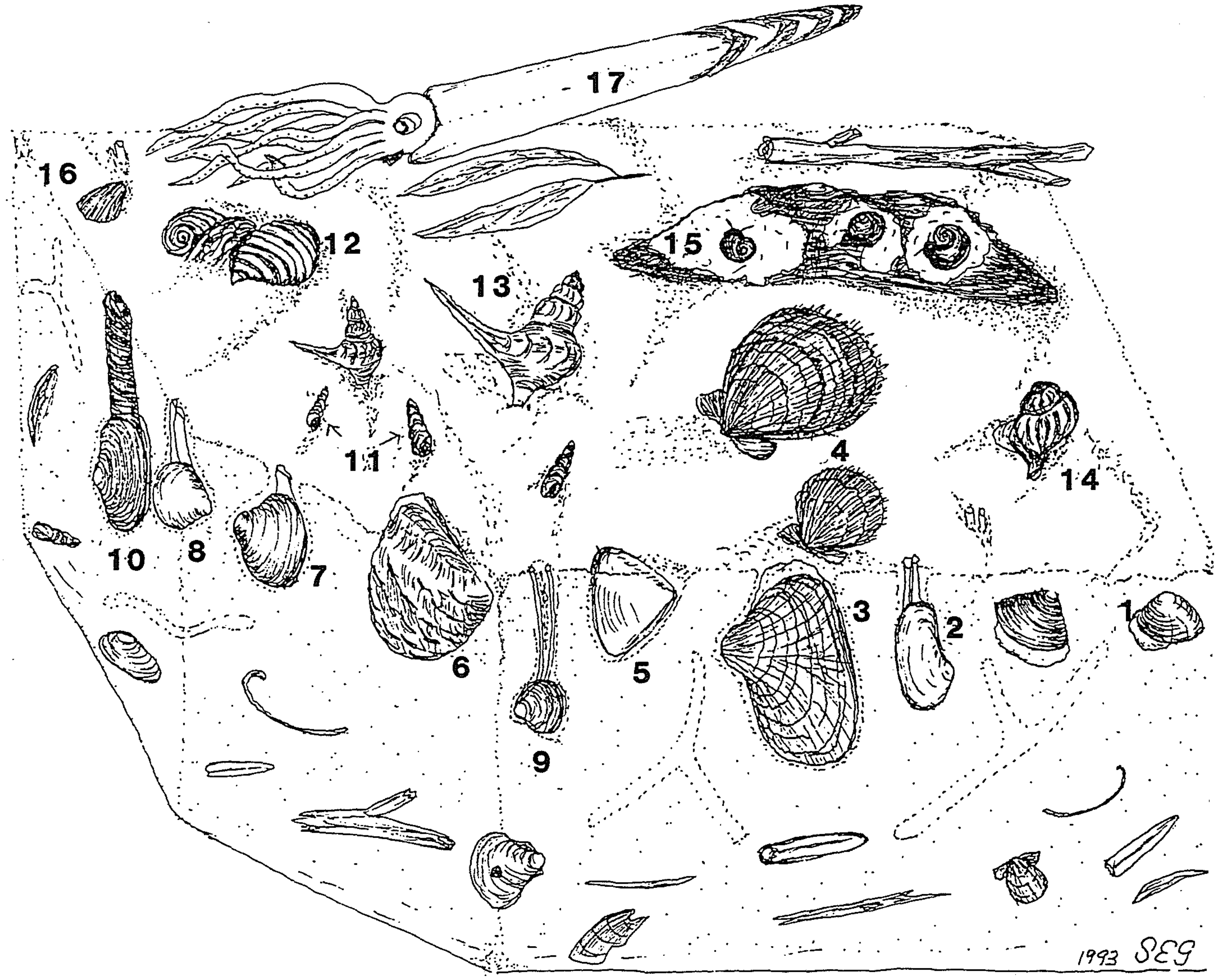


Figure 101. Paleoecological reconstruction of a latest Cretaceous (Maastrichtian) community of the Katiki Formation, Waianakarua River, North Otago. 1, Leionucula suboblonga; 2, Neilo (Neiloides) cymbula; 3, Cucullaea (Cucullastis) zealandica; 4, Mixtipecten amuriensis; 5, Eselaevitrigonia? n. sp.; 6, Pacitrigonia hanetiana; 7, Lahillia aotearoa n. sp.; 8, Eriphyla meridiana; 9, Aphrodina (Tikia) wilckensi; 10, Panopea clausa; 11, ?Costacolpus solitaria; 12, Protodolium speighti; 13, Perissoptera waiparaensis; 14, Saulopsis? n. gen. n. sp.?; 15, Eriptycha punamutica; 16, ?Granocardium (Ethmocardium) woodsi; 17, Dimitobelus (Dimitocamax) hectori?.

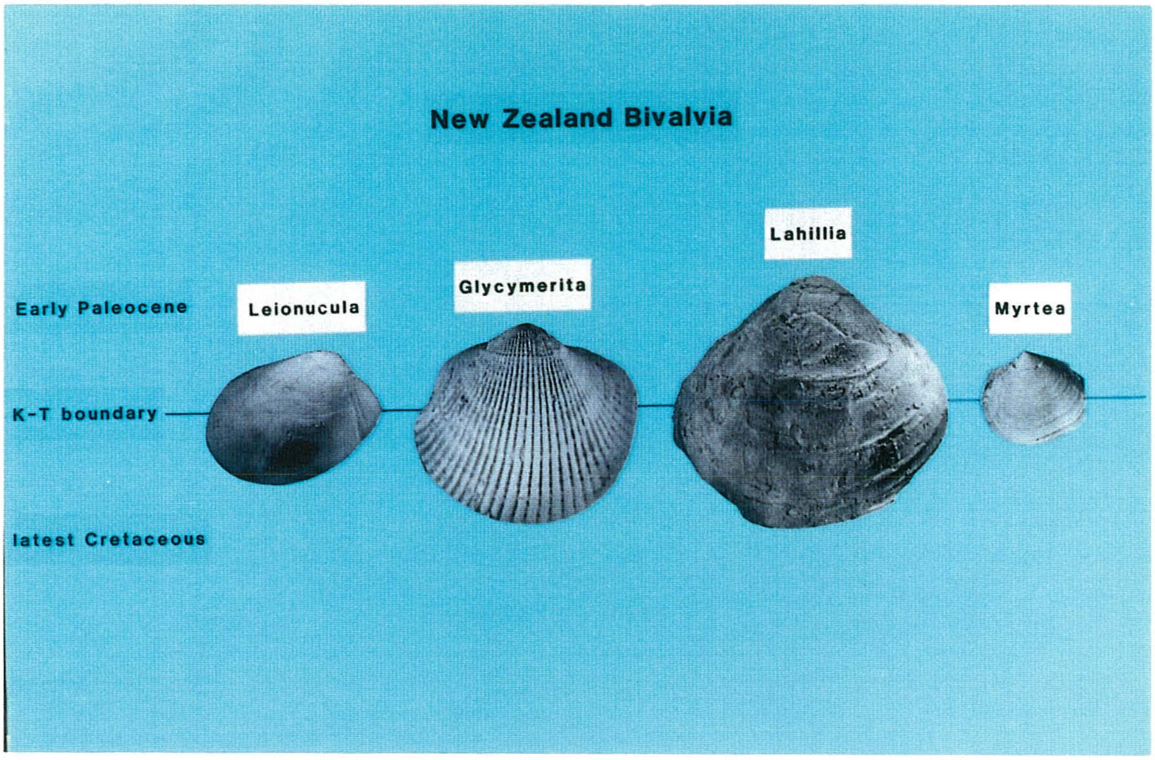


Figure 102. Some New Zealand bivalves that crossed the K-T boundary.

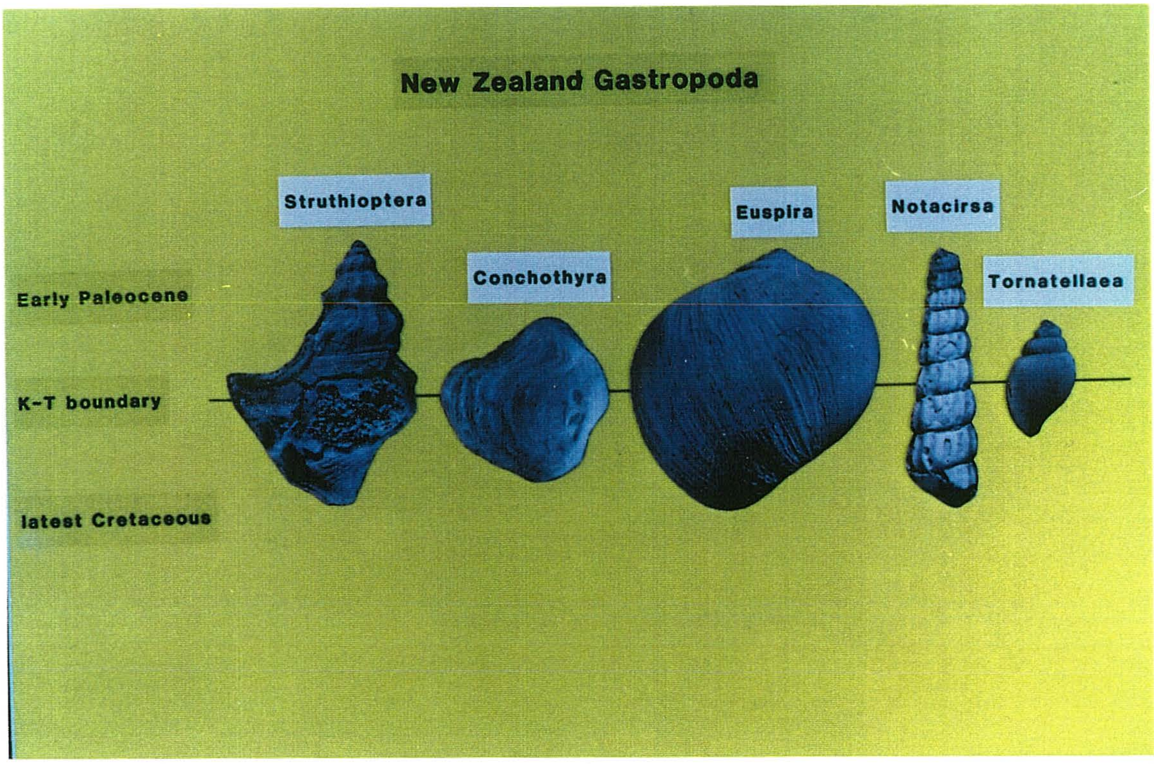


Figure 103. Some New Zealand gastropods that crossed the K-T boundary.

feeders (e. g. *Cucullaea* (*Cucullastis*), *Glycymerita*, *Thyasira* (*Conchocele*), *Myrtea*, *Lahillia*, *Aphrodina* (*Tikia*), and *Panopea*). There do not appear to be significant differences in proportions of infaunal suspension feeders of those taxa that became extinct and of those that survived, although the number of taxa was greatly reduced by the Paleocene.

Gastropod survivors were predominantly epifaunal to semi-infaunal carnivores, about 7 of 10 taxa or 70% (namely *Amauropsona*, *Euspira*, *Acirsa* (*Notacirsa*), *Saulopsis* n. gen., *Tornatellaea*, *Cylichnania*, and *Odostomia*). *Bittiscala* was probably an epifaunal herbivore or browser. *Struthioptera* and *Conchothyra* were most likely semi-infaunal deposit feeders. It is interesting to note that most of these survivors were probably eurybathyal with both Late Cretaceous and Paleocene representative species recorded in shallow and deeper shelf environments.

A significant number of Lazarus taxa have been identified in the New Zealand fauna. Thirteen of 79 bivalves (c. 16.5%) can be included in this category and 7 of 47 gastropods (c. 15%). Characteristic taxa that are present in uppermost Cretaceous rocks, absent from the Paleocene, and which reappear later in the Tertiary include *Saccella* s. l., *Solemya*, *Barbatia*, *Limopsis* s. s., *Modiolus*, *Pinna*, *Limatula* s. s., *Acesta*, *Raeta*, *Zenatia*, *Mya*, *Thracia*, *Cuspidaria*, *Perotrochus*, *Chelotia*, *Calliostoma* s. l., *Turbo*, and *Opalia*. Several other taxa disappeared from the New Zealand fossil record during the Maastrichtian, but reappeared elsewhere in the world during the Tertiary (e. g. *Tindaria*, *Limea* (*Pseudolimea*), *Crassostrea*, *Granocardium* (*Ethmocardium*), *Cymbophora*, *Cyclorismina*, *Cyrtodaria*, *Chelotia*, *Patelloida*, *Calliomphalus*, *Chrystostoma*, *Vanikoro*, *Trichotropis* (*Cerithioderma*), *Sycostoma*, *Pseudoperissolax*, and *Perissitys*). In total, about 64 of 128 New Zealand bivalve, gastropod and scaphopod genera/subgenera (c. 50%) survived the K-T boundary event(s).

Taxa that disappeared from the New Zealand fossil record and elsewhere in the Paleocene include *Ledina*, *Spineilo*, *Cucullaea* (*Cucullona*), *C*. (*Cucullastis*), *Limopsis* (*Limopsista*), *Mactra* s. l., *Aphrodina* (*Tikia*), *Marwickia*, *Dosinia* (*Dosinobia*), *Conominolia*, *Bittiscala*, *Zeacolpus* (*Leptocolpus*), *Drepanocheilus* (*Tulochilus*), n. gen.? n. sp. aff. *Hemichenopus*, *Conchothyra*, *Sigapatella* (*Spirogalerus*), *Taniella* (*Pristinacca*), *Taieria*, *Fyfea*, *Microfulgur*, *Wangaluta* n. gen., *Alcithoe* s. l., *Amuletum*, *Eothesbia*, *Antepepta*, *Coptostomella*, *Wangacteon*, *Kaurueon* n. gen., *Ongleya*, *Cylichnania*, *Priscaphander*, and *Eomathilda*. In total, 31 of 114 bivalve and gastropod genera/subgenera (c. 27%) are assumed to have become extinct sometime during the Paleocene.

There is insufficient biostratigraphic resolution to state accurately when each of the Maastrichtian species became extinct in New Zealand, but of 159 reported latest Cretaceous species none are present in "Wangaloan" (upper Lower Paleocene) rocks. *Lahillia* *neozelanica* was thought possibly to cross the K-T boundary (Beu and Maxwell, 1990), but this work has shown that the Late Cretaceous *Lahillia* represents a new species, *L*. *aotearoa* n. sp., which is described in the Cretaceous bivalve systematics section. No Cretaceous molluscan species is recorded in New Zealand Paleocene rocks. All 159 species apparently became extinct in latest Maastrichtian or earliest Danian time.

Survivorship/extinction patterns of New Zealand K-T boundary molluscs parallel moderately well those of the well known and important macrofossil-rich Brazos River sections of east Texas, U. S. Gulf Coast. Both are inferred to exhibit an initial radiation phase during the Early Paleocene characterised by unusually high speciation, probably filling the ecological vacuum left by the extinction. Later, this was followed by extinction of many species in these families in the late Danian (approaching 30% in the New Zealand fossil record). Gamma (total) species-level diversity of 159 bivalves, gastropods and scaphopods reported in the New Zealand latest Cretaceous is significantly lower than that of Brazos River at 500 known species. In the Brazos River section Hansen (1988) recorded a marked drop in gamma diversity from 500 to only 100 species in the early Danian. Gamma diversity (total molluscs) is on the order of 170 species for the New Zealand "Wangaloan", an increase over the K-T boundary, suggesting that although the extinction was severe in New Zealand at species-level, diversity quickly recovered in the few million years following the catastrophe. Gamma diversity is inferred to have dropped during the unfossiliferous earliest Paleocene interval by analogy with the Brazos River sections. Note, though, that for the bivalve component, diversity dropped dramatically over the K-T boundary interval in New Zealand from 79 to only 35 species in the "Wangaloan". In contrast, gastropod diversity across the K-T boundary rose from 47 recorded species in the latest Cretaceous to 76 species in the Paleocene. I would like to hypothesise that because herbivores and grazers were particularly hard-hit groups at the end of the Cretaceous, carnivorous and deposit feeding gastropods may have radiated into niches vacated by these groups and flourished (e. g. Acteonidae, Naticidae, Turridae). Thus, bivalve diversity dropped substantially over the K-T boundary and gastropod diversity climbed. This idea might explain the "flip-flop" in species-level gastropod diversity across the boundary. It is also apparent that epifaunal and infaunal suspension feeding bivalves did not regain ground in terms of diversity until later in the Paleogene.

Compared to end-Cretaceous bivalve extinction patterns of Tethyan and northern hemisphere faunas (Jablonski, 1991), the New Zealand record reveals a significant difference. Jablonski reported the following extinction intensities: North Africa, 49% lost of 80 genera; in Atlantic Coastal Plain, 53% lost of 117 genera; Northern Europe, 45% lost of 107 genera. The Late Cretaceous genus-level diversity of 79 recorded New Zealand taxa is comparable to that of North Africa, but in New Zealand only c. 39% of bivalve genera became extinct at the end of the Cretaceous suggesting that the extent of the extinction event at genus-level was not as great in the high southern latitudes as in the northern hemisphere and Tethyan realms. Epifaunal suspension feeders suffered considerable losses in New Zealand end-Cretaceous bivalves at c. 39%, comparable to severe losses of these groups in Europe and North America. Rhodes and Thayer (1991) found that the K-T boundary event was selective against suspension feeders. Later Cretaceous deposit feeding bivalves in New Zealand and elsewhere were seemingly extinction-resistant, probably because their energy requirements allow these bivalves to be more independent of primary production. A significant reduction in primary production at the K-T boundary would have affected suspension feeders more than deposit feeders, leading to selective extinctions as observed in the fossil record of New Zealand.

As in the Brazos River section, the New Zealand Paleocene faunas are characterised by a rapid evolutionary radiation of many new species. After the extinction pulse at the end of the Cretaceous, the ecological void left from the decimation of many molluscan groups probably resulted in rapid filling of niches by opportunistic species and "bloom" families (Hansen, 1988, p. 42). Some molluscan families show a veritable burst of speciation in the New Zealand Paleocene. An example is the sole recorded species of the Acteonidae, Tornatellaea evansi n. sp., in the Late Cretaceous. In the Paleocene there was a dramatic increase to 12 recorded species of this family. Also, only one species of Turritellidae, Costacolpus solitaria (Wilckens, 1922), is recorded in the Late Cretaceous, and three in the Paleocene. And, four species of Naticidae are recorded in the Late Cretaceous and 14 in the Paleocene. Those groups with planktotrophic development may have radiated more quickly into uninhabited niches compared to their slower counterparts with direct development. Many representatives of these "bloom" families probably had planktotrophic larval development. It is not obvious why many of these groups became extinct during the

Paleocene, but may indicate that "the losers" were not superior competitors or could not cope with increasing sea-surface temperatures at the end of the Paleocene. The observed patterns could also indicate that survival is stochastic. Paleocene mollusc data of New Zealand is also consistent with the idea that gastropods "always outpaced bivalves in bursts of speciation during the early Tertiary radiation." (Hansen, 1988, p. 46). The bulk of evidence supports the hypothesis that the "Wangaloan" fauna represents an initial radiation phase following the K-T boundary extinction event.

NOTES ON APPROACHES TO TAXONOMY

"It is well known that a definition of the term **species** is very difficult, principally because it has a value in one class of animals different from what it has in others. It is, in fact, a term only for our own convenience, although absolutely necessary if we desire to classify natural objects. The distinction does not exist in nature in a strictly invariable sense, although it must always be strongly supported by the facts of nature. And thus the term **species** must have certain acknowledged limits, which limits, however, cannot be accepted as fixed, but have, for the most part, to be determined in individual cases. And this is no doubt a matter of much delicacy and will depend much upon the author's views."

Ferdinand Stoliczka (1866, p. 214)

Some comment seems warranted on my approaches to taxonomy in this project. The myriad of approaches to taxonomy used since the time of Carl Gustav Linné in the eighteenth century have been shaped largely by scientific observation, philosophy peripheral to science and individual experience. More often than not most paleontologists have refined taxonomic methods adopted by their respective mentor(s). Because taxonomy is the root of paleontology and its many interrelated subdisciplines (e. g. evolutionary theory, biostratigraphy, paleoecology, paleobiogeography, functional morphology), a consistent taxonomic approach is paramount. Without sound classification and nomenclature of organisms, it is virtually impossible to have a coherent and ordered system for storing and using data. A fossil not properly identified, but used for paleontological interpretation, will obviously bias that particular interpretation. The geological joke that if you give two paleontologists the same fossil you will get two different names has an ominous undertone especially when broad interpretations presented by particular paleontologists are based on published and unpublished faunal/floral lists by many different workers. For example, one of the serious shortcomings of paleobiogeographic studies is the monographic effect, in which lists of fossils used in a particular project have been identified by several workers with variable experience and expertise. Scientists should become well-acquainted with fossils used in a particular study instead of relying on identifications made by someone else. Often this is logistically difficult since important collections of fossils are housed at various institutions around the globe, but at least this should help diminish the number of congeneric and conspecific taxa.

Because paleontologists have limited data on soft parts of fossil organisms, differentiation of species based solely on hard parts can be risky. Separation of fossil species is usually a matter of individual opinion, which has changed little over time. As an example, Stoliczka (1866, p. 214, footnote) in an early discourse on taxonomic practice stated that "If species of Ammonites are made on such as easy scale, as has lately been done by my friend Prof. Oppel, in his Palaeont. Mittheilungen, we shall soon have descriptions of single specimens instead of species!" Having a large enough population of a particular group decreases the chance of error, but since fossil assemblages are usually characterised by a few taxa that are common and many that are rare, availability of sufficient numbers of particular taxa is important. Hence, separation of taxa is not always clear-cut unless one has knowledge of known morphological variability of particular groups. Simple regression analysis utilising comparisons of, for example, length/height ratios of measured specimens, can complement or verify probable identifications and may separate various taxa. The number of synonymies could be reduced in the literature if workers who plan to erect new taxa compare their proposed new taxa with respective type-species. This practice has been largely followed in this thesis. Newly proposed taxa that are based on comparisons of various nominal taxa rather than types risk synonymy if this practice is not adopted.

Deducing evolutionary histories of fossil groups can be made by morphological assessments of overall form or by cladistic analyses. Cladistic analyses can be especially useful in deducing phylogenetic relationships of fossils groups with complex morphology. The greatest subjectivity in cladistic studies is the choice of taxonomic characters. There also is a minor element of subjectivity in identifying primitive vs. derived character states and choosing the best cladogram. Absence of data on soft parts plague many molluscan cladistic studies, so that "?"s abound in columns corresponding to missing data in data matrices (see, for example, the data matrix of Cardiidae character states by Schneider, 1992, Appendix 4). Nevertheless, cladistic analyses can be a valuable starting point and as a future project, I plan to attempt a cladistic analysis of the wholly Austral and biostratigraphically important gastropod family Struthiolariidae. Enough data on both soft and hard parts of Struthiolariidae have been published to perform a preliminary phylogenetic analysis.

Another seemingly endless source of controversy and debate amongst paleontologists is the "Do I give this rare or unique, moderately preserved specimen(s) of a species, that is derived from a sole locality now drowned beneath a reservoir, a new name or leave it in open nomenclature?" problem. Some paleontologists contend that if there is only a unique specimen known and there is little chance of finding additional material one should leave the species in open nomenclature. I believe that if one can properly demonstrate that a rare species is new and can be readily distinguished from the type-species and related described species, then there is no reason to leave the species in open nomenclature. Even if the said species is not all that well preserved but has sufficiently preserved characters to differentiate it from other taxa, I see no problem in giving the new species a name.

A more minor yet potentially emotive aspect of the taxonomic method is the name in binomial nomenclature. What is a name and what derivatives can be used? According to the International Code of Zoological Nomenclature (1985, Article 11, p. 19) "A name must be spelled in Latin letters and used as a scientific name by the author when published. (i) A name may be a Latin or latinized word. (ii) A name may be a word in another language that uses the Latin alphabet, or be formed from such a word, whether ending of the name is one used in Latin or not. (iii) A name may be formed from a language that uses a non-Latin alphabet, or that has no alphabet, or to represent a natural sound, or as an arbitrary combination of letters, if it is written in Latin letters and so constructed that it can be used as a word and deemed to be Latin...(vi) A name, if not Latin, may be latinized by given a Latin determination..." These conditions indicate that virtually any name can be given to a fossil, suffice it meets the conditions of the Code. Even names derived from the vernacular, such as "zigzag" - as I have used to characterise the zigzag trace of spiral sculpture of Ringicula zigzagia n. sp. - are acceptable; one would not necessarily have to use "ziczac". Possibilities of combinations of names, derived from various languages, dialects and vernacular words, are endless. Many unusual names have been proposed, including Hallucigenia for an enigmatic early macroinvertebrate which needs little explanation and Itibittium for a minute fossil cerithiid gastropod related to Bittium. Other colourful names have been proposed, such as Hunkydora, Ninjemys and Wakiewakie. A name merely fixes and identifies a particular taxon in binomial nomenclature. In New Zealand, names of fossil have been traditionally based on Latin, Greek and Maori derivatives, people, places, and morphology. I see no problem, whatsoever, including names derived from cultures outside the Realm of New Zealand (e. g. Australian aborigines, South American, Indian, etc.), especially since the country is knowingly composed of characteristically diverse cultures and was originally part of Gondwana along with these other landmasses.

CONCLUSIONS

The composition of latest Cretaceous to Paleocene shelf macrofaunas of New Zealand is closely linked with changing environmental conditions resulting from the final fragmentation of Gondwana, development of open oceanic conditions by about Early Campanian time (c. 80-85 Ma), and the K-T boundary event. The relatively rich latest Cretaceous to Paleocene molluscan record totalling 329 recorded species, of which 118 are considered new, is amongst the best in the southern hemisphere. This good record allows a detailed analysis of changes in faunal composition across the K-T boundary, including the extent of the mass extinction event at the end of the Cretaceous.

New data from many areas in New Zealand indicate that latest Cretaceous and Paleocene molluscan assemblages are much more geographically widespread than previously thought. Latest Cretaceous (Campanian? to Maastrichtian) assemblages extend from the tip of Northland to southeastern Otago, South Island. Paleocene assemblages are present in a few localities in North Island, in particular Kaiwhata River and Wimbledon (mid to Late Paleocene), and several Early Paleocene localities occur from North Canterbury to southeastern Otago. Newly reported Early Paleocene localities include some along the Waihao River, South Canterbury; some in the Five Forks-Kakanui River area, North Otago; Mount Watkin, North Otago; East Taieri, eastern Otago; and a locality along the Akatore Fault scarp, southeastern Otago.

Significant problems exist in correlating latest Cretaceous and Paleocene macrofossil localities due to rarity of biostratigraphically important index species, paucity of microfossil at key localities, facies faunas, and incomplete knowledge of stratigraphic ranges of some mollusc taxa. At present it is very difficult to establish Piripauan and Haumurian age relationships in the field and laboratory (even although the type sections are in stratigraphic sequence), since key index fossils are rare or missing at many localities. Furthermore, this study reveals that taxa supposedly restricted to the *Inoceramus pacificus* - *Dimitibelus lindsayi* Assemblage-zone of Warren and Speden (1978), in the Okarahia Sandstone of inferred Piripauan age, are present elsewhere in New Zealand in Haumurian rocks, which have been dated by microfossils and ammonites. Some supposed restricted taxa in the *I. pacificus* - *D. lindsayi* Zone have affinities with Maastrichtian taxa elsewhere in the southern hemisphere, and many are not particularly age diagnostic. There is scope for a national study to be undertaken to increase biostratigraphic resolution in this part of the column.

New data from this study indicates that rocks containing the "Wangaloan" fauna are much more geographically extensive than previously recognised. Historically, the "Wangaloan" fauna was thought to be geographically restricted and of little use in making direct correlation between the molluscan-based Wangaloan stage and the foraminiferan-based Teurian Stage. The Wangaloan was thought to be a partial correlative of the Teurian Stage and commonly it was omitted from the local stage scheme. Nevertheless, some paleontologists have continued to use the "Wangaloan" in an informal sense for the distinctive, shallow marine molluscan faunas of the earliest Tertiary of New Zealand. Further, "Wangaloan" has been retained/used because its relationship to the very long Teurian Stage (c. 8 m. y.) is not established clearly. Exclusion of the Wangaloan from the local stage scheme is not entirely satisfactory especially since work at Wangaloa, southeastern Otago, has established that the basal part of the Wangaloa Formation is uppermost Cretaceous in age suggesting that a complete K-T boundary section may be present. No stratigraphic break can be detected. With further research the relationship of the Wangaloan to the Teurian Stage could be established better. Recent dates from dinoflagellate assemblages at Wangaloa point to a late Early Paleocene age for the micro- and macrofossil assemblages which correlate with the *Palaeocystodinium golzowense* Zone (Wilson, 1992b). The Wangaloan has priority over the Teurian because it is the older name; thus, it may be appropriate to subdivide the current Teurian into a revised Wangaloan (basal) and Teurian (upper).

I propose that an assemblage zone be established for the extensive Paleocene molluscan-rich faunas of South Island because these fossils can now be correlated with some confidence with other coeval microfossil-poor rocks. The name *Zeacolpus* (*Leptocolpus*) *semiconcavus* Assemblage-zone is proposed. The *Z*. (*L*.) *semiconcavus* Zone can be correlated with the lower part of the *P*. *golzowense* Zone and is recognizable from North Canterbury to southeastern Otago.

The latest Cretaceous to Paleocene molluscan faunas of New Zealand are important from a global perspective in that few coeval faunas elsewhere in the southern hemisphere are as well documented and/or the record is not as complete as found in this country. The observed changes in composition of these faunas across the K-T boundary are dramatic and yield important new clues about the effects of the break-up of Gondwana and environmental perturbations on the shallow shelf faunas of New Zealand. Approximately 65% of recorded bivalve and 94% of gastropod genera/subgenera made their first appearance during the latest Cretaceous in New Zealand.

New Zealand Late Cretaceous and Paleocene molluscs can be divided into four biogeographic groupings at genus- and subgenus-level; these are endemic, paleoaustral, Indo-Pacific/Tethyan, and cosmopolitan. The endemic component in the Late Cretaceous fauna was relatively low at c. 8% of the total recorded taxa, compared to the marked increase to c. 32% during the Paleocene, reflecting New Zealand's geographic and genetic isolation at this time. The paleoaustral element was weak at c. 21% of the total fauna during the Late Cretaceous, but it increased substantially during the Paleocene to c. 60%. The inferred warm-water Indo-Pacific/Tethyan element was strong during the Late Cretaceous at c. 48% of the total fauna, but by Paleocene time had decreased to c. 26%. The cosmopolitan component was c. 28% of the total fauna during the Late Cretaceous and this decreased substantially by Paleocene time to c. 12%.

At species-level the Late Cretaceous and Paleocene molluscan faunas encompass three general groupings; these are widespread or cosmopolitan species, endemic species of cosmopolitan or wide-ranging genera, and endemic species of endemic genera/subgenera.

Very few cosmopolitan species have been recorded in the Late Cretaceous fauna, apart from Lycettia lanceolata (Sowerby, 1823) and Entolium menbranaceum (Nilsson, 1827). No cosmopolitan species have been recorded from the New Zealand Paleocene. Endemic species of cosmopolitan or wide-ranging genera comprise the majority of the fauna at c. 92% during the Late Cretaceous. Late Cretaceous endemic species of endemic genera/subgenera make up a small proportion of the total at c. 6%. At species-level the "Wangaloan" fauna is probably entirely endemic apart from the possible records of C. (Cucullona) inarata Finlay and Marwick, 1937, from the mid Paleocene of southeastern Australia and Taieria allani Finlay and Marwick, 1937, from the Late Paleocene of Chatham Islands.

The macrofaunal changes across the K-T boundary in New Zealand are dramatic. As in the Late Cretaceous many new groups appeared during the Paleocene. The "Wangaloan" fauna is highly distinctive at genus- and species-level and bears little resemblance to coeval faunas in the northern and southern hemisphere, except for many taxa in the Pebble Point Formation of southeastern Australia. Of Paleocene bivalves 51% of the total recorded number of genera/subgenera are first reported in rocks of this age. Approximately 88% of gastropod genera/subgenera made their first appearance during the Paleocene.

Changes in climatic, oceanic and tectonic regimes related to the final fragmentation of Gondwana greatly influenced the composition and distributions of shallow, benthic biotas of the southern hemisphere, including those of New Zealand. Because of the decreased latitudinal gradient of sea-surface temperatures, warm currents, increased shelf area following the break-up of Gondwana, and favourable oceanic circulation including marine links from New Zealand to Antarctica via a probable Trans-Antarctic seaway, there were strong faunal communications between faunas extending from New Caledonia and Australia reaching around the rim of the southern circum-Pacific to southern South America. Austral molluscan faunas of these areas were generally homogeneous in composition, but with a moderately strong endemic component at genus- and subgenus-level. However, it is proposed here that the New Zealand Subprovince of the Austral Province of Kauffman (1973) be abandoned in light of the low overall proportion of c. 8% endemics during the Late Cretaceous.

Six by six data matrices were compiled of similarity coefficient values of Late Cretaceous and Paleocene shelf molluscan faunas of Australia, New Caledonia, New Zealand, Chatham Islands, Antarctica, and southern South America to test the Weddellian Province concept of Zinsmeister (1979). Zinsmeister hypothesised that the Austral Province of Kauffman lost its identity and broke up into smaller provinces by Late Cretaceous time, and the Weddellian Province was proposed for one of these which encompassed the areas named above. The Weddellian Province was recognised via the distribution of characteristic taxa such as Lahillia, Struthioptera, Struthiolariidae, and Taioma in the southern continents during the latest Cretaceous and early Paleogene. Because paleobiogeography is shifting from a qualitative to a more quantitative phase, it is desirable to use statistical tests to sharpen the definition of various proposed biotic provinces. New data and the revised New Zealand molluscan faunas were used to provide a preliminary test of the Weddellian Province using Simpson, Dice and Simple Matching binary coefficients.

New Zealand, New Caledonia and Chatham Islands molluscs reveal the strongest faunal ties during the latest Cretaceous. Computed Simpson coefficient values indicate a 0.71 degree of similarity between the bivalve faunas of New Zealand and New Caledonia and a 0.76 degree of similarity between the bivalves of New Zealand and Chatham Islands. Limited gastropod data support these marked faunal ties. At species-level a few taxa are common to these areas, including Leionucula suboblonga (Wilckens, 1905), Panopea malvernensis Woods, 1917, P. clausa Wilckens, 1910, and possibly Protodolium speighti (Trechmann, 1917) (New Zealand and New Caledonia only). The only described latest Cretaceous bivalve and gastropod faunas of Australia, in the Carnarvon and Perth basins, bear little resemblance to the faunas of New Zealand and the rest of the Weddellian Province; I regard them as part of a different biotic province. Because the only Late Cretaceous data from southeastern Australia are present in subsurface cores in which little is known about the composition of these faunas (T. A. Darragh, pers. commun., 1991), it is conjecture as to whether these faunas belonged to the Weddellian Province. However, it would not be surprising if faunal ties between New Zealand and southeastern Australia were marked in the Late Cretaceous, because of the close similarities of the faunas of New Zealand and New Caledonia during the Late Cretaceous and New Zealand and southeastern Australia during the Paleocene.

Latest Cretaceous bivalve ties are also strong between New Zealand and Antarctic Peninsula at a Simpson coefficient value of 0.68, considering that paleogeographic reconstructions indicate that these faunas were separated by more than 90° of longitude during the Late Cretaceous. Latest Cretaceous bivalves in New Zealand and southern South America have a somewhat lower but still moderately strong Simpson value of 0.49. I suggest that this lower value for New Zealand and South America reflects a larger distance and limited shelfal communication across the Scotia Arc region of the proto-Drake Passage during the latest Cretaceous. Further, there may be bias due to the monographic effect. Antarctica and New Caledonia bivalve faunas have strong ties at a Simpson value of 0.58, whereas despite their proximity, southern South America and Antarctic Peninsula have a puzzlingly low value at 0.48.

Apart from faunas along the western sector of the Gondwana Realm, Paleocene assemblages indicate greatly reduced faunal ties during this interval. Simpson coefficient values of 0.36 and 0.91 were computed between the bivalve and gastropod faunas of New Zealand and southeastern Australia, suggesting that marine links were still strong, compared to probable severed ties between New Zealand and the Antarctic Peninsula-southern South America region during the Paleocene. Unsurprisingly, Simpson coefficient values are low between the faunas of New Zealand and Antarctic Peninsula and southern South America for the Paleocene, suggesting that the faunas of these areas belonged to a different province or subprovince. Compelling qualitative and quantitative evidence suggests that the Weddellian Province did exist for a short time during the latest Cretaceous, but by Paleocene time had been reduced to a small region including New Zealand, southeastern Australia and possibly Chatham Islands, along the newly opened Tasman Sea.

The good fossil record of New Zealand Late Cretaceous and Paleocene molluscan assemblages from a spectrum of environments allows a detailed examination of the supposed mass extinction event at the end of the Cretaceous and ensuing changes in the biosphere. New Zealand data support the idea that gradual climate changes, coupled with a probable extraterrestrial impact(s) in lower latitudes, caused an interval of mass extinction and suppressed biomass productivity. Extinction was followed by faunal rebound during the Early Paleocene. Because the oldest Paleocene mollusc assemblages in New Zealand are late Early Paleocene in age, indicating a gap from latest Maastichtian to earliest Danian time, there is no evidence of a low diversity disaster fauna directly following the extinction. However, the extent of the supposed initial radiation phase can be demonstrated from the New Zealand fossil record.

In total about 39% of bivalve genera/subgenera and 36% of gastropod taxa became extinct in New Zealand and elsewhere at the end of the Cretaceous. Infaunal and epifaunal suspension feeders were particularly hard hit with c. 89% of bivalves becoming extinct and a significant proportion of epifaunal herbivores and browsers at c. 65%. Few carnivores became extinct. These statistics indicate that productivity decreased at the base of the food chain at the K-T boundary, affecting suspension feeders herbivores and browsers, more than deposit feeders and carnivores. About 50% of bivalve, gastropod and scaphopod genera/subgenera cross the K-T boundary and many of the survivors are inferred to have been eurybathyal. Nearly half of the Paleocene bivalve survivors were infaunal suspension feeders, whereas few were epifaunal. New Zealand data support the idea that the K-T boundary extinction selected against suspension feeders. Most gastropod survivors were carnivores and deposit feeders. About 20 genera/subgenera are Lazarus taxa that reappeared after the Paleocene in New Zealand and elsewhere around the globe. A significant proportion of the Paleocene survivors and newly evolved taxa (c. 27%) disappeared during the Paleocene. Other factors implicated in the demise of many molluscan groups at this time, and with overall changes in composition, include a documented general decrease in sea-surface temperatures across the K-T boundary, changes in oceanic circulation associated with the break-up of Gondwana, monographic effect, collection failure, and non-preservation.

The K-T boundary extinction event was severe at species-level in New Zealand, but at genus-level was not as catastrophic at 39% of the bivalve fauna, compared to documented extinction patterns in North Africa, Atlantic Coastal Plain, and northern Europe. This data provides evidence that the extinction event was not as severe in the high southern latitudes. Gamma species diversity during the Late Cretaceous in New Zealand at 159 species nearly matches that of the Paleocene at 170 species, suggesting that, by the late Early Paleocene, diversity quickly recovered in the first few million years following the catastrophe, compared to other K-T boundary sections around the globe (e. g. Brazos River, Texas). However, whereas bivalve species diversity dropped dramatically across the K-T boundary from 79 to 35, gastropod diversity increased from 47 to 76 species, giving credence to the hypothesis that carnivores and deposit feeders radiated into niches vacated by groups that became extinct. This may explain the presence of several "bloom" families (e. g. Acteonidae, Turridae, Naticidae) which show a burst of speciation in the New Zealand Paleocene. Paleocene mollusc data support the idea that gastropods outpaced bivalves during the early Tertiary in terms of radiation. Furthermore, research on K-T boundary molluscs in New Zealand supports the hypothesis that the "Wangaloan" fauna not only represents rapid evolution from genetic/geographic isolation, but also an initial radiation phase reflecting high speciation in which many new groups infilled vacated niches left by the extinction, followed by another less severe extinction event in the late Danian.

SYSTEMATIC PALEONTOLOGY

Before a detailed paleobiogeographic study of the latest Cretaceous to early Paleogene molluscan faunas of New Zealand could be accomplished it was paramount that an exhaustive taxonomic review of the faunas be undertaken. These faunas have not been studied in detail for well over 50 years, so that our view of these fossil Mollusca is somewhat biased, in part due to out-of-date taxonomy. Molluscan systematics has advanced greatly in the last 50 years.

Recent research, and additional collecting in this project, have greatly improved our knowledge of the composition of latest Cretaceous to early Paleogene molluscan faunas of New Zealand. In this study, fossils were collected from key localities using traditional means (e. g. rock hammer and chisel) and using the petrol-driven Pionjär rock drill/hammer (Figures 104-105). Fossils were prepared in the laboratory using a pneumatic air scribe and various dental tools. Fossils were coated with ammonium chloride before macrophotography and gold and/or platinum for scanning electron microscopy.

Summarized herein is a systematic catalogue of these fossil molluscs (Bivalvia, Gastropoda, and Scaphopoda) which is divided into two sections: 1) latest Cretaceous (Campanian? to Maastrichtian) Mollusca of New Zealand; and 2) Paleocene (Danian to Thanetian) Mollusca of New Zealand. Fossil collections used in this study are numerous and began historically with J. Buchanan's small collection of molluscs from Wangaloa, southeastern South Island, in late 1868 or early 1869 and extend to the present. To date 159 molluscan species have been recorded from the Campanian? to Maastrichtian (uppermost Cretaceous) of New Zealand and 170 species from the Early to Late Paleocene. Descriptions of all of the fossil localities known for the Late Cretaceous to Paleocene are included in Appendix A. Chatham Islands Cretaceous and Paleocene fossil localities are also presented in Appendix A.

The specimens and collections used in this study are housed in many institutions in New Zealand and abroad. Acronyms used in the text for these institutions are as follows: Geology Museum at Otago University Geology Department (OU); Otago Museum (OM) Institute of Geological and Nuclear Sciences (IGNS), previously the New Zealand Geological Survey (NZGS), and type Mollusca (TM); Auckland University (AU); Auckland Institute and Museum (AIM) and type Mollusca (Ge); Canterbury Museum, Christchurch (CM); Natural History Museum, London (BMNH); Naturhistoriska Riksmuseet, Stockholm, Sweden (MO); United States National Museum, Smithsonian Institution (USNM); Centro de Investigaciones en Recursos Geológicos, Buenos Aires, Argentina (CIRGEO); Museo de La Plata, Argentina (MLP); Institute of Polar Studies, Ohio State University, Columbus (IPS); and Orton Geological Museum, Ohio State University (OGM).

Where possible and appropriate, previously described species are redescribed, figured, and their taxonomy modernized. In-depth treatment of each species is not always necessary or feasible, and in some cases little new data are presented besides new localities, citings in the literature, and/or minor taxonomic comments. Stratigraphic ranges given are New Zealand ranges, unless stated otherwise. Depending on the availability of material of previously described taxa, supplementary descriptions are sometimes given. Museum numbers have been assigned and are presented here for many Campanian to Paleocene molluscan types for the first time. A summary of all known New Zealand localities (indicated by fossil record numbers) for each species is presented, most for the first time since their erection generally over the time interval of 1911 to 1937; refer again to Appendix A for locality descriptions and metricated/imperial grid references. Although most grid references are six digit numbers, some are eight reflecting additional accuracy. Unless stated otherwise, localities are all New Zealand localities. Questionable occurrences of species at various localities are shown as a "?" before the locality. Figured specimens may be both type specimens or other specimens. A "?" is also used throughout the systematics section and plate captions to denote uncertainties in identification at various taxonomic levels. Some recently obtained species are considered to be new, but have not been worked up and are left in open nomenclature pending further work. "Hypotype", although still in common use by numerous workers, is not used here with reference to specimens from this study as the term is not recognized by the International Code of Zoological Nomenclature (1985); however, "hypotype" will be retained here for the purposes of those specimens previously described and designated as hypotypes by various workers in the literature. Specimens other than types are referred to as figured specimens followed by museum numbers or may be cited simply as specimen plus museum number. Many species including types illustrated in the systematic catalogue are photographed for the first time; some previously were depicted by line drawings. Species proposed by Linné will be written, as for example "Linné, 1758", not "Linnaeus, 1758", in agreement with Jeffreys (1862, pp. ix-x) who discussed the "controversy" (which apparently still persists in some circles) surrounding the spelling of the Swedish naturalist who upon receiving a "patent of nobility" assumed the name of Linné, the name he always used and preferred in his works. Systematic arrangement of the Bivalvia generally follows Moore (ed.) (1969), **Treatise on Invertebrate Paleontology, Part N, Mollusca 6, Bivalvia**; Vokes (1980), **Genera of the Bivalvia: A Systematic and Bibliographic Catalogue (Revised and Updated)**; Vaught (1989), **A Classification of the Living Mollusca**; and Beu and Maxwell (1990), **Cenozoic Mollusca of New Zealand.** Systematic arrangement of the Gastropoda generally follows Moore (ed.) (1960), **Treatise on Invertebrate Paleontology, Part I, Mollusca 1, Gastropoda**; Ponder and Warén (1988); Vaught (1989), **A Classification of the Living Mollusca**; and Beu and Maxwell (1990), **Cenozoic Mollusca of New Zealand.** The traditional ordinal names Archaeogastropoda, Mesogastropoda and Neogastropoda are used in this study; however, these names are included with the proviso that future work may see the abandonment of these names because these taxonomic groupings may be grades rather than clades, as advocated by Bieler (1992) among other workers. Systematic arrangement of the Scaphopoda again follows Vaught (1989), Beu and Maxwell (1990) and Steiner (1992). Superfamilial endings of "-acea" are preferred here to "-oidea", because the latter may be confused with and is close to ordinal endings of "-oida".

Note: In this thesis, a genus name followed by the term sensu stricto implies that the subgenus name is the same as the genus, whereas a genus name followed by the term sensu lato implies that the subgenus is uncertain.

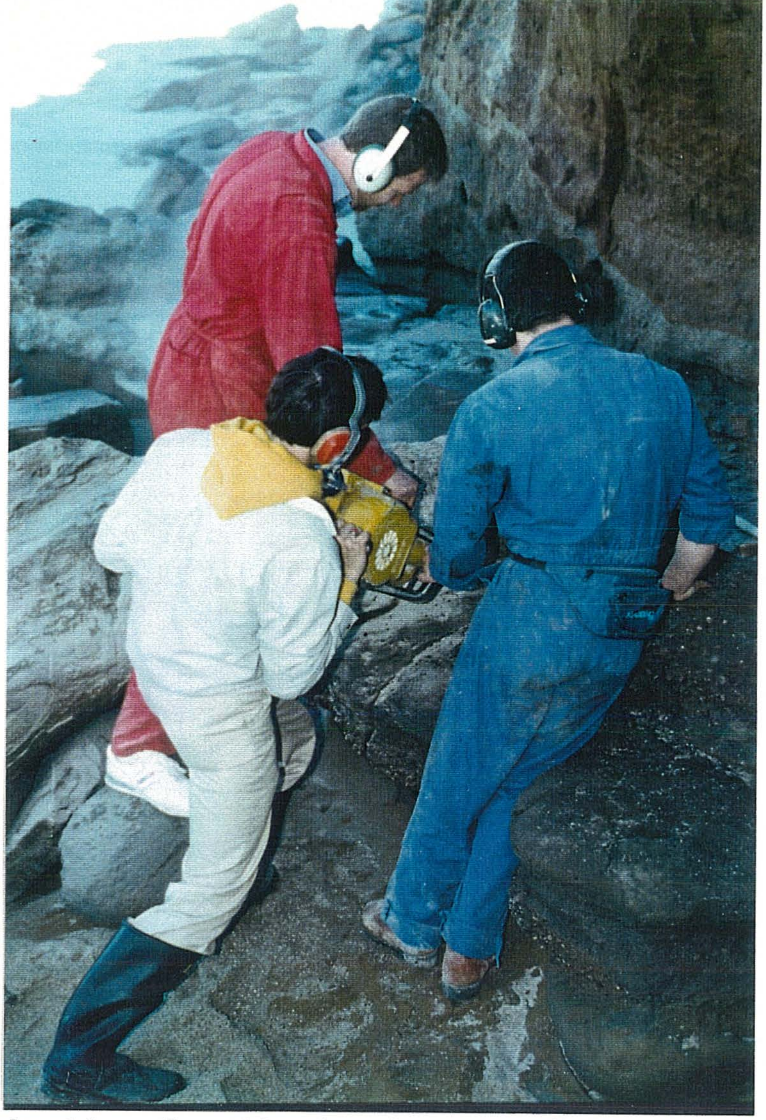


Figure 104. Collecting fossils in the Wangaloa Formation, Mitchells Rocks, Wangaloa, using petrol-driven Pionjär rock drill/hammer. Grid reference: H46/c.768337. Left to right, S. Munro, J. D. Stilwell and C. M. Jones.

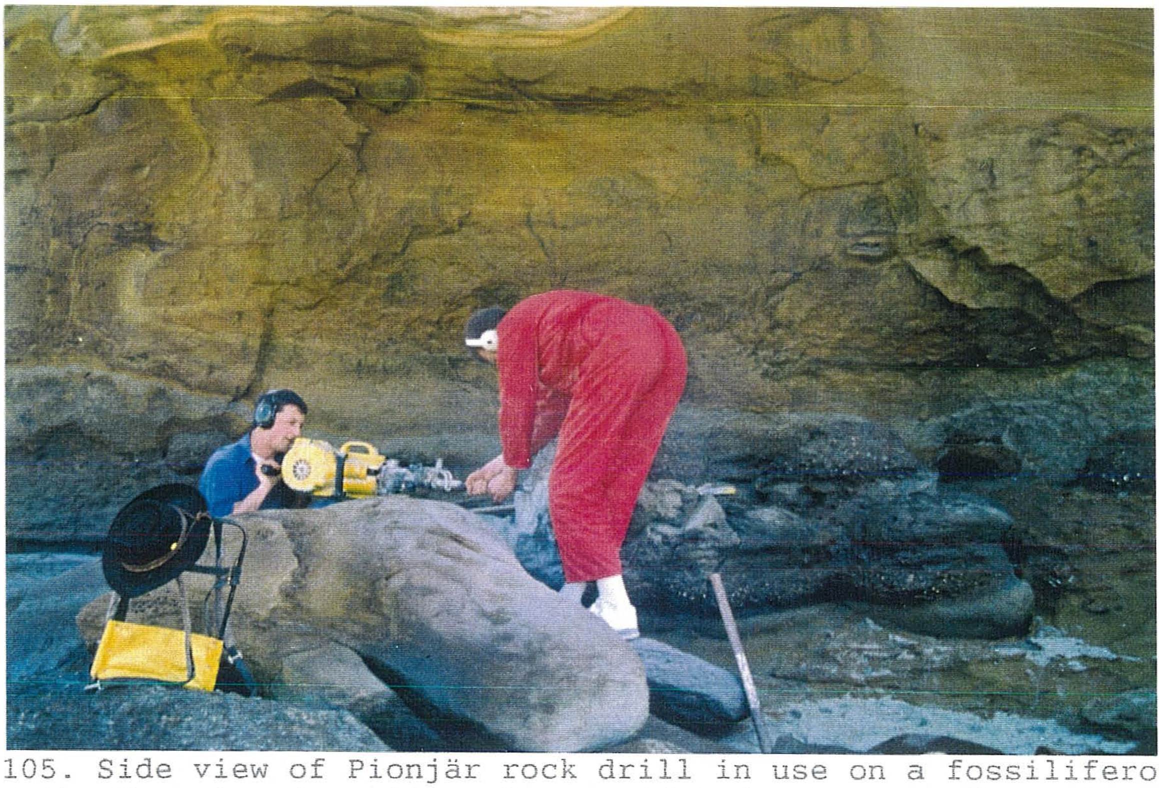


Figure 105. Side view of Pionjär rock drill in use on a fossiliferous lens in the Wangaloa formation. Same grid reference as above. C. M. Jones (left) and S. Munro (right).

Phylum MOLLUSCA Linné, 1758

Class BIVALVIA Linné, 1758

Subclass PALEOTAXODONTA Korobkov, 1954

Order NUCULOIDA Dall, 1889

Superfamily NUCULACEA Gray, 1824

Family NUCULIDAE Gray, 1824

Discussion.-Before this report no systematic work had been published on Cretaceous nuculid bivalves of New Zealand and also very little has been published about the early Paleogene nuculid record. This is surprising as nuculid bivalves are relatively common in Upper Cretaceous marine sediments in Northland and are present, although not abundant, in the Upper Cretaceous fine-grained sandstone facies of the Okarahia Sandstone at Haumuri Bluff and Katiki Formation at Shag Point and Waianakarua River, South Island. At least three genera, *Nucula* s. l. Lamarck, 1799, *Linucula* Marwick, 1931, *Leionucula* Quenstedt, 1930, are represented in the New Zealand Cretaceous fossil record. Nuculidae are present in Upper Cretaceous marine strata of New Zealand, New Caledonia, Antarctica and South America, but none have been reported from Australia or Chatham Islands. The group was, however, not particularly speciose during the Late Cretaceous around the southern circum-Pacific. This reported absence of Nuculidae in the Late Cretaceous of Australia is presumably due to the continent's tectonic regime during the Late Cretaceous and perhaps the lack of suitable facies preserved for deposit feeders in the known, very patchy, Upper Cretaceous sedimentary record. Collection failure and paucity of information with respect to the Late Cretaceous Australian molluscan record may also be variables controlling the poor nuculid record in Australia. Nucula s. l. teopuensis n. sp., Linucula bullensis n. sp., N. s. l. kaiparensis n. sp., N. s. l. manuensis n. sp., and Leionucula suboblonga (Wilckens, 1905) represent the only described species of Nuculidae around the southern Gondwana margin during the latest Cretaceous.

Nuculid bivalves have been collected from numerous localities throughout New Zealand. Late Cretaceous species of uncertain affinity, other than described species, are included in the numerous localities listed below. Refer to Appendix for locality descriptions, grid references, etc. These are: Green Island, Otago, South Island, I44/f8489; ?East Taieri, Otago, South Island, I44/f8516; ?Road cut, Akatore Fault scarp, Otago, South Island, I45/f8519; East wing, Haumuri Bluff, South Island, O32/f9032; Cheviot, South Island, O33/f9044; Whangaroa Harbour, Northland, P04/f9494, P04/f9564; Ngaiana Stream area, North Island, T26/f9535, T26/f9536; Clarke Creek, Manu Creek District, North Island, Z14/f8492; central eastern South Island, L35/f6511; mouth of Conway River, South Island, O32/f8507; Batley, Kaipara, Northland, Q08/f9023; Whakapirau Creek, Northland, Q08/f9667; Bull Point, Kaipara, Northland, Q08/f9668; and near Kekerengu River, Marlborough, South Island, P30/f8702.

Subfamily NUCULINAE Gray, 1824

Genus NUCULA Lamarck, 1799

Subgenus NUCULA Lamarck, 1799

Nucula Lamarck, 1799, p. 87.

Type species.-(by monotypy) Arca nucleus Linnè, 1758.

Biogeographic element.-Cosmopolitan (Kauffman, 1973, p. 358).

Discussion.-Warren and Speden (1978, p. 22, Tab. 2) reported the presence of Nucula at only one locality (S56/f32 = O32/f8032) in the Upper Cretaceous (Haumurian Stage) Conway Siltstone at Haumuri Bluff, South Island, and it is not known whether this species can truly be assigned to Nucula s. s. as the species was not figured. A search for specimens representing this species by myself and I. W. Keyes in the macrofossil collections housed at the Institute of Geological and Nuclear Sciences (Lower Hutt) was unsuccessful. To date only Leionucula Quenstedt has been recorded from South Island (this work). Evans (1985, p. 618, Tab. 1) reported the presence of Nucula from Northland, but study of his material housed at Auckland University Geology Department indicates that the predominant nuculid bivalve in his collection is a species of Leionucula and was misidentified as a species of Nucula. The oldest known record of the Nucula group in the New Zealand Cretaceous is an undescribed species of Nucula reported by Wellman in Challis (1966, p. 134) in Motuan (mid Cretaceous) rocks southwest of Mount Lookout, Awatere Valley. Nucula Lamarck is poorly represented in Upper Cretaceous rocks around the southern circum-Pacific margin.

NUCULA s. l. TEOPUENSIS n. sp.

Plate 1 Figures 3, 5, 7, 9-11

Diagnosis.-Elongate, subtrigonal shell; umbones located a third of shell length from posterior margin; posterodorsal margin quite steep, short, gently convex; posterior margin angulate; anterodorsal margin gently sloping, moderately long, slightly convex; commarginal sculpture more pronounced than radial of closely spaced, bifurcating ribs; sculpture cancellate on posterior and anterior thirds of shell; ventral margin finely crenulate; differs from Nucula amica Gardner, 1916, in having bifurcating ribs and steeper anterior margin.

Description.-Shell moderately large, approximately 0.6 mm thick, elongate subtrigonal, bluntly rostrate posteriorly; equivalve; umbones small, located about a third of length of shell from the posterior margin; anterodorsal margin moderately long, gently sloping, slightly convex to nearly straight, becoming broadly rounded at anterior margin; posterodorsal margin very steep, short, slightly convex, becoming sharply angulate at posterior margin; ventral margin broadly rounded anteriorly, becoming straight posteriorly; lunule narrow, moderately long, bordered by marked ridge; escutcheon very open, wide, marked by strong umbonal ridge which fades moderately towards angulate posterior margin; commarginal sculpture of more than 60, closely spaced, pronounced, discordant, bifurcating ribs that become more closely spaced and subdued towards umbones; sculpture more cancellate on anterior and posterior third of shell; commarginal sculpture stronger than radial sculpture; radial ribs mostly weak, stronger anteriorly and posteriorly; posterior adductor scar elongate, subelliptical; ventral?-median muscle scar circular; ventral margin finely crenulate within.

Dimensions.-Holotype Ge 6380 (AIM), length 11.5 mm, height 8.5 mm, width of paired valves 6.5 mm; paratype Ge 6379 (AIM), length 11.0 mm, height 8.5 mm, width of paired valves 5.5 mm (mostly complete).

Types.-Holotype Ge 6380 (AIM); paratype Ge 6379 (AIM).

Figured specimens.-Ge 6380, Ge 6379 (both AIM).

Type locality.-north side of promontory between Te Opu and Whakapirau creeks, Kaipara, Northland, Q08/f9639.

Material.-Two calcified, articulated, mostly complete specimens. An articulated juvenile, L 3863 from AU 2553, may represent this species.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from Kaipara, Northland.

Discussion.-Nucula s. l. teopuensis n. sp. is quite distinct from and apparently not closely related to Linucula bullensis n. sp., also from Upper Cretaceous marine rocks of New Zealand. Nucula s. l. teopuensis n. sp., which is only known from one locality in Kaipara, Northland, has a elongate-subtrigonal outline and sculpture of pronounced commarginal ribs and more subdued radial ribs that becomes sharply cancellate on the posterior and anterior third of the shell. The Maastrichtian nuculid Nucula amica Gardner, 1916, (recently refigured by Wingard and Sohl, 1989, Plate 5, Figures 4 and 7) from the Monmouth Formation of Maryland is remarkably similar to N. s. l. teopuensis n. sp. in external morphology, but the latter New Zealand species has bifurcating commarginal ribs and a slightly steeper anterior margin. As a side note, Wingard and Sohl (1989) used confusingly the term "collabral ribs" to describe the umbonal sculpture morphology of Nucula amica which can be more simply defined by the descriptive use of "commarginal"; the term "collabral" is normally restricted to gastropod outer lip morphology (Arnold, 1965; cf. Beu and Maxwell, 1990). The bifurcated sculpture only of N. teopuensis n. sp. is reminiscent of a Maastrichtian corbulid bivalve, Corbula chilensis (d'Orbigny, 1847) (see Stinnesbeck, 1986, pp. 183-184, Pl. 5, Fig. 5a).

Because Nucula s. l. teopuensis n. sp. has relatively pronounced commarginal sculpture, it is not placed in Nucula s. s. An appropriate position for this species is uncertain and may well represent a new group.

Etymology.-Species named after Te Opu Creek, near the type locality.

NUCULA s. l. KAIPARAENSIS n. sp.

Plate 1 Figures 8, 15-16

Diagnosis.-Shell small, ovately subtrigonal to subquadrate, well-inflated; umbones prominent, located at posterior third of length of shell; posterodorsal margin moderately sloping converging to a narrowly rounded posterior margin; anterodorsal margin moderately long, gently convex; anterior margin obliquely truncated; sculpture predominently of raised, closely spaced commarginal ribs, and secondarily of sparse, bifurcating ribs; umbonal ridge prominent, wide, intersecting anteroventral margin; similar to species of Leionucula but with marginal crenulations.

Description.-Shell moderately small, subtrigonally to subquadrately ovate, well-inflated, obliquely truncated anteriorly; equivalve; umbones prominent, located about a third of length of shell from posterior margin; anterodorsal margin moderately short, straight, converging to a narrowly rounded posterior margin; posterodorsal margin moderately long, slightly convex, converging to an obliquely truncated, steep anterior margin; ventral margin gently rounded; lunule and escutcheon poorly developed; umbonal ridge marked, wide, intersecting anteroventral margin; commarginal sculpture of numerous, closely spaced ribs, differentially bifurcating on umbonal flank; ventral margin finely denticulate (poorly preserved in available material).

Dimensions.-Holotype Ge 7674.1 (AIM), length 5.0 mm, height 4.0 mm, width of paired valves 3.0 mm; paratype Ge 7674.2 (AIM), length 5.0 mm, width 4.0 mm, width of paired valves 3.0 mm.

Types.-Holotype Ge 7674.1 (AIM); paratype Ge 7674.2 (AIM).

Figured specimen.-Ge 7674.1 (AIM).

Type locality.-Te Opu, Kaipara, Northland, Q08/f9639.

Material.-Two well-preserved, articulated specimens.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from Te Opu, Kaipara, Northland.

Discussion.-Nucula s. l. kaiparaensis n. sp. can be separated from Linucula bullensis n. sp., N. s. l. teopuensis n. sp., and N. s. l. manuensis n. sp. in having an obliquely truncated anterior margin and numerous, closely spaced commarginal ribs without radial sculpture. The presence of marginal crenulations excludes N. s. l. kaiparensis n. sp. from placement within Leionucula Quenstedt; otherwise, N. s. l. kaiparensis n. sp.

approaches New Zealand latest Cretaceous to Tertiary Leionucula species in general outline.

NUCULA s. l. MANUENSIS n. sp.

Plate 1 Figures 6, 12-14

Diagnosis.-Moderately large, thin, narrowly subtrigonal shell; anterodorsal and posterodorsal margins steep; sculpture of fine commarginal threads and moderately weak, fine, radial threads; hinge plate narrow with moderately blunt, peg-like? teeth; distinguished from Nucula severnensis Wingard and Sohl, 1989, in being more narrowly subtrigonal with more projecting umbones.

Description.-Shell moderately large, thin, moderately to well-inflated, narrowly subtrigonal shell with height to length ratio greater than one; umbones very prominent, projecting, strongly opisthogyrate; escutcheon well-developed, bordered by strongly arcuate umbonal ridge; lunule long, moderately wide; posterodorsal margin moderately long, straight, strongly declivous, merging towards moderately narrow, rounded posterior margin; anterodorsal margin long, gently convex, very steep at same angle as posterodorsal margin, merging towards more broadly rounded anterior margin; ventral margin broadly rounded; shell mostly smooth except for fine, commarginal growth increments and poorly developed radial sculpture; hinge plate narrow with numerous, moderately blunt, peg-like? teeth that increase in size from beak.

Dimensions.-Holotype TM 7464 (IGNS) length 9.5 mm, height 10.5 mm, width of single valve 4.0 mm; paratype TM 7466 (IGNS) length 12.0 mm, height 11.0 mm, width of single valve 5.0 mm; paratype

TM 7465 (IGNS) length 10.5 mm, height 11.0 mm.

Types.-Holotype TM 7464 (IGNS); paratypes TM 7465 (IGNS), TM 7466 (IGNS).

Figured specimens.-TM 7464, TM 7465, TM 7466 (all IGNS).

Type locality.-Clarke Creek, Taurangakautuku River, Manu Creek S. D., North Island, Z14/f8492.

Material.-Six, calcified specimens, some incomplete.

Stratigraphic range.-Formation unknown, but believed to be Piripauan or Haumurian in age (upper Campanian or Maastrichtian, Upper Cretaceous).

Geographic distribution.-Known from a small area in Clarke Creek, North Island.

Discussion.-*Nucula* s. l. *manuensis* n. sp. is proposed for a nuculid species with a moderately large, narrowly subtrigonal shell with a height to length ratio of slightly greater than one and very steep anterodorsal and posterodorsal margins. *Nucula* s. l. *manuensis* n. sp. is not closely related to *Linucula bullensis* n. sp., *N*. s. l. *teopuensis* n. sp. or *N*. s. l. *kaiparensis* n. sp., all from the Late Cretaceous of New Zealand. In general outline, dentition and sculpture, *N*. s. l. *manuensis* n. sp. approaches *N*. *severnensis* Wingard and Sohl, 1989 (pp. D16-D17, Pl. 3, Figs. 11-19, Pl. 5, Figs. 2, 11, Pl. 6, Fig. 3, Pl. 7, Fig. 3), from the middle to upper Maastrichtian of Alabama, Georgia and Maryland, but the New Zealand species is more narrowly subtrigonal with more distinct, projecting umbones. The description of *N*. s. l. *manuensis* n. sp. partially matches the generic diagnosis of the Early Eocene Asian genus *Gibbonucula* Eames, 1951, but the New Zealand species does not have coarse commarginal sculpture and a crenulated ventral margin like *Gibbonucula*. The genus-level assignment of *N*. s. l. *manuensis* n. sp. is uncertain.

Etymology.-Species named for its type locality near Manu Creek.

Genus *LINUCULA* Marwick, 1931

Linucula Marwick, 1931, p. 49

Type species.-(by original designation) *Nucula ruatakiensis* Marwick, 1926c.

Biogeographic element.-Paleoaustral as interpreted herein.

Discussion.-The geologic range of *Linucula* Marwick, 1931, is greatly extended herein to the latest Cretaceous of New Zealand. *Linucula bullensis* n. sp. described below represents the oldest recorded member of the genus. A Paleocene species, *L. austrobullata* n. sp., is described in this work in the section on Paleocene New Zealand bivalves. See this discussion for further comments on *Linucula*. Beu and Maxwell (1990, p. 33, Fig. 6a) reported the first appearance of *Linucula* to be the Late Oligocene (Duntroonian).

LINUCULA BULLENSIS n. sp.

Plate 1 Figures 1-2, 4

Diagnosis.-Shell moderately small, subtrigonal; anterodorsal margin short, steep, straight; posterodorsal margin sleeply sloping, moderately long, gently convex; sculpture of prominent commarginal ribs and weak, more closely spaced radial threads; growth pauses more pronounced towards ventral margin; differs from *L. ruatakiensis* (Marwick, 1931) and *Nucula severnensis* Wingard and Sohl, 1989, in being smaller, more ovate and having more pronounced commarginal ribs.

Description.-Shell moderately small, moderately thick, subtrigonal; umbones small, located about one third the length of shell from posterior margin; posterodorsal margin short, steeply sloping, straight, merging to a broadly rounded posterior margin; anterodorsal margin steeply sloping, long, broadly convex, merging to a narrowly rounded anterior margin; ventral margin well rounded; lunule relatively long, narrow, bordered by moderately strong umbonal ridge; escutcheon small, open, not well defined; sculpture of approximately 35 strong, commarginal ribs and numerous, closely spaced radial threads; growth pauses more distinct towards ventral margin; dorsal margins apparently crenulated (poorly preserved on paratype); ventral margin crenulated.

Dimension.-Holotype, Ge 7924 (AIM) length 4.0 mm, height 3.5 mm, width of paired valves 2.5 mm; paratype, Ge 5972 (AIM) length, 4.0 mm, height 4.0 mm, width of paired valves 2.5 mm.

Types.-Holotype, Ge 7924 (AIM); paratype, Ge 5972 (AIM).

Figured specimen.-Ge 7924 (AIM).

Material.-Two specimens, one well-preserved. A possible third specimen is poorly preserved.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626 [N28/f626] (type); south side of Whakapirau Creek 2.5 km east of Rout Point, Kaipara, Northland, Q08/f9637; (?) northeast shore of Kawitu Estuary, Hokianga, Northland, O05/f9596.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Restricted to Kaipara and Hokianga?, Northland.

Discussion.-*Linucula bullensis* n. sp. can be separated from *N*. s. l. *teopuensis* n. sp. in having a much smaller, subtrigonal shell with steeper anterodorsal and posterodorsal margins. *Linucula bullensis* n. sp. also lacks the distinctive commarginal sculpture of divaricating ribs that is pronounced in *N*. s. l. *teopuensis* n. sp. In outline *L*. *bullensis* n. sp. approaches the Maastrichtian nuculid *N*. *severnensis* Wingard and Sohl, 1989 (pp. D16-D17, Pl. 3, Figs. 11-19; Pl. 5, Figs. 2, 11; Pl. 6, Fig. 3; Pl. 7, Fig. 3), from the Severn Formation of Maryland, but the New Zealand species is slightly more ovate, somewhat smaller, and has more pronounced commarginal ribs.

The presence of dorsal crenulations (albeit poorly preserved in the paratype) indicates a close relationship to *Linucula* Marwick, 1931. The type species, *L*. *ruatakiensis* Marwick, 1926c (p. 327, Pl. 75, Figs. 7, 9; Fleming, 1966, p. 102, Pl. 2, Figs. 34-35) from the Tongaporutuan to Waipipian? Stages (Upper Miocene to Upper Pliocene?) of New Zealand is differentiated from *L*. *bullensis* n. sp. is being much less ovate with weaker commarginal sculpture. The Paleocene species *L*. *austrobullata* n. sp. is remarkably similar to *L*. *bullensis* n. sp., but the latter Cretaceous species has coarser commarginal sculpture. These two taxa probably represent a lineage.

Etymology.-Species named after type locality, Bull Point, Kaipara.

Subfamily NUCULOMINAE Maxwell, 1988a

Discussion.-Maxwell (1988a, p. 87) in his review of the Nuculidae proposed the subfamily Nuculominae for those nuculids without radial structural elements. The Nuculominae include Leionucula (= ?Ennucula), Brevinucula, Austronucula, and Condylonucula. The present newly described species from the New Zealand Paleocene, Leionucula palaioanaxea Stilwell, 1993, has radial elements as does the Austral species L. suboblonga Wilckens, 1905, discussed below from the Late Cretaceous, but these are probably not structural and represent very weak surface striae similar to an Early Miocene species of Brevinucula discussed by Maxwell (1988b, p. 89). Nuculinae have radial structural elements. Maxwell's scheme is followed herein.

Genus LEIONUCULA Quenstedt, 1930

Leionucula Quenstedt, 1930, p. 110, 112.

Type species.-(by original designation) Nucula albensis d'Orbigny, 1844.

Synonyms.-?Ennucula Iredale, 1931; Lissanucula Woodring, 1973.

Biogeographic element.-Cosmopolitan (Kauffman, 1973, p. 358).

Discussion.-Stilwell (1993) recognized the need for a critical review of Leionucula Quenstedt and Ennucula Iredale as the taxonomy of these two groups has been in a state of flux for over 60 years. The confusion has arisen, in part, because the hinge of the type species of Leionucula, L. albensis, has never been figured (see d'Orbigny, 1844, Pl. 301, Figs. 15-17, for external views; also Woods, 1899, pp. 24-25, Pl. 4, Figs. 9-16, 17?; Schenck, 1934, pp. 33-35, Pl. 3, Figs. 5, 5a-b). D'Orbigny (1844, Pl. 301) inadvertently kept Fig. 15 as a mirror inverse; the figure is of a left valve, not a right valve (J. D. S., pers.

obs.). The holotype of the type species is articulated so that the hinge cannot be studied. A specimen with a hinge was mentioned by Schenck (1934, footnote p. 34), but after several attempts at finding this specimen it has not been located in any museum. Although features of the hinge given by Schenck are not detailed, sufficient information is known to question the distinctiveness of Ennucula, which is most likely a synonym. See Stilwell (1993) for an extensive review of Leionucula and Ennucula. This is the first report of Leionucula from the New Zealand Late Cretaceous. Earlier, Speden (1975, p. 47, Tab. 6) recorded Leionucula sp. from the Korangan to Urutawan Stages (Lower Cretaceous) of Waimana Valley and Waiotahi Valley, Raukumara Peninsula, North Island, but this identification is not confirmed here. Speden's specimens of Leionucula sp., housed at the Institute of Geological and Nuclear Sciences, are too poorly preserved for accurate assessment.

LEIONUCULA SUBOBLONGA (Wilckens, 1905)

Plate 2 Figures 1-13

Nucula suboblonga Wilckens, 1905, pp. 33-34, not figured (not p. 53. See Zinsmeister and Macellari, 1988, error); 1910, pp. 22-24, Pl. 2, Figs. 1a, b, 2; Medina et al., 1981, p. 170.

Nuculoma (Palaeonucula) poyaensis Freneix, 1956, pp. 157-158, Pl. 1, Figs. 1a, b.

Leionucula poyaensis (Freneix, 1956). Freneix, 1980, pp. 75-77, Pl. 1, Figs. 1-4.

Nucula (Leionucula) suboblonga (Wilckens), Zinsmeister and Macellari, 1988, p. 256, Fig. 3.1-5.

?Nucula (Leionucula) cf. N. (L.) suboblonga (Wilckens), Griffin, 1991, pp. 121-122, Fig. 2.1-3.

Leionucula cf. L. suboblonga (Wilckens), Stilwell in Aitchison et al., 1993, Figure 5a.

Supplementary description.-Shell moderate to large for the family, thick, well inflated; obliquely subovate to subtrigonal; umbones small, located a quarter of the length of the shell from the posterior margin; anterodorsal margin long, slightly convex; posterodorsal margin short, steep, nearly straight; anterior margin moderately rounded; posterior margin more sharply rounded than posterior; ventral margin broadly rounded, smooth; surface of shell smooth except for numerous, narrow, unequally spaced, commarginal growth pauses, more closely spaced at ventral margin, and numerous, closely spaced radial striae; radial sculpture weaker than commarginal sculpture; lunule elongate, narrow, bounded by sharp ridge; escutcheon open, broadly rounded, bounded by strongly convex umbonal ridge; rostral sinus poorly to moderately developed on some specimens; resilifer oblique; hinge plate relatively narrow; anterior half of hinge with at least eleven subchevron-shaped, well developed teeth; posterior half of hinge with at least eight subchevron-shaped, well developed teeth; posterior adductor scar suboval; inner margin smooth; pallial line integripalliate.

Dimensions.-OU 40972 length of hinge 19.0 mm; OU 40973 length 24.0 mm; OU 40974 (from OU 11132), length 31.0 mm nearly complete, height 20.0 mm, width of paired valves 17.5 mm; OU 40656 (OU), length 39.0 mm, height 29.0 mm, width of paired valves mostly complete, 19.5 mm; L 3864 (from AU 8763), length

38.0 mm, height 29.5 mm, width of paired valves, 22.0 mm; L 3865 (from AU 2553), length 35.0 mm, height 26.0 mm, width of single right valve 11.5 mm; Ge 7686.2 (AIM) length 28.0 mm; Ge 7686.4 (AIM) length 23.0 mm; Ge 7705 (AIM), length 45.5 mm, height 36.5 mm, width of left valve 14.0 mm; Ge 7690.1 (AIM), length 11.5 mm, height 8.0 mm, width of paired valves 5.5 mm; Ge 7690.2 (AIM), length 17.0 mm, height 12.5 mm, width of paired valves, 8.0 mm; Ge 7722 (AIM), length 13.0 mm, height 9.5 mm, width of paired valves 6.5 mm.

Types.-Lectotype, MO 1424a (See Zinsmeister and Macellari, 1988); hypotypes, USNM 404809; USNM 404810; USNM 404811; USNM 404812; USNM 404813.

Type locality.-Swedish South Polar Expedition locality 9, Seymour Island, Antarctic Peninsula.

Figured specimens herein.-OU 40972-40974, OU 40656, L 3864-3865 (AU); Ge 7705, Ge 7722, Ge 7690.1-2, Ge 7686.2, Ge 7686.4 (all AIM).

Material.-72 specimens, most of which are articulated and well-preserved.

Localities.-Shag Point, South Island, J43/f159A, J43/152A, ?J43/f6472, ?J43/f6494; Waianakarua River, South Island, J42/f178 and J42/f218; north side of promontory between Te Opu and Whakapirau creeks, Kaipara, Northland, Q08/f9639; Shore of Otamatea River arm approximately 0.75 km NE of Batley, Northland, Q08/f9636; Bull Point, Kaipara, Northland, Q08/f9626 [N28/f626] and Q08/f143; Taipa Estuary, Mongonui, O04/f131; Hukatere Peninsula south of Puriori Point, Q08/f9660 [N28/f660]; Te Opu, Kaipara Harbour, Northland, Q08/f9639 [N28/f639]; W coast of Rawene Peninsula, Northland, P04/8596.

Stratigraphic range.-Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous) and an unspecified horizon with Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Southern Patagonia, Antarctic Peninsula, New Caledonia, Northland and South Island, New Zealand.

Discussion.-Wilckens (1905, pp. 33-34) first described *Leionucula suboblonga* from Cerro Cazador, southern Patagonia, but did not figure his newly described species. In 1910, Wilckens (pp. 22-23, Pl. 2, Figs. 1a-1b, 2) reported the presence of this species on Seymour Island, Antarctic Peninsula, and figured for the first time specimens of *Leionucula suboblonga*, which were better preserved than the holotype. Zinsmeister and Macellari (1988, p. 256) in a review of *Leionucula suboblonga* designated a specimen (MO 1424a), collected on the Swedish South Polar Expedition of 1901-1903, as the lectotype because the holotype is presumed lost. Zinsmeister and Macellari (1988, p. 256) also synonymised a Late Cretaceous (early Campanian) species from New Caledonia (*Leionucula poyaensis* Freneix, 1956) with *L. suboblonga* because the measurements of the two species were found to be identical. Freneix (1981) gave a detailed study of the paleobiogeographic, biostratigraphic and paleoecologic implications of the early Campanian bivalve fauna, including *Leionucula*, of New Caledonia. The New Zealand specimens of *L. suboblonga* are typically slightly more elongate anteriorly than the Antarctic specimens, but I cannot separate them on morphological grounds. I believe that this slight difference in profile probably reflects intraspecific and not interspecific variation. Although generally a conservative group, nuculid bivalves do exhibit minimal intraspecific variation in morphology.

Although the specimens collected from Shag Point are not particularly well preserved, the material available suggests to me that the species from Fairfield Quarry, Shag Point and Waianakarua River are conspecific with and can be assigned to L. suboblonga, although with some reservation until better material is collected. Locality J42/f218 along the North Branch of the Waianakarua River in South Island, discovered in early 1992 by the author and J. D. Campbell, has the only known calcified specimens of L. suboblonga from South Island. Remarkably well-preserved specimens of L. suboblonga have been collected from numerous localities in Northland; these specimens reveal microsculpture in exquisite detail and are among some of the best preserved fossils from the New Zealand Cretaceous. It should be noted that Wilckens (1910, Pl. 2, Figures 1a, 1b, 2) failed to figure this species accurately as details of the prominent, radial microsculpture are not present in his drawings, except for a presumed, unfigured enlargement of Fig. 1a below Fig. 1b.

This first report of Leionucula suboblonga in the South Island and Northland, New Zealand, bridges a gap in the previously reported geographic occurrences of the species along the Austral Weddellian Biotic Province. The discovery of this species in New Zealand suggests that it ranged from the extreme eastern sector of Gondwana including New Caledonia by as early as early Campanian time to the western sector of Gondwana across Antarctica and southern South America by the Maastrichtian. Leionucula suboblonga represents one of few species-level taxa that was geographically widespread across the Weddellian Province, as species level endemism was apparently already high during the latest Cretaceous in the high southern latitudes.

Superfamily NUCULANACEA H. and A. Adams, 1858

Family NUCULANIDAE H. and A. Adams, 1858

Subfamily NUCULANINAE H. and A. Adams, 1858

Genus NUCULANA Link, 1807

Nuculana Link, 1807, p. 155.

Type species.-(by original designation) Arca rostrata Chemnitz, 1774 (= Arca pernula Müller, 1771).

Synonyms.-Eptoleda Iredale, 1939; Exocholeda Iredale, 1939; Kamaleda Iredale, 1939; Leda Iredale, 1939; Ledaspina Marwick, 1931 (recently synonymised with Yoliella by Maxwell, 1998a); Monopleura Philippi, 1887; Perrisonota Conrad, 1869; Zygonoleda Iredale, 1939 (Puri in Moore, 1969, p. N235).

Biogeographic element.-Cosmopolitan (Puri in Moore, 1969, p. N235).

Discussion.-Marwick (1953, p. 88) reported the oldest known New Zealand occurence of Nuculana Link, which is Early Jurassic. The genus was first reported in the New Zealand Cretaceous by Woods (1917), who described Nuculana amuriensis from marine sediments of Haumuri Bluff, South Island. Maxwell (1988b, p. 38) was unsure of the generic assignment of N. amuriensis. A second nuculanid species, Nuculana sp., was left in open nomenclature by Woods (1917, p. 18) due to poor preservation.

Cenozoic New Zealand nuculanid taxa previously allocated to Nuculana have been reassigned over the years to various genera other than Nuculana suggesting that, if indeed Nuculana is not represented in the Cenozoic, the genus disappeared from the New Zealand area by the latest Cretaceous. Elsewhere, the genus is known from Triassic rocks to Recent and is considered to be cosmopolitan (Puri in Moore, 1969, p. N235); Puri's interpretation of Nuculana is considered to be extremely broad (P. A. Maxwell, pers. commun. 1993). Around the southern rim of the southern circum-Pacific during the Late Cretaceous, Nuculanidae are not well-represented. No nuculanids are known from the Late Cretaceous of Australia or Antarctica. The absence of Nuculanidae from the mid shelf faunas of the Lopez de Bertodano Formation of the Antarctic Peninsula is surprising as similar mid shelf facies are present in New Zealand that have abundant nuculanids. Stinnesbeck (1986) reported three new nuculanid taxa, Nuculana amuriensis rostrata, Nuculana cuneiformis, and Yoldia levitesta from the Quiriquina Formation of the Maastrichtian of central Chile, but no nuculanids have been recorded from the Late Cretaceous of Patagonia. Nuculana cuneiformis may actually be more closely related to Saccella. No Late Cretaceous nuculanids have been described, in addition, from New Caledonia.

Puri in Moore (1969, p. N235) listed Spineilo Finlay and Marwick, 1937, as a synonym of Nuculana. Spineilo, a malletiid bivalve unrelated to Nuculana, is most emphatically not a synonym of Nuculana and Puri's synonymy is surprising. Nuculana is characterised by an elongate, rostrate shell that is truncated posteriorly. Nuculana also typically has strong, commarginal sculpture. Maxwell (1988a, p. 91) disagreed with Allen and Hannah's (1986) interpretation of Nuculana which he considered to be unjustifiably "very broad". Extinct and extant nuculanas are interpreted to have been fairly mobile, siphonate detritivores (McKerrow (ed.), 1978, pp. 211, 235).

Nuculanid bivalves are known from numerous localities in New Zealand and at many localities these bivalves are not well-preserved. Latest Cretaceous localities with poorly preserved nuculanid specimens or those with uncertain affinities include (see Appendix A for locality details): H46/f9510, I44/f8489, I44/f8516, ?K35/f7509, M34/f7254, O05/f9524, O32/f9032, O32/f9542, O33/f9044, P05/f9502, S28/f114, T27/f6729, U26/f6496, V19/f184, X16/9206, X16/f9534, X17/7674, Z14/f8492, I44/f8510, ?I44/f8512, J43/f115, L35/f6511, O32/f8849, P05/f9499, Q08/f9023, Q09/f9502, Q09/f9503, V19/f6507, ?O32/f9030, P05/f9491, and P05/9539.

NUCULANA AUSTRODISCORDIA n. sp.

Plate 3 Figures 1-2, 5

Diagnosis.-Narrow, elongate shell with moderately developed rostrum; umbonal ridge well-developed; commarginal sculpture of marked, discordant, spaced ribs, more discordant on anterior and posterior thirds of shell.

Description.-Shell of average size for genus, thin, elongate, narrow, subtrigonal, rostrate; rostrum moderately developed, posterior truncation short, narrow, blunt, slightly rounded; umbones small, more anterior; umbonal ridge well-developed; anterodorsal margin moderately short, gently declivous, merging towards moderately rounded, convex anterior margin; posterodorsal margin long, slightly sloping, gently concave from umbo to point midway along posterodorsal margin, becoming slightly convex on posterior half, merging to narrow, acutely rounded posterior margin; ventral margin broadly rounded, convex; lunule poorly developed; escutcheon well-developed, long, narrow, bordered by strong, concave, umbonal ridge; sculpture variable of microscopic commarginal striae from umbo to midway on flank, becoming stronger ventrally of spaced, discordant, ribs, more discordant on posterior and anterior thirds of shell, and becoming slightly bevelled posteriorly; some specimens with nearly straight, horizontal commarginal ribs medially and with ribs that disappear anteriorly and posteriorly and do not bifurcate.

Dimensions.-Holotype Ge 7921 (AIM), length 13.5 mm, height 5.5 mm; paratype Ge 5978 (AIM), length 9.0 mm incomplete, height 5.5 mm; paratype Ge 7918 (AIM), length 9.0 mm, height 5.0 mm; paratype Ge 5976 (AIM), length 12.0 mm, height 5.5 mm, width of paired valves 4.0 mm.

Types.-Holotype Ge 7921 (AIM); paratypes Ge 5978 (AIM), Ge 7918 (AIM), Ge 5976 (AIM).

Figured specimens herein.-Ge 7921, Ge 7918 (AIM), Ge 5978 (all AIM).

Material.-22 calcified, mostly disarticulated specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626 [N26/f626] (type) and Q08/f9909; south side of Whakapirau Creek, 2.5 km east of Rout Point, Kaipara, Northland, Q08/f9637; Te Opu, Kaipara, Northland, Q08/f9639; promontory between Te Opu and Whakapirau Creeks, Kaipara, Northland, Q08/f9639 (same fossil record number as previous locality).

Stratigraphic range.-Unspecified horizon with Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from several localities in Kaipara, Northland.

Discussion.-Significant sculptural differences separate New Zealand Cretaceous *Nuculana* species. As the species name suggests, *Nuculana austrodiscordia* n. sp. has pronounced, discordant, commarginal sculpture of bifurcating and "incomplete", primary riblets. The term "incomplete" is used here loosely for those commarginal riblets that suddenly disappear on the flanks and do not bifurcate. Preservation of specimens of *N. austrodiscordia* n. sp. is such that commarginal microsculpture is revealed in exquisite detail. One large specimen of *N. austrodiscordia* n. sp., Ge 5976 (AIM), is 12.0 mm in length. In overall external morphology excluding details of sculpture, *N. austrodiscordia* n. sp. is comparable to the type species of *Nuculana*, *N. pernula* (Müller, 1771) (more recently figured by Puri *in* Moore, p. N236, Fig. A6-8a-8c) in from the Recent of Europe, but the former Cretaceous species has the prominent, discordant sculpture that is wanting in the Recent European species *N. pernula*. It is quite possible that the discordant sculpture of *N. austrodiscordia* n. sp. served some functional significance as perhaps an aid in burrowing.

Etymology.-Species named from variation of "australis" (= southern) and the Latin "discordia" (= discord) for its pronounced discordant sculpture.

NUCULANA ANTICHTHONA n. sp.

Plate 3 Figures 3-4, 6-9

Diagnosis.-Moderately elongate, subovate shell with moderately developed rostrum; shell moderately inflated; anterodorsal portion of hinge with approximately 11 teeth; commarginal sculpture mostly smooth of weak, microscopic threads; lacks the discordant, commarginal sculpture pronounced in *N. austrodiscordia* n. sp.

Description.-Shell moderately elongate, subovate, moderately inflated with moderately developed rostrum; umbones small, subcentral, weakly opisthogyrate; lunule not well-developed; escutcheon long, narrow, bordered by sharp ridge; anterodorsal margin short, gently to moderately sloping, convex, merging towards well-rounded, convex anterior margin; posterodorsal margin long, nearly straight to very slightly concave, subhorizontal, merging towards moderately narrowly rounded, convex, bluntly truncated, posterior margin; ventral margin moderately to broadly rounded; umbonal sculpture of microscopic, commarginal threads; sculpture nearly obsolete, mainly smooth, of faint, commarginal threads that become slightly stronger ventrally; anterior adductor scar elongate, subcrescent-shaped; pallial sinus moderately? deep.

Dimensions.-Holotype Ge 6386.1 (AIM), length 8.5 mm, height 5.0

mm, width of paired valves 3.5 mm; paratype Ge 6386.2 (AIM), length 7.0 mm, height 4.0 mm, width of paired valves 3.0 mm; paratype Ge 7718 (AIM), length 12.0 mm, height 7.5 mm, width of paired valves 5.5 mm; Ge 7608 (AIM), length 8.5 mm, height 4.5 mm; paratype Ge 6395.1 (AIM), length 7.5 mm, height 4.5 mm, width of paired valves 3.0 mm.

Types.-Holotype Ge 6386.1 (AIM), paratypes Ge 6386.2 (AIM), Ge 7718 (AIM), Ge 7608 (AIM), Ge 6395.1 (AIM).

Figured specimens herein.-Ge 6386.1 (AIM), Ge 6395.1 (AIM).

Material.-26 specimens.

Localities.-Promontory between Te Opu and Whakapirau Creeks, Kaipara, Northland, Q08/f9639 (type); south side of Whakapirau Creek, 2.5 km east of Rout Point, Kaipara, Northland; Whakapirau Creek, Kaipara, Northland, Q08/f9637 [N28/f637]; concretion on shore, NW side of Bull Point, Kaipara, Northland, Q08/f9626 [N28/806390]; shore of Otomatea Arm, 0.8 km NE of Batley, Kaipara, Northland Q08/f9636 [N28/848374]; Bull Point (also NW shore), Kaipara, Northland, Q08/f9626 [N28/f626].

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Several localities within the Kaipara area, Northland.

Discussion.-*Nuculana antichthona* n. sp. is differentiated from *N. austrodiscordia* n. sp. by having a less narrow and elongate, more inflated shell that is mostly smooth except for near-microscopic commarginal threads, unlike *N. austrodiscordia* which has a more elongate, compressed shell with prominent, discordant sculpture. Nuculana antichthona n. sp. is quite similar to the type species of Nuculana, N. pernula (Müller, 1771) (more recently figured by Puri in Moore, 1969, p. N236, Fig. A6-8a-8c) from the Recent of Europe, but is distinguished by differences in sculptural features and rostrum. Stinnesbeck (1986, p. 163-164, Pl. 1, Figs. 4-6) erected a new nuculanid subspecies from the Maastrichtian Quiriquina Formation of central Chile, Nuculana amuriensis rostrata, for a form closely related to Nuculana amuriensis Woods, 1917, that appears to have an affinity to N. antichthona n. sp., but the Chilean species has a more rostrate, commarginally sculptured shell with more prominent umbones.

Etymology.-Species named from the Greek "antichthonos" (= southern hemisphere).

NUCULANA? AMURIENSIS Woods, 1917

Plate 3 Figures 10-11

Nuculana amuriensis Woods, 1917, p. 18, Pl. 6, Fig. 1; Warren and Speden, 1978, Fig. 28-8.

Nuculana (Jupiteria) amuriensis Woods, Fleming in Wellman, 1959, p. 141.

Jupiteria amuriensis (Woods), Crampton and Moore, 1990, Appendix 1, p. 346.

Dimensions.-Lectotype TM 2465 length 10.5 mm, height 6.5 mm.

Types.-Lectotype TM 2465 (IGNS; Woods, 1917, Pl. 6, Fig. 1; Warren and Speden, 1978, Fig. 26-8).

Figured specimens.-Lectotype TM 2465 (IGNS); OU 40986 probably represents this species.

Material.-Lectotype and many possible, poorly preserved specimens from Waianakarua River.

Localities.-East wing, Haumuri Bluff, southern Marlborough, South Island, O32/f9032, [S56/f28], O32/f9027; north face, Haumuri Bluff, O32/f9529; west wing, Haumuri Bluff, O32/f8025; Okarahia Stream, southern Marlborough, South Island, O32/f8790; near bend of "Matsumoto" Stream (tributary of Okarahia Stream), southern Marlborough, South Island, O32/f8787; Haumuri Bluff, O32/f9504, O32/f9028 (type); tributary of Mikonui Stream, southern Marlborough, South Island, O32/f8788; just south of Mikonui Stream, O32/f8774A; ?just NNW of junction of Taieri Beach and Taieri Mouth roads, South Island, I45/f8517; Birch Hollow, Mid Waipara, southern Canterbury, South Island, M34/f1; ?Ocean View, Dunedin, I44/f8517 [S163/f517]; ?North Branch of Waianakarua River, J42/f218; ?Fairfield Quarry, Otago, South Island, I44/f8512; Mangahouanga Stream, western Hawke's Bay, float *3 of Crampton and Moore, 1990, p. 346, V19/f6909.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Tarapuhi Grit? (lower Haumurian Stage, Maastrichtian, uppermost Cretaceous); Saurian Sands, Conway Siltstone, Saddle Hill Formation, Fairfield Greensand Member of Brighton Formation?, Katiki Formation, Maungataniwha Sandstone (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic Distribution.-East coast of North Island and middle eastern to southeastern coast of South Island.

Discussion.-The exact generic placement of this small nuculanid species is problematic based on present available material which, for the most part, is generally poorly preserved. Specimens of

N.? amuriensis consistently have features somewhat intermediate between assigned species of Nuculana and Jupiteria, thus this species is a prime example of the problems associated with poorly known Nuculanidae taxonomy. Woods (1917, p. 18) compared Nuculana? amuriensis with Cretaceous taxa of Egypt, Tunis and England, but never compared the species with the type, N.pernula (Müller, 1771) from the Recent of Norway?, of which it seems not closely related except for similarities in overall shape and commarginal sculpture. Nuculana? amuriensis lacks a distinct rostrum and umbonal ridge, so prominent in N. pernula, but appears also not to be related to Jupiteria of which it has been reassigned (Fleming in Wellman, 1959, p. 141; Crampton and Moore (1990, p. 346). No discussion of N.? amuriensis was presented in the latter two papers, but I suspect that the species was reassigned to Jupiteria based on the absence of an umbonal ridge, but in overall external features N.? amuriensis approaches extant and extinct species of Nuculana more than to Jupiteria concava (Bronn, 1831) (Sacco, 1898, pp. 56-57, Pl. 12, Figs. 1-3; supposed figure of this species by Puri in Moore, 1969, p. N236, Fig. A6-11 is actually Teretileda aculata (Iredale)), the type of Jupiteria, of which the New Zealand Cretaceous species little resembles, except for the apparent absence of an umbonal ridge. Nuculana? amuriensis may well represent a new group, but the absence of well-preserved material prevents further assessment.

Genus JUPITERIA Bellardi, 1875

Jupiteria Bellardi, 1875, p. 20.

Type species.-(by subsequent designation, Dall, 1898), Nucula concava Bronn, 1831.

Synonym.-Teretileda Iredale, 1929 (Puri in Moore, 1969, p. N235).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-Maxwell (1988b) in his study of the New Zealand Late Miocene deep-water Mollusca of the Stillwater Mudstone, northwestern South Island, reviewed the classification of New Zealand nuculanid species assigned to Jupiteria Bellardi and commented on how little attention the type species of Jupiteria, J. concava (Bronn, 1831), has received since it was designated nearly one hundred years ago. Jupiteria concava is characterised by its small size, ovate-trigonal outline, blunt rostrum, fine growth lines, and anterior and posterior teeth of similar length that are separated by a triangular resilifer (Maxwell, 1988b, pp. 38-39). Earlier, Puri (1969, p. N237) stated that the main distinguishing features of J. concava are a small, inflated, corbuloid shell, a blunt rostrum that is barely ridged, and a shallow sinus. Maxwell (1988a, p. 91) believed that Jupiteria is worthy of generic status rather than a subgenus of Nuculana Link. A complete review of the Jupiteria-Nuculana groups, and indeed the family Nuculanidae for that matter, is needed as, for example, several New Zealand taxa assigned to Jupiteria bear little resemblance to the type species, J. concava (Bronn, 1831). Because some nuculanids exhibit an apparent continuum of form or intermediate features between various genera, assignment to genera is not always clear-cut and remains problematic. Maxwell (1988a, p. 91) suggested that "very careful attention must be paid to the finer details of shell shape, sculpture (including microsculpture where present), hinge and ligament, and course, anatomy", but in reality few neontologists and paleontologists study in detail important morphological parameters such as microsculpture which may or may not be of supraspecific importance. Until a detailed phylogenetic analysis of the Nuculanidae has been completed, many groups such as *Jupiteria* and *Nuculana* will continue to be treated as "waste paper basket" taxa, along with numerous other poorly known molluscan groups.

As mentioned previously, Woods (1917, p. 18, Pl. 6, Fig. 1) described a nuculanid species *Nuculana amuriensis* from the Late Cretaceous of Haumuri Bluff, South Island, which Finlay (1927, p. 445) believed to be more closely related to *Jupiteria*. *Nuculana*? *amuriensis* is not closely related to *Jupiteria* and is herein not included in this group as the Cretaceous species is quite unlike the type species, *J. concava*. As mentioned above Maxwell (1988b, p. 38) treated the affinities of *N. amuriensis* as uncertain. However, Woods (1917, p. 18, Pl. 6, Fig. 2) figured a second nuculanid species known from a single poorly preserved cast and referred this taxon to *Nuculana* sp. *Nuculana* sp. can probably be referred to *Jupiteria* or more likely to *Saccella* (s. l.) sp., although this assignment can only be considered tentative. An assignment of *Ledina* Sacco, 1898, cannot be ruled out. *Jupiteria* in New Zealand extends from the latest Cretaceous (a range extension from the most recent report of middle Eocene by Beu and Maxwell, 1990, p. 33) to the Recent and is known elsewhere from Late Cretaceous to Recent of many regions, including Europe, North America, Jamaica and Australia. *Jupiteria* was reported in the New Zealand Cretaceous for the first time by Marwick and

Fleming *in* Wellman (1959, p. 138), an identification which is supported here.

JUPITERIA *PALAIOZELANDICA* n. sp.

Plate 3 Figure 15

?*Nuculana* sp., Woods, 1917, p. 18, Pl. 6, Fig. 2.

Diagnosis.-Shell small, narrowly elongate, subovate to subtrigonal, rostrate, inflated; posterior ridge poorly defined; shell mostly smooth with well-defined, widely spaced growth lamellae.

Description.-Shell fairly small, moderately inflated, narrowly elongate, subovate to sutrigonal, moderately rostrate posteriorly with poorly defined postero-umbonal ridge; umbones small, broadly triangular, subcentral, more anterior, beaks moderately opisthogyrous; anterodorsal margin moderately sloping, gently convex, merging towards a well rounded anterior margin; posterodorsal margin gently sloping, only slightly convex, merging to narrowly rounded posterior margin; ventral margin broadly rounded, more straight posteriorly; commarginal sculpture mostly smooth with four pronounced, unequally spaced growth lamellae that commence midway on flank and numerous threads; macroscopic sculpture nearly absent from umbones.

Dimensions.-Holotype Ge 7683 (AIM), length 11.0 mm, height 4.0 mm, width of paired valves 2.5 mm.

Type.-Holotype Ge 7683 (AIM).

Figured specimen.-Ge 7683 (AIM).

Type locality.-Te Opu, Kaipara, Northland, Q08/f9639.

Material.-One well-preserved, articulated specimen.

Stratigraphic range.-Probably unspecified unit within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Restricted to Kaipara, Northland.

Discussion.-Jupiteria palaiozelandica n. sp. has a close morphological affinity to New Zealand Tertiary species assigned to Jupiteria. Jupiteria hampdenensis (Marwick, 1942) (p. 269, Pl. 23, Figs. 4, 6; Fleming, 1966, p. 104, Pl. 3, Figs. 52, 53) from the middle Eocene (Bortonian Stage) of New Zealand is very similar and apparently most closely related to J. palaiozelandica n. sp. in having a smooth shell with pronounced growth pauses and an elongate subovate to subtrigonal outline, in being moderately rostrate and having a poorly defined postero-umbonal ridge. The former new New Zealand Cretaceous species differs from J. hampdenensis in having a more narrowly elongate shell and a more gently convex ventral margin. The type species of Jupiteria, J. concava (Bronn, 1831) (see Sacco, 1898, pp. 56-57, Pl. 12, Figs. 1-3) from the Pliocene of Italy, has a broader shell and a very blunt rostrum compared to J. palaiozelandica n. sp.

Etymology.-Species named from the Greek "palaois" (= old) for its presence in the Cretaceous of New Zealand.

JUPITERIA? NOTOLISSA n. sp.

Plate 3 Figure 12

Diagnosis.-Thin, moderately large, broadly ovate shell with blunt rostrum posteriorly; umbones only slightly opisthogyrate; surface mostly smooth, except for very fine commarginal threads and growth pauses more ventrally.

Description.-Shell moderately large for family, thin, slightly to moderately inflated, broadly ovate with blunt rostrum posteriorly; length to height ratio nearly 1:1; umbones small, subcentral, only slightly opisthogyrate; anterodorsal margin short, gently sloping, slightly convex, merging to very broadly rounded anterior margin; posterodorsal margin moderately long, moderately steep, slightly convex, merging to moderately narrowly rounded posterior margin; ventral margin convex; lunule small, moderately narrow; escutcheon long, narrow, bordered by poorly to moderately developed umbonal ridge; surface commarginal sculpture mainly smooth of numerous, microscopic threads and more distinctive growth pauses ventrally.

Dimensions.-Holotype Ge 7923 (AIM), length 9.0 mm, height 8.0 mm, width of paired valves 4.0 mm; paratype Ge 8087.1 (AIM), length 8.0 mm, height 6.5 mm, width of paired valves 3.0 mm; paratype, Ge 8087.2 (AIM), length 7.5 mm (mostly complete), height 5.5 mm, width of paired valves 3.0 mm.

Types.-Holotype Ge 7923 (AIM); paratypes Ge 8087.1, Ge 8087.2 (AIM).

Figured specimen.-Ge 7923 (AIM).

Type locality.-Bull Point, Kaipara, Northland, Q08/f9626 [N28/f626].

Material.-Three well preserved articulated specimens and two poorly preserved specimens.

Localities.-Same as type locality.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from Kaipara, Northland.

Discussion.-*Jupiteria*? *notolissa* n. sp., of uncertain affinity, is known only from articulated, presumably adult specimens from one locality at Bull Point, Kaipara, Northland. In external morphological features, *J. notolissa* n. sp. approaches the type species of *Jupiteria*, *J. concava* (Bronn, 1831) (Sacco, 1898, pp. 56-57, Pl. 12, Figs. 1-3; not specimen figured by Puri *in* Moore, 1969, p. N236, Fig. 11), but not nearly as much as the previously described species *J. palaiozelandica* n. sp which also appears to be more related to early Paleogene taxa of New Zealand. *Jupiteria*? *notolissa* n. sp. can be separated from *J. concava* by having slightly less opisthogyrate umbones and more convex posterodorsal and anterodorsal margins. Rostrums of the two above species are equally poorly developed. A New Zealand late Miocene species, *J. kouhaiensis* (Marwick, 1931) (p. 52, Figs. 15-16; Fleming, 1966, pp. 104-105, Pl. 3, Figs, 55, 56) is quite similar in general outline and sculpture, but differs in detail of dorsal and ventral margins and umbones. Maxwell (1988b, p. 40) and Beu and Maxwell (1990, p. 393) referred *Jupiteria kouhaiensis* to *Pseudotindaria* within the Neilonellidae, but *J. notolissa* n. sp. seems more appropriately placed within *Jupiteria* at this time though details of hinge structure not revealed in available material may shed light on the most appropriate taxonomic placement of this species.

Etymology.-Species named from the Greek "notos" (= south) and for its smooth shell from the Greek "lissos" (= smooth).

Genus SACCELLA Woodring, 1925

Saccella Woodring, 1925, p. 15.

Type species.-(by original designation), Arca fragilis Chemnitz, 1784.

Synonym.-Ledina Sacco, 1898, non Dall, April, 1898 (Puri in Moore, 1969, p. N237).

Biogeographic element.-Cosmopolitan (Puri in Moore, 1969, p. N237).

Discussion.-Puri in Moore (1969, p. N237), Abbott (1974, p. 414), and Powell (1979, p. 359) stated that the main diagnostic features of Saccella Woodring are a rostrate shell, sculpture of strong concentric rugae, equal anterior and posterior series of teeth and a U-shaped pallial sinus, and Maxwell (1988a, p. 91) also included an elongate-ovate outline and a well-defined postero-umbonal ridge as diagnostic characters of Saccella. Maxwell (1988a, p. 91) commented on Allen and Hannah's (1986) "Reclassification of the Recent genera of the Subclass Protobranchia (Mollusca: Bivalvia)" and disagreed with their interpreting Jupiteria "in a very broad sense to include Saccella". Both groups have been distinct since "at least the Middle Eocene" (Maxwell, 1988a, p. 91). Study of various new species of Jupiteria and Saccella in the Cretaceous of New Zealand suggests that these two groups have been distinct long before the Middle Eocene and perhaps as early as Campanian time, much earlier than previously reported, although the postero-umbonal ridge of New Zealand Cretaceous Saccella species was apparently not as well-developed as in Cenozoic taxa at this time. Species of Saccella are known from numerous localities around the globe from the Late Cretaceous to Recent. Saccella n. sp. was reported by Marwick and Fleming in Wellman (1959, p. 138) from Haumurian rocks (Maastrichtian, uppermost Cretaceous) in the Kaipara, Whangaroa and Barron's Hill areas, but was not figured and as a consequence, it is not known if their Saccella n. sp. is truly conspecific with S. primaeva n. sp. described below. Saccella (s. l.) sp. (Woods, 1917, p. 18, Pl. 6, Fig. 2, Nuculana sp.) was also reported by Marwick and Fleming in Wellman (1959, p. 141) as being present in Piripauan rocks (Campanian, Upper Cretaceous) of New Zealand, but this species seems more appropriately placed within Jupiteria.

SACCELLA? PRIMAEVA n. sp.

Plate 3 Figures 14, 17

Diagnosis.-Elongate, subovate, shell with moderately developed rostrum; postero-umbonal ridge poorly to moderately developed; commarginal sculpture of moderately coarse, numerous flattened ribs that increase in strength midway on flank.

Description.-Shell small, elongate ovate, inflated, with moderately developed rostrum; umbones moderately small, wide, subcentral, more anterior, only slightly opisthogyrate; postero-umbonal ridge poorly to moderately developed; lunule and escutcheon poorly developed; anterodorsal margin moderately short, gently sloping, convex, merging to broadly rounded anterior margin; posterodorsal margin long, gently sloping as in anterodorsal margin, broadly convex, merging to narrowly acute, rounded, posterior margin; sculpture of numerous, flattened, moderately pronounced commarginal ribs that become stronger midway on the flank; macroscopic sculpture present on umbones; approximately six anterodorsal and posterodorsal hinge teeth; pallial sinus broadly U-shaped.

Dimensions.-Holotype Ge 5915 (AIM), length 4.5 mm, height 3.0 mm, width of paired valves 2.0 mm; paratype Ge 5916 (AIM), length 3.0 mm, height 2.0 mm, width of paired valves 1.5 mm; Ge 7620 (AIM), length 5.0 mm, height 3.5, width of paired valves 2.5 mm; paratype Ge 5917 (AIM), length 3.5 mm, height 3.0 mm, width of paired valves 2.0 mm; paratype Ge 5912 (AIM), length 3.5 mm (nearly complete), height 2.5 mm, width of paired valves 2.0 mm; paratype Ge 5919 (AIM), length 4.0 mm, height 3.0 mm, width of single valve 1.5 mm.

Types.-Holotype Ge 5915 (AIM); paratypes, Ge 5916, Ge 7620, Ge 5917, Ge 5912, Ge 5919 (all AIM).

Figured specimens herein.-Ge 5915-5916 (AIM).

Material.-11 specimens, mostly articulated.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626 (type; East Coast of Matakohe Arm and Batley, same fossil record number); Hukatere Peninsula, Northland, Q08/f9660.

Stratigraphic range.-Unspecified horizon within Unit 4d? of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known from various localities around the North Kaipara Harbour area.

Discussion.-*Saccella*? *primaeva* n. sp. is here considered an early member of the nuculanine genus *Saccella* Woodring, but is somewhat atypical of *Saccella* s. s. as it has a poorly to moderately developed postero-umbonal ridge. Superficially, *S*.? *primaeva* n.

sp. approaches morphologically some Tertiary New Zealand taxa assigned to Pseudoportlandia Woodring such as P. ellisi (Marwick, 1926) (p. 328, Pl. 75, Figs. 12, 14; Fleming, 1966, p. 104, Pl. 3, Figs. 49, 50) from the Late Miocene of New Zealand, but S.? primaeva n. sp. is distinctly rostrate. Otherwise, S.? primaeva n. sp. appears consistent with most Cenozoic species of the Saccella group with its elongate-ovate outline, developed rostrum and strong, commarginal sculpture of flattened ribs. The type species of Saccella, the Miocene to Recent S. fragilis (Chemnitz, 1784) (see Brambilla, 1976, p. 93, Pl. 22, Figs. 9, 10, for figure of a Pliocene specimen from Villalvernia (Alessandria)), is separated from S.? primaeva n. sp. by having a more well-developed rostrum and coarser commarginal sculpture, but the two species are quite similar morphologically.

Etymology.-Species named from the Latin "primaevus" (= early, young) for its record in the New Zealand Cretaceous.

SACCELLA (s. l.) sp.

Not Figured

Nuculana sp., Woods, 1917, p. 18, Pl. 6, Fig. 2; Warren and Speden, 1978, p. 46, Fig. 27, p. 50, Tab. 5; Crampton and Moore, 1990, Appendix 1, p. 346.

Nuculana (Saccella s. lat.) sp., Fleming in Wellman, 1959, p. 141.

Previously figured specimen.-TM 2454 (IGNS; Woods, 1917, Pl. 6, Fig. 2).

Figured specimen herein.-TM 2454 (IGNS).

Localities.-"West wing" of Haumuri Bluff, southern Marlborough (exact locality not known but believed to be O32/f8025); Te Hoe River area, western Hawke's Bay, Waiau River float *1 and Mangahouanga Stream float *3 of Crampton and Moore (1990), and V19/f184.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous) and Maungataniwha Sandstone (Piripauan to Haumurian stages, upper Campanian to Maastrichtian, Upper to uppermost Cretaceous).

Geographic distribution.-Eastern North Island and northeastern South Island.

Discussion.-The affinities of this nuculanid species are not known, due to poor preservation. The species appears to be more related to Saccella than to Nuculana, especially in overall outline and is tentatively assigned to Saccella (s. l.) sp. due to its similarities with New Zealand species assigned to Saccella. Saccella arowhana (Marwick, 1931) (p. 51, Fig. 23; Fleming, 1966, p. 104, Pl. 3, Fig. 42) from the Miocene of New Zealand agrees quite well with Saccella (s. l.) sp. in general outline.

Genus PSEUDOPORTLANDIA Woodring, 1925

Pseudoportlandia Woodring, p. 20.

Type species.-(by original designation) Leda clara Guppy, 1873.

Synonyms.-?Portlandella Stewart, 1930 (Abbott, 1974, p. 418).

Biogeographic distribution.-Cosmopolitan (Puri in Moore, 1969, p. N239).

Discussion.-Retention of numerous New Zealand Cenozoic nuculanid species as well as this Late Cretaceous species, previously assigned to Pseudoportlandia, in this genus can only be considered tentative. Zinsmeister (1984, p. 1504) (as also discussed by Beu and Maxwell (1990, p. 100)) suggested that New Zealand species previously assigned to Pseudoportlandia be given a new name, as "the blunt ill-defined rostrum and thick hinge plate...warrant the erection of a new genus", a position cautioned by Beu and Maxwell who believed a revision of the numerous nuculanid genus-group taxa would be necessary before erecting a new name. Pseudoportlandia solenelloides (Marshall, 1919), for example, from the mid Eocene of New Zealand (refigured by Beu and Maxwell, p. 100, Pl. 5, Figs. a, b) is, indeed, unlike typical Pseudoportlandia (See Woodring, 1925, p. 20, Pl. 1, Figs. 17-19 for figures of the type, P. clara). This New Zealand Late Cretaceous species seems related to P. solenelloides and will be identified as "Pseudoportlandia" sp. here until the taxonomy of the group is better known. Although the geologic range of Pseudoportlandia was previously reported as Tertiary to Recent (Puri in Moore, 1969, p. N239), the genus may have extended into the latest Cretaceous.

PSEUDOPORTLANDIA? sp.

Plate 4 Figure 3

Dimensions.-Ge 8102 (AIM) length 13.5 mm incomplete, height 9.0 mm.

Figured specimen.-Ge 8102 (AIM).

Material.-One nearly complete, disarticulated specimen; Ge 7915 (AIM) and specimen from GS 729 may be related forms.

Locality.-Te Opu, Kaipara, Northland Q08/f9639.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Restricted to one known locality in Northland.

Discussion.-Only one, nearly complete specimen of Pseudoportlandia? sp. could be located for study. The morphologic similarity between the above Cretaceous New Zealand species and a mid Eocene (Bortonian Stage) species, P. solenelloides (Marshall, 1919) (p. 233, Pl. 15, Figs. 4-6; refigured by Beu and Maxwell, p. 100, Pl. 5, Figs. a, b), is strong, except that the Cretaceous species has irregular, commarginal sculpture. I defer naming this probable new species at this time, due to the absence of more complete material. Of note, specimen TM 7759 (IGNS) (see Plate 4, Figures 4-5), from Okaihau, Bay of Islands, may be a related form.

Family MALLETIIDAE Adams and Adams, 1858

Genus TINDARIA Bellardi, 1875

Tindaria Bellardi, 1875, p. 28.

Type species.-(by monotypy) Tindaria arata Bellardi, 1875.

Biogeographic element.-Cosmopolitan, as interpreted here.

Discussion.-The groups Tindaria and Pseudotindaria are in a state of taxonomic flux and a short review of the problem is appropriate here. Tindaria was erected by Bellardi (1875) for a Late Miocene fossil from Italy, T. arata, with no known direct ancestors (Warén, 1989, p. 255). "Concentric" (commarginal) sculpture, beaks facing slightly forward, and "fat" (presumably inflated) shell are prominent features of Tindaria (McAlester in Moore, 1969, p. N235; Abbott, 1974, p. 413). McAlester in Moore (1969, p. N235) and Maxwell (1988b, p. 41) stated the age of Tindaria arata as Pliocene, not Miocene. Sanders and Allen (1977) designated Tindaria erebus Clarke, 1959, from the Recent of the Atlantic Ocean, as the type of Pseudotindaria, the only detectable morphological difference between Tindaria and Pseudotindaria being that the latter genus is siphonate. However, a major problem arises when the siphonate or asiphonate nature of T. arata is addressed and that it is not known if T. arata was asiphonate. Maxwell (1988b, p. 41) stated that T. arata was apparently asiphonate, based on figures of the species reproduced in Sacco (1898, Pl. 12, Figs. 55, 56), but topotypic material of T. arata available to Warén (1989, p. 255) indicated that Maxwell's (and Sanders and Allen's) assumption that T. arata was indeed asiphonate could not be confirmed. Recent species assigned to Tindaria are asiphonate.

The familial placement of Tindaria is also problematic and has been assigned by various workers to Malletiidae or Tindariidae. Pseudotindaria has been assigned to either Tindariidae or Neilonellidae. Until more data are available for these problematic groups, Tindaria will be retained here in Malletiidae. The range of Tindaria was previously given to be Tertiary to Recent (McAlester in Moore, 1969), but if T.? veta n. sp. from the Late Cretaceous is truly assignable to Tindaria the group extended well into the Late Mesozoic. A drawback in the identification of this species is the lack of hinge details for study with the material available. Otherwise, in general outline, sculpture and details of pallial line T.? veta n. sp. seems more appropriately placed in Tindaria.

TINDARIA? VETA n. sp.

Plate 4 Figures 1-2

Diagnosis.-Moderately thick, elongate, subtrigonal shell; gently sloping anterodorsal and posterodorsal margins; shell smooth except for faint, commarginal growth pauses; pallial line integripalliate.

Description.-Shell small, moderately thick, elongate-subtrigonal, very bluntly rostrate; umbones small, subcentral, more anterior; anterodorsal margin short, gently sloping, slightly concave merging towards well-rounded, moderately narrow anterior margin; posterodorsal margin moderately long, gently sloping, straight to gently convex, merging towards narrowly rounded posterior margin; ventral margin moderately to broadly rounded; lunule and escutcheon poorly developed; commarginal sculpture mostly smooth of faint, closely spaced threads, becoming stronger towards ventral margin; anterior adductor scar elongate, subovate?; pallial line integripalliate.

Dimensions.-Holotype Ge 7678.1 (AIM), length 5.0 mm, height 3.5 mm, width of paired valves 3.0 mm; paratype Ge 7678.2 (AIM), length 3.5 mm, height 2.5 mm, width of paired valves 2.0 mm; paratype Ge 7931 (AIM), length 5.0 mm, height 4.5 mm, width of single valve 2.5 mm; paratype Ge 7624 (AIM) (internal mold), length 4.5 mm, height 3.5 mm, width of paired valves 2.5 mm.

Types.-Holotype Ge 7678.1 (AIM); paratypes Ge 7678.2, Ge 7931, Ge 7624, all AIM.

Figured specimen.-Ge 7678.1 (AIM).

Material.-14, mostly articulated, specimens.

Localities.-Te Opu, Kaipara, Northland Q08/f9639 [N28/f639] (type); Bull Point, Kaipara, Northland Q08/f9626 [N28/f626]; Hukatere Peninsula, Northland, Q08/f9660; northeast shore of Kaiwitu Estuary, Hokianga, Northland, O05/f9596.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from Northland.

Discussion.-The generic placement of Tindaria? veta n. sp. can only be treated as tentative at this time, but based on shell outline and integripalliate pallial line this species seems most appropriately placed in Tindaria. The shell outline of Tindaria, a conservative character of the group, is generally subtrigonally subovate and Tindaria? veta n. sp. is no exception. Tindaria? veta n. sp. is similar in outline to several Northern Hemisphere Tindaria species and New Zealand Tertiary fossil species assigned and provisionally assigned to Pseudotindaria. Tindaria? veta n. sp. is very similar to Pseudotindaria catillus Maxwell, 1988b (see p. 42, Pl. 1i-1), from the Late Miocene of western South Island and Pseudotindaria? ferrari (Fleming, 1950) (see pp. 240-241, Pl. 24, Fig. 1; Beu and Maxwell, 1990, p. 393) from the mid Eocene of North Island, New Zealand, but the former Cretaceous species is more elongate with weaker commarginal ornament. Pseudotindaria catillus was siphonate, precluding its placement within Tindaria which is presumed to be asiphonate. Tindaria species today are known from relatively deep water and are generally rare (Abbott, 1974, p. 413; Maxwell, 1988b, p. 41.).

Etymology.-Species named from the Latin "vetus" (= old) for its early record in the Cretaceous of New Zealand.

Genus NEILO A. Adams, 1854

Neilo A. Adams, 1854, p. 93.

Type species.-(by monotypy) Neilo cumingii A. Adams, 1854 (= Nucula australis Quoy and Gaimard, 1835).

Biogeographic element.-Cosmopolitan (Marshall, 1978, p. 425).

Discussion.-Neilo has a long but patchy geologic record in New Zealand and has been reported Upper Cretaceous rocks of South Island and eastern North Island and regionally in the Late Oligocene to Recent. Neilo is usually placed in Malletiidae (Fleming, 1966, p. 100; McAlester in Moore, 1969, p. N233; Marshall, 1978, p. 425; Vokes, 1980, p. 4; Beu and Maxwell, 1990, p. 393), but also has curiously been assigned recently to Neilonellidae by Vaught (1989, p. 114) in a classification of the living Mollusca. The genus is confined today to the New Zealand area (Marshall, 1978, p. 425). Apart from a probableNeilo, a single cast of N. cf. sinangula Finlay of Fleming (1950, p. 241), from the Bortonian (upper Middle Eocene) Pahi Greensand of Northland, no other early Paleogene Neilo species have been reported from New Zealand. Further collecting by myself in 1993 in the Pahi Greensand exposed along Kaipara Harbour, Northland, revealed no further Neilo specimens. In Antarctica Neilo is known only from the mid Eocene to lowermost Oligocene? La Meseta Formation (Stilwell and Zinsmeister, 1992, Tab. 1, p. 25) where it is restricted to the middle units Telm3 and Telm5. No *Neilo* species have been reported from the Late Cretaceous to Paleogene of Australia, but the genus is present in Upper Campanian to Maastrichtian rocks of southern South America (Riccardi, 1988, Tab. 7, p. 49).

The main diagnostic feature separating *Neilo* from *Malletia* Des Moulins is a much stronger anterior development of the hinge in *Neilo* (Marshall, 1978, p. 425). *Neilo* differs from *Spineilo* Finlay and Marwick in being less elongate and more truncated posteriorly (Beu and Maxwell, 1990, p. 77). *Spineilo* is more rostrate with a very pointed posterior end compared to *Neilo*. Zinsmeister (1984, p. 1502-1503) proposed the malletiid genus *Australoneilo* for a group of malletiid bivalves similar to *Neilo*, but differing from typical *Neilo* with its "absence of concentric ribbing and poorly developed posterior rostrum". *Neilo* species can be important depth and climate indicators and are commonly present in "fine-grained, poorly oxygenated muds rich in anaerobic bacteria" (Marshall, 1978, p. 425).

Freneix (1980) in a classic study of the Late Cretaceous bivalves of New Caledonia erected a new subgenus of *Neilo*, *Neilo* (*Neiloides*), and suggested that *Neilo* *cymbula* (Woods, 1917), *Neilo* *rudis* (Wilckens, 1907), *N*. *pencanoides*, and *N*. *pencana* (Philippi, 1887) are representatives of *N*. (*Neiloides*) along with her previously erected species, *N*. (*N*.) *routhieri* (Freneix, 1958) from the Campanian of numerous localities in New Caledonia. *Neiloides* differs from *Neilo* s. s. (translated from French) in having a more trigonal outline, in lacking an elevated posterior carina or ridge, and having a sinus that is less well-developed

(Freneix, 1980, p. 80). The absence of an elevated, posterior ridge in the austral Cretaceous species of *Neilo* listed above is probably a primitive character of the group and indeed, Freneix 's separation of *Neilo* s. s. and *N*. (*Neiloides*) seems warranted and is followed here. To further strengthen Freneix's (1980) case for splitting *Neilo* s.s. and *N*. (*Neiloides*), *Neilo* species, extinct and extant, are generally morphologically conservative and I believe that the pronounced differences between the two groups are supraspecific level characters and should not be treated as interspecific variation.

Subgenus *NEILOIDES* Freneix, 1980

Neilo (*Neiloides*) Freneix, 1980, pp. 80-81.

Type species.-(by original designation) *Neilo* (*Neilo*) *routhieri* Freneix, 1958.

NEILO (*NEILOIDES*) *CYMBULA* Woods, 1917

Plate 4 Figures 6-13

Malletia (*Neilo*) *cymbula* Woods, 1917, p. 18, Pl. 6, Figs. 3a, b.

Neilo cymbula Woods, Marwick and Fleming *in* Wellman, 1959, p. 138; Crampton and Moore, 1990, p. 340, Fig. 8A.

Dimensions.-OU 40941 length 24.5 mm, height 14.5 mm; OU 40938 length 27.5 mm, height 16.0 mm, width of articulated valves 11.5 mm; OU 40940 length 47.0 mm, height 29.0 mm; OU 40939 length 41.5 mm, height 21.5 mm.

Types and figured specimen.-Holotype TM 2453 (IGNS; Woods, 1917, Pl. 6, Fig. 3); TM 6866 (IGNS; Crampton and Moore, 1990, Fig. 8A).

Figured specimens herein.-TM 2453 (IGNS), TM 6866 (IGNS), OU

40938, OU 40939, OU 40940, OU 40941.

Material.-14 specimens.

Localities.-"Saurian Beds, Middle Waipara", South Island, Loc. 761 of Woods, 1917, p. 18, M34/f7263 (type); Shag Point, South Island J43/f159, J43/f6544; Brighton, South Island, I44/f8573; Barron's Hill, South Island, I45/f8510 [S163/f510]; ?NNW junction of Taieri Beach and Mouth roads, I45/f8517 [S163/f517]; 200 m south of Saddle Hill Road, South Island, I45/f8665 [S163/f665]; North Branch of Waianakarua River, South Island, J42/f082, J42/f178, J42/f215, J42/f218; South Branch of Waianakarua River, South Island, J42/f127; Kaiwara River, North Canterbury, South Island, N33/f9811; Te Hoe River area, western Hawke's Bay, North Island, V19/f129, V19/f184, V19/f185, V19/f186, Mangahouanga Stream float *3, North Island (of Crampton and Moore, 1990), V19/f6909.

Stratigraphic range.-Saurian Sands, Silverstream? Formation (Upper Cretaceous); Katiki Formation, Barrons Hill Lens of Brighton Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Abbotsford Formation (uppermost Cretaceous? or lowermost Tertiary?); Maungataniwha Sandstone (Piripauan to Haumurian stages, upper Campanian to Maastrichtian, Upper Cretaceous).

Geographic distribution.-Eastern North Island to southeastern South Island.

Discussion.-Woods (1917, p. 18) remarked that *Neilo* (*Neiloides*) *cymbula* resembled *Malletia pencana* (Philippi, 1887) from the Cretaceous of Chile, but *N*. *cymbula* is "less inequilateral, more convex, less pointed posteriorly, and the ribs more numerous and not so strong". Stinnesbeck (1986, p. 167) (translated from German) also remarked that Neilo cymbula and Neilo pencana (see Pl. 1, Figs. 12-14, specimens from the Maastrictian Quiriquina Formation, Central Chile) are quite similar, except that N. cymbula is less elongate and the umbones are more central compared to N. pencana. Unfortunately, specimens of N. quiriquinae (Philippi, 1887) (see Stinnesbeck, 1986, p. 167, Pl. 1, Figs. 15, 16) are usually poorly preserved for accurate comparison with other Neilo taxa, but the two specimens of N. quiriquinae figured by Stinnesbeck approach the outline of N. cymbula more closely than to N. pencana. Except for widely spaced, commarginal ribs and details of the hinge of N. quiriquinae few other features of this species are detectable. Neilo cymbula is also quite similar to a malletiid bivalve from the Late Cretaceous of Snow Hill Island, Antarctic Peninsula, Malletia pencanoides Wilckens, 1910 (pp. 25-26, Pl. 2, Figs. 5-7), the taxonomic placement of which needs reappraisal. The commarginal sculpture of Malletia pencanoides is moderately strong, but from Wilckens' drawing is apparently not as strong as N. cymbula which also has a subhorizontal posterodorsal margin compared to M. pencanoides, the posterodorsal margin of which is moderately sloping. Unfortunately, the holotype of M. pencanoides has an incomplete posterior margin. Malletia pencanoides is probably a Neilo, but the relatively poor state of preservation of Wilckens' material prompts me to defer placement of the species in Neilo at this time. Freneix (1980, p. 80) placed all of the above discussed species within Neilo

(Neiloides) which is followed here. There is little doubt, also, that Neilo quiriquinae (Philippi, 1887) should be included in Neilo (Neiloides). Freneix (1980, p. 80) reported that Neilo (N.) pencanoides is present also in the Campanian of southern Patagonia, but this report has not been confirmed to my knowledge. Two specimens housed at the Auckland Institute and Museum, Ge 8614, from the Hukatere Peninsula, Northland, and Ge 8024, from Kaipara are possibly assignable to Neilo as they have fairly strong, commarginal ribs, but are too incomplete for an accurate assessment. Neilo beui Stilwell and Zinsmeister, 1992 (see p. 52, Pl. 1, Figs. m, p, q), from the mid? to Late Eocene of Seymour Island, Antarctic Peninsula can be separated from N. cymbula by its more anteriorly situated umbones, but otherwise the similarity of the Antarctic species to N. cymbula is striking. Perhaps Neilo beui should also be included in Neilo (Neiloides). Marwick and Fleming in Wellman, 1959 (p. 138) identified three new species of Neilo in the latest Cretaceous of Northland, but this number of new taxa is highly unlikely per the material at hand. At least one of these inferred new taxa can be assigned to Australoneilo, not Neilo.

Little is known of the variability of N. (N.) cymbula due to the generally poor nature of the material available. Woods' (1917) figure of the holotype of N. (N.) cymbula (length 25 mm) is most certainly a juvenile specimen as some presumed gerontic individuals (ie. OU 40940 from lot OU 11119 from the Katiki Formation of Shag Point) reached a length of nearly 50 mm and height of 30 mm. Neilo (Neiloides) cymbula is inferred to have been an infaunal, siphonate, detritus feeding bivalve of low mobility (Crampton and Moore, 1990, p. 346).

Genus *AUSTRALONEILO* Zinsmeister, 1984

Australoneilo Zinsmeister, 1984, pp. 1502-1503.

Type species.-(by original designation) *Australoneilo rossi* Zinsmeister, 1984.

Biogeographic element.-Paleoaustral, as inferred here.

Discussion.-The presence of *Australoneilo* in the Late Cretaceous of New Zealand extends the known geographic and geologic range of the taxon to the eastern sector of Weddellian Province and provides evidence that the group may have originated in the New Zealand region and dispersed westward by earliest Tertiary time. This model of the dispersal of *Australoneilo* can only be considered tentative at this time as the age of the previously oldest known *Australoneilo*, *A. gracilis* (Wilckens, 1905) from southern Patagonia and Antarctic Peninsula, is uncertain. Zinsmeister and Macellari (1988, p. 258) addressed the problem of the uncertainties, namely locality and also stratigraphic position, associated with Wilckens' type locality of *A. gracilis*. The rocks at Cerro Cazador and Sierra Baguales containing *A. gracilis* are known to range from Upper Cretaceous to early Tertiary in age whereas *A. gracilis* is restricted to the lowermost Tertiary (most likely Paleocene) Sobral Formation of Seymour Island. *Australoneilo zelandica* n. sp. may indeed be the oldest recorded *Australoneilo* species around the southern circum-Pacific. An newly described species of *Australoneilo* from the mid Paleocene Pebble Point Formation of southeastern

Australia (Darragh, in press) indicates that the genus survived well into the Tertiary along the eastern sector of the Weddellian Province and possibly became extinct in Australia by the end of the Paleocene, but the Late Paleocene molluscan record in Australia is poorly known.

Australoneilo is characterized by its relatively thick, smooth, elongated shell with a poorly developed rostrum (Zinsmeister, 1984, p. 1502-1503). The type species, *Australoneilo rossi* Zinsmeister, 1984, is distinguished from the Recent Norway type species of *Pseudomalletia* Fischer, 1886, *P. obtusa* (G. O. Sars, 1872) (see figures in Abbott, 1974, p. 412, Fig. 4813) in being much larger with a more elongate and rostrate shell, more projecting umbones and more sloping anterodorsal and posterodorsal margins. *Pseudomalletia* and *Australoneilo* may be phylogenetically closely linked.

During the latest Cretaceous to earliest Tertiary interval *Australoneilo* preferred a mid to outer shelf environment and fine-grained facies as interpreted by New Zealand and Antarctic occurrences, but apparently migrated sometime during the Paleocene to a shallower shelf environment. The presence of *Australoneilo rossi* in Telm5 of the La Meseta Formation, Seymour Island, suggests a nearshore environment as interpreted by Stilwell and Zinsmeister (1992, pp. 42-43). A mode of life similar to Recent *Malletia* species (i. e. deposit feeder, possibly highly mobile at variable depths from shallow water to abyssal depths) was inferred for *Australoneilo* by Macellari (1988, p. 41). *Australoneilo* apparently became extinct in the southern hemisphere by the end of the Eocene.

AUSTRALONEILO ZELANDICA n. sp.

Plate 4 Figures 14-15; Plate 5 Figures 1-6

Diagnosis.-Moderately elongate, moderately thick, inflated shell; rostrum very poorly developed; posterodorsal margin long, mostly straight; shell mostly smooth except for spaced, growth pauses, becoming more bunched together towards ventral margin; differs from *Australoneilo gracilis* (Wilckens) in inflation, shape of posterodorsal margin, and posterior margin; can be separated from *A. casei* Zinsmeister and Macellari by being more inflated with more prominent umbones.

Description.-Shell medium-sized, moderately elongate, moderately thick, inflated with very poorly developed rostrum; umbones small, located approximately a one third of length of shell from anterior margin; umbonal ridge very weakly developed; anterodorsal margin short, moderately sloping, straight to very gently convex, merging towards moderately narrow, well-rounded anterior margin; posterodorsal margin long, moderately sloping, mostly straight except for slight concavity near intersection of posterodorsal and posterior margin which is somewhat angled; posterior margin moderately rounded, slightly less than anterior margin; ventral margin long, broadly rounded; shell mostly smooth except for well-spaced growth pauses that become more bunched and stronger towards ventral margin; umbonal sculpture of near-microscopic, commarginal threads; hinge plate long, narrow, posterior portion of hinge with approximately 20 chevron-shaped teeth that gradually increase in strength from umbo towards posterior margin; pallial details unknown.

Dimensions.-Holotype L 3866 (from AU 2571), length 27.0 mm, height 17.0 mm, width of single right valve 7.0 mm; paratypes L 3867 (from AU 2571), length 21.0, height 13.5 mm; L 3868 (from AU 2571), length 24.0 mm, height 15.5 mm, width of paired valves 13.5 mm; L 3869 (from AU 2571), length 24.0 mm incomplete, height 18.0 mm, width of single left valve 6.0 mm; TM 7467 (IGNS) length 40.5 mm, height 25.0 mm; Ge 6420 (AIM) length 17.5 mm, height 10.0 mm, width of paired valves 8.0 mm; Ge 6411 (AIM), length 18.0 mm, height 7.0 mm.

Types.-Holotype L 3866 (AU); paratypes L 3867 (AU), L 3868 (AU), L 3869 (AU), TM 7467 (IGNS), Ge 6410 (AIM), Ge 6411 (AIM). Ge 6403 (AIM) may represent this species.

Figured specimens herein.-Same as above.

Material.-61 calcified specimens, both articulated and disarticulated.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626 [N28/f626] (type), Q08/f9909, Q08/f143; Te Opu, promontory between Te Opu and Whakapirau creeks and north side of promontory between Opu and Whakapirau creeks, Kaipara, Northland, Q08/f9639; Whakapirau Creek, Kaipara, Northland, Q08/f9637 [N28/f637]; shore of Otomatea Arm, 0.8 km northeast of Batley, Kaipara, Northland, Q08/f9636.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochton" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Restricted to the Kaipara area, Northland.

Discussion.-*Australoneilo zelandica* n. sp. seems most closely related to *Australoneilo gracilis* (Wilckens, 1905) (see p. 35, Pl. 5, Fig. 10; also, Wilckens, 1910, p. 25, Pl. 2, Fig. 4; Zinsmeister and Macellari, 1988, p. 258, Figs. 3.6, 3.7) from the latest Cretaceous? to Early Paleocene of southern Patagonia and Antarctic Peninsula and *Australoneilo casei* Zinsmeister and Macellari, 1988 (see p. 258, Figs. 3.8, 3.9) from the Early Paleocene of Seymour Island, Antarctic Peninsula. *Australoneilo zelandica* n. sp. differs from *A*. *gracilis* in inflation, shape of posterodorsal margin, and posterior margin. *Australoneilo gracilis* is slightly more elongate and more compressed with a slightly concave posterodorsal margin and slightly more pointed posterior margin compared to *A*. *zelandica* n. sp. The overall outline of *A*. *zelandica* n. sp. is more like *A*. *casei*, but *A*. *zelandica* n. sp. is much more inflated with more prominent umbones. The inflation and shape of *A*. *zelandica* n. sp. is not unlike a malletiid bivalve of uncertain affinity described by Wilckens (1910, pp. 25-26, Pl. 2, Figs. 5-7) as *Malletia pencanoides* from the Late Cretaceous of Snow Hill Island, Antarctic Peninsula that apparently has moderately strong commarginal sculpture probably precluding its placement in *Australoneilo*. The posterior margin of the holotype of *Malletia pencanoides* is incomplete. *Malletia pencanoides* was assigned by Freneix (1980, p. 80) to *Neilo* (*Neiloides*). The type species of *Australoneilo*, *A*. *rossi* Zinsmeister, 1984 (see pp. 1503-1504, Fig. 3H-K; also Stilwell and Zinsmeister, 1992, p. 51, Pl. 1, Figs. k-o), from the Eocene of Seymour Island is also similar to *A*. *zelandica*, but the Antarctic species is much more narrowly elongate with a slightly stronger umbonal ridge and convex ventral margin.

Reduction in valve inflation and lengthening of shell seem to be the most prominent changes in *Australoneilo* species from Late Campanian? or Maastrichtian to Eocene time. *Australoneilo gracilis* and *A. casei* appear to be morphologically intermediate forms between *A. zelandica* and *A. rossi* which both share a moderate degree of valve inflation and shell elongation. *Australoneilo gracilis* and *A. casei* are of close lineal descent and *A. zelandica* n. sp. may be ancestral as indicated by close morphological affinity. No specimens of an undescribed species of *Australoneilo* (Darragh, in press) from the mid Paleocene of southeastern Australia are available for comparison.

Australoneilo zelandica n. sp. is one of the most common bivalves in the fine-grained, mid to outer shelf, Upper Cretaceous deposits of Kaipara, Northland.

Subclass CRYPTODONTA Neumayr, 1884

Order SOLEMYOIDA Dall, 1889

Superfamily SOLEMYACEA Gray, 1840

Family SOLEMYIDAE Gray, 1840

Genus *SOLEMYA* Lamarck, 1818

Solemya Lamarck, 1818, p. 488.

Type species.-(by subsequent designation, Children, 1823) *Solemya mediterranea* (= *Tellina togata* Poli, 1795).

Synonyms.-*Solenimya* Bowdich, 1822; *Solenomya* Children, 1823; *Stephanopus* Scacchi, 1833; *Solenymia* Swainson, 1840; *Solenymya* Schaufuss, 1869 (Cox *in* Moore, 1969, p. N242).

Biogeographic element.-Cosmopolitan (Cox *in* Moore, 1969, p. N241).

Discussion.-*Solemya* is not well represented in Cretaceous or Tertiary rocks around the southern circum-Pacific. *Solemya suroradiata* n. sp. from Kaipara, Northland, is the only known species of this group from the Cretaceous of New Zealand and is quite rare. Undescribed species of *Solemya* are present in the Tertiary of New Zealand, the oldest being a middle Eocene (Bortonian Stage) species in the Pareora Pipeline area of South Island and a much younger Late Miocene (Tongaporutuan? Stage) species of Kouhai Creek, Uawa South District, North Island (Marwick, 1931, p. 48, Fig. 1; Fleming, 1966, p. 100, Pl. 1, Fig. 1). A Late Cretaceous species of *Solemya*, *S*. *rossiana* Wilckens, 1910 (pp. 65-67, Pl. 3, Fig. 9; also figured by Zinsmeister and Macellari, 1988, pp. 258-259; Fig. 3.12-3.15) has been recorded from the Antarctic Peninsula and although generally uncommon, is fairly abundant at a few localities on Seymour Island (Palamarczuk *et al*., 1984, p. 400; Zinsmeister and Macellari, 1988, p. 259). An Eocene species of *Solemya*, *S*. *peteri* Zinsmeister, 1984, is also known from Seymour Island, Antarctic Peninsula (see p. 1505, Fig. 3L; also Stilwell and Zinsmeister, 1992, pp. 52-53, Pl. 1, Fig. r). No *Solemya* species have been discovered in Upper Cretaceous rocks of Australia or southern South America, but an Early Miocene species, *S*. *antarctica*, was described by Philippi (1887) from Chile and represents the sole known occurrence of the group in southern South America (Zinsmeister, 1984, p. 1505).

The ecology and inferred paleoecology of *Solemya* has been commented on by several workers. Hickman (1984) in a classic study of six Cenozoic deep-water communities identified the *Thyasira*-*Lucinoma*-*Solemya* community as one of recurring infaunal ecological associations characterized by low diversity "in both laminated and massively bedded mudstone and siltstone units" and by mostly articulated shells. As *Solemya* today, a rapid burrower, can be found from intertidal to bathyal-abyssal depths it is not necessarily a diagnostic taxon of deep water or a particularly good depth indicator (Hickman, 1984, p. 1227; Macellari, 1988, p. 42). As reviewed by Allen and Sanders (1969, pp. 388-389) *Solemya* has an extreme reduction in gut size; the gut is so small that it is astounding that it can provide enough nutrients from its digestive processses. Species of *Solemya* rely on chemosymbiotic bacteria to survive in anoxic conditions (P. A. Maxwell, pers. commun., 1993). All of the specimens of *S. suroradiata* n. sp., an inferred middle to outer shelf shelf *Solemya* species from Kaipara, are articulated.

SOLEMYA SURORADIATA n. sp.

Plate 5 Figures 7, 9-10, 12

Solemya n. sp., Marwick and Fleming *in* Wellman, 1959, p. 138.

Diagnosis.-Medium-sized, very narrowly subovate to subrectangular, elongated, compressed shell; umbones located about a quarter of the length of shell from posterior margin; shell ornamented with anterior and posterior radial, flat-topped ribs, numbering about 13 on anterior portion of shell; distinguished from *Solemya peteri* Zinsmeister by being more narrowly elongate with more numerous and closely spaced ribs anteriorly; differs from S. rossiana Wilckens in being less inflated with more pronounced ribs anteriorly.

Description.-Shell medium-sized, thin, elongated, very narrowly subovate to subrectangular, compressed; umbones small, beak slightly sunken, located about a quarter of the length of shell from posterior margin; dorsal margin gently sloping; posterodorsal margin short, straight to gently sloping, merging with well-rounded posterior margin; anterodorsal margin long, straight, merging with well-rounded? anterior margin; ventral margin long, straight; shell ornamented with radiating, moderately prominent, flat-topped ribs, the posterior portion of shell with fewer than 10, spaced moderately weak ribs, posterior ribs separated by two very broad ribs, situated along a perpendicular and slightly oblique line from umbones along dorsal margin; medial, broad ribs merge with anterior portion of shell with approximately 13, moderately strong, spaced, flat-topped ribs.

Dimensions.-Holotype Ge 5977 (AIM), length 38.0, height 14.5, width of paired valves 9.0 mm; paratype Ge 7654 (AIM), length 43.0 mm, height 18.0 mm; paratype Ge 7601.2 (AIM), length 33.5 mm incomplete, height 16.5 mm; paratype Ge 7707 (AIM), length 35.0 mm, height 15.5 mm.

Types.-Holotype Ge 5977 (AIM), paratypes, Ge 7654, Ge 7601.2, Ge 7707 (all AIM).

Figured specimens herein.-Ge 5977, Ge 7654, Ge 7601.2 (all AIM).

Material.-Four calcified, articulated specimens and probable fragments.

Localities.-Whakapirau Creek, Kaipara, Northland, Q08/f9637 (type); north side of promontory between Opu and Whakapirau creeks, Kaipara, Northland, Q08/f9639; concretion on shore, northwest side of Bull Point, Kaipara, Northland, Q08/f9626; shore of Otomatea Arm, 0.8 km northeast of Batley, Kaipara, Northland, Q08/f9636; ?Awakei Creek, tributary of Waitangi River, Bay of Islands, North Island, P05/f9502; Batley, Kaipara, Northland, Q08/f9023; ?Manu Creek, North Island, Z14/f8492; ?lower Shag Valley, Otago, South Island, J43/f6471; ?North Branch of the Waianakarua River, Otago, South Island, J42/f082.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon", ?Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from a small area in Kaipara, Northland, for certain; possibly Otago, South Island.

Discussion.-Solemya suroradiata n. sp. seems more closely related to a mid Eocene species, S. peteri Zinsmeister, 1984 (p. 1505, Fig. 3L; see also Stilwell and Zinsmeister, 1992, pp. 52-53, Pl. 1, Fig. r), from the La Meseta Formation of Seymour Island, Antarctic Peninsula, than to a Late Cretaceous species, S. rossiana Wilckens, 1910 (pp. 65-67, Pl. 3, Fig. 9; also Zinsmeister and Macellari, 1988, pp. 258-259, Fig. 3.12-3.15), also from Seymour Island, or to undescribed Tertiary species from New Zealand. Solemya suroradiata n. sp. is more narrowly elongate with more numerous and more closely spaced ribs on the anterior portion of the valves, compared to S. peteri. Solemya rossiana is more inflated anteriorly with fewer, less pronouced ribs on the anterior portion of the valves. A New Zealand, Late

Miocene *Solemya* sp., *S*. n. sp. of Marwick, 1931 (p. 48, Fig. 1), was left in open nomenclature, presumably due to poor preservation of his material and unfortunately an accurate assessment of the differences between *S*. *suroradiata* n. sp. and *S*. n. sp. of Marwick (1931) is not possible at present. *Solemya suroradiata* n. sp. is one of the rarest Late Cretaceous bivalve taxa with only four collected specimens. One specimen of *S*. *suroradiata* n. sp., discovered in the collections housed at the Auckland Institute and Museum (Ge 5977, AIM), was misidentified as *Anthonya* sp. and is herein designated as holotype. A specimen identified by Stilwell *in* Aitchison *et al*. (1993, p. 50) as *Solemya*? sp. from the Maastrichtian Katiki Formation of the North Branch of the Waianakarua River, Otago, may represent *S*. *suroradiata* n. sp., but is too incomplete for an accurate assessment.

Subclass PTERIOMORPHIA Beurlen, 1944

Order ARCOIDA Stoliczka, 1871

Superfamily ARCACEA Lamarck, 1809

Family ARCIDAE Lamarck, 1809

Subfamily ARCINAE Lamarck, 1809

Genus *BARBATIA* Gray, 1842

Barbatia Gray 1840, p. 151 [nomen nudum]; 1842, p. 81; 1847, p. 197.

Type species.-(by subsequent designation, Gray, 1857) *Arca barbata* Linné, 1758.

Synonyms.-See Newell *in* Moore (1969, p. N252) for extended list and also Abbott (1974, p. 421).

Biogeographic element.-Cosmopolitan (Newell *in* Moore, 1969, p. N252).

Discussion.-*Barbatia* species are uncommon in Upper Cretaceous rocks around the southern circum-Pacific. Only *Barbatia mackayi* Woods, 1917, from the South Island, New Zealand, is known with any certainty. Crampton and Moore (1990, p. 346) identified a possible species of *Barbatia* from the Upper Cretaceous Maungataniwha Sandstone of the Te Hoe River area, western Hawke's Bay, North Island, but more material is needed for a firm assignment. In New Zealand, *Barbatia* makes a first appearance in the Late Campanian (Piripauan Stage) record and disappears soon afterwards until the late Early Miocene (Altonian Stage). From the Miocene, *Barbatia* extends to the Recent in New Zealand where it is not particularly speciose.

Barbatia is characterized by having a generally small, compressed, elongate-ovate, inequilateral shell with a small, byssal gape and terminations that are rounded or subangular and slightly expanded (Newell *in* Moore, 1969; Abbott, 1974, p. 421; Dance, 1990, pp. 223-224) and extends from Jurassic to Recent, worldwide. *Barbatia* also has a variably developed ligament with closely spaced ligament grooves, a narrow taxodont hinge plate and relatively small teeth. *Barbatia* is an epibyssate suspension feeder (Warren and Speden, 1978, p. 50, Tab. 5). Note McKerrow (ed.) (1978, p. 317, Fig. 105) for a reconstruction of a Cretaceous benthic community, including *Barbatia*.

BARBATIA MACKAYI Woods, 1917

Plate 5 Figures 13-14

Barbatia mackayi Woods, 1917, p. 19, Pl. 6, Figs. 4a-4b; Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5.

Dimensions.-Holotype TM 2451 (IGNS), length 51.0 mm, height 31.5 mm, width of single valve, 10.0 mm.

Type.-Holotype TM 2451 (IGNS; Woods, 1917, Pl. 6, Fig. 4).

Type locality.-West wing of Haumuri Bluff, South Island, GS 13, O32/f8025 [S55/f25].

Figured specimen.-TM 2451 (IGNS).

Material.-One moderately preserved specimen, the holotype.

Localities.-Same as type and possibly O32/f8529 [S55/f529]; ?near Kekerengu River, Marlborough, South Island, P30/f8702; ?Mangahouanga, western Hawke's Bay, North Island V19/f26; ?Kaiwara River, North Canterbury, N33/f9811; ?Barrons Hill, Otago, I44/f8510.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous) and possibly Brighton Formation, Maungataniwha Sandstone (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Silverstream? Formation (Upper Cretaceous).

Geographic distribution.-East coast of South Island (South Marlborough) and possibly east coast of North Island and southeastern South Island.

Discussion.-*Barbatia mackayi* Woods, 1917, is a rare species known only for certain from a narrow interval in the lower part of the Okarahia Sandstone, Haumuri Bluff, South Island (See Warren and Speden, 1978, p. 13, Fig. 3 for position of GS 13, O32/f8025 [S55/f25], within section). Virtually no new data are available for this species, except for possible geographic extensions. The size, sculpture and outline of B. mackayi are strikingly similar to the type species of Barbatia, B. barbata (Linné, 1758) (refigured by Newell in Moore, 1969, p. N252, Fig. C2-6a, b) from the Recent of the Mediterranean, but the radial sculpture of B. mackayi is more subdued and ribs more flattened. The hinge of B. mackayi is unknown.

Family CUCULLAEIDAE Stewart, 1930

Discussion.-Zinsmeister and Macellari (1988, p. 259) reviewed in detail the taxonomic uncertainties of the relationships between the Parallelodontidae and Cucullaeidae and stated that assignment of some genera to either of the above families is "somewhat arbitrary" as "no precise limits have been defined to separate the two families". Until a detailed phylogenetic study has been accomplished, the relationships of the two families will remain obscurred.

Five cucullaeid groups are represented in the Late Cretaceous record of New Zealand. These are Cucullaea s. s., C. (Cucullastis), Nordenskjoeldia, Austrocucullaea, and Indogrammatodon. The latter two genera are reported here in the New Zealand Cretaceous fossil record for the first time. Crampton (1988, p. 23, Tab. 1) recorded the presence of Cucullaria? in the basal breccia-conglomerate facies of the Maungataniwha Sandstone of northern Hawke's Bay, North Island, but his identification can only be considered tentative, pending further work. Cucullaeid bivalves are conspicuously absent in the Cretaceous macrofauna of Northland.

Genus CUCULLAEA Lamarck, 1801

Cucullaea Lamarck, 1801, p. 116.

Type species.-(by subsequent designation, Children, 1823) *Cucullaea auriculifera* Lamarck, 1801.

Synonyms.-*Cucullana* Lichtenstein, 1818; *Dicranodonta* Woods, 1899; *Ashcroftia* Crickmay, 1930; *Archaeodon* Crickmay, 1930 (Newell *in* Moore, 1969, p. N260).

Biogeographic element.-Indo-Pacific/Tethyan?, as inferred here.

Discussion.-*Cucullaea* Lamarck may be separated from *Austrocucullaea* Zinsmeister and Macellari, 1988, as the latter genus has "narrow, rounded, radial ribs with relatively wide interspaces with fine secondary riblets" (p. 259). *Cucullaea*, a shallow burrower and infaunal suspension feeder (Macellari, 1988, p. 42), is a shallow water group found today and in the geologic past in inner or mid-shelf environments (Maxwell, 1988b, p. 20; Beu and Maxwell, 1990, p. 76).

Cucullaeid bivalves have been identified from several localities throughout New Zealand. *Cucullaea* was first identified in the New Zealand Cretaceous by von Haast (1871, p. 35), who noted the presence of the group in the lower sandstone layer of Haumuri Bluff ("Amuri Bluff Beds"), southern Marlborough, South Island. Most likely, this species of *Cucullaea*, noted by von Haast, is *C*. (*Cucullastis*) *zealandica* Woods, 1917, which is now known to be present in numerous localities in the Haumuri Bluff area. Poorly preserved specimens of *Cucullaea* or those specimens of uncertain affinity are known from (refer to Appendix for locality and stratigraphic details): I44/f8489, ?V19/f6511, V19/f6649, W18/f10, W18/f14A, J43/f6472, J43/f6494, ?O32/f8514, O32/f8787, P05/f9499, and V18/f6909.

Subgenus CUCULLAEA s. s.

CUCULLAEA cf. C. ANTARCTICA Wilckens, 1905

Plate 6 Figures 1-2, 5

cf. *Cucullaea antarctica* Wilckens, 1905, pp. 36-37, Pl. 6, Figs. 5a-b, 6; Zinsmeister and Macellari, 1988, pp. 261-262, Figs. 5.11-12 and 7.1-7.

Dimensions.-TM 7468 (IGNS) length 63.0 mm, height 58.5 mm; TM 7469 (IGNS) length of hinge 42.0 mm.

Type.-Lectotype, MLP 9116 (designated by Zinsmeister and Macellari, 1988, p. 261).

Figured specimens.-TM 7468 (IGNS), TM 7469 (IGNS).

Material.-Two incomplete specimens.

Locality.-Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6909.

Stratigraphic range.-Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Restricted to western Kawke's Bay.

Discussion.-Two incomplete specimens labelled as *Cucullaea* n. sp. cf. *Cucullaea* sp. of Woods, 1917, and housed at IGNS in Lower Hutt, TM 7468 and TM 7469 from GS 11359, are very similar to figured specimens of the Late Cretaceous species, *Cucullaea antarctica* Wilckens, 1905 (pp. 36-37, Pl. 6, Figs. 5a-b, 6), the type locality of which is Sierra de Los Baguales in Argentina and not Antarctica. Recently, Zinsmeister and Macellari (1988. p. 261-262, Figs. 5.11-12; 7.1-7) extended the geographic distribution of *C. antarctica* to include the Antarctic Peninsula where it ranges on Seymour Island from Unit 6 to the middle part of Unit 9 of the Lopez de Bertodano Formation (upper

Maastrictian) and is locally abundant. One specimen from western Hawke's Bay (TM 7468, IGNS) has an outline, sculpture and duplivincular ligament structures of successive chevrons like C. antarctica, but the umbones are more curved. The subhorizontal pseudolateral teeth of TM 7469 (IGNS) are also very similar to C. antarctica. One of the specimens, TM 7468 has the curved umbones similar to Cucullaea sp. of Woods, 1917, Pl. 7, Fig. 3, and seems different from the supposed same species figured in Pl. 7, Figs. 2a-b, but the sculpture appears not to be the same. More material is needed before the species can be firmly assigned to C. antarctica or given a new name.

Subgenus CUCULLASTIS Finlay and Marwick, 1937

Cucullastis Finlay and Marwick, 1937, p. 20.

Type species.-(by orginal designation) Cucullaea (Cucullastis) barbara Finlay and Marwick, 1937.

Biogeographic element.-Endemic as inferred here.

Discussion.-Cucullaea (Cucullastis) was proposed by Finlay and Marwick (1937, p. 20) for a cucullaeid group that is "easily distinguished by its great inflation and high, broad beaks, combined with the vertically compressed disk and sinused ventral margin, also by the sculpture of spaced, raised ribs on the left valve". Curiously, Finlay and Marwick failed to explicitly differentiate between Cucullaea (Cucullona) and C. (Cucullastis), both newly erected subgenera from the Paleocene of New Zealand. Finlay and Marwick (1937, p. 21) decided that C. (Cucullastis) barbara and C. zealandica Woods, 1917, are probably closely related and of the same lineage, but this relationship could only be treated as tentative as no hinges of *C. zealandica* were available to them. Although the hinge of *C. zealandica* is still unknown, this species, as Finlay and Marwick conjectured, is most probably related to the *C.* (*Cucullastis*) group.

Newell *in* Moore (1969, p. N260) treated *Cucullaea* (*Cucullastis*) as a synonym of *Cucullaea* s. s., but he did not discuss his reasons for this seemingly unwarranted synonymy. *Cucullaea* (*Cucullastis*) has a subquadrate outline, very high umbones, a pronounced concavity medially along the ventral margin, and a relatively broad hingeplate with subhorizontal teeth quite unlike *Cucullaea* s. s. These two groups are distinct and should be treated as such at least at subgenus-level, if not perhaps at genus-level.

Cucullaea (*Cucullastis*) is an apparently endemic group and has not been reported outside the New Zealand area. In New Zealand the range of *C.* (*Cucullastis*) is Late Campanian to Danian.

CUCULLAEA (*CUCULLASTIS*) *ZEALANDICA* (Woods, 1917)

Plate 6 Figures 3-4, 6-10

Cucullaea zealandica Woods, 1917, p. 20, Pl. 6, Figs., 7a, 7b; Pl. 7, Fig. 1.

Cucullaea (*Cucullastis*) *zealandica* Woods, 1917, Fleming *in* Wellman, 1959, p. 141; Warren and Speden, 1978, p. 38, Fig. 25-9; Stilwell *in* Aitchison *et al*., 1993, Fig. 3b-c.

Types.-Lectotype TM 2450 (IGNS; Woods, 1917, Pl. 6, Fig. 7; Warren and Speden, 1978, Fig. 25-6); TM 2459 (IGNS; Woods, 1917, Pl. 7, Fig. 1).

Dimensions.-TM 7470 (IGNS) length 42.0 mm, height 32.0 mm; TM 7471 (IGNS) length 36.0 mm incomplete; TM 7473 (IGNS) length 59.5 mm incomplete; TM 7474 (IGNS) length 32.5 mm.

Figured specimens.-TM 2450, TM 2459, TM 7470, TM 7471, TM 7473, TM 7474 (all IGNS).

Material.-Ten specimens.

Localities.-Western Hawke's Bay, Mangahouanga Stream float *3, North Island, of Crampton and Moore (1990); north face of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 [S55/f25], O32/f9504 [S55/f504], O32/f9529 [S55/f529], O32/f9530 [S55/f530], O32/f9027 [S55/f27], O32/f9028 [S55/f28]; Okarahui Stream, southern Marlborough, O32/f8790; lower Conway rail cutting, southern Marlborough, O32/f8793; ?tributary of Mikonui Stream, southern Marlborough, O32/f8788; just south of Mikonui Stream, O32/f8774A; near Kekerengu River, Marlborough, P30/f8702; North Branch of the Waianakarua River, South Island, J42/f082, J42/f178, J42/f215, J42/f218; Shag Point, South Island, J43/f159, J43/f6544 (see OU 11120); ?Chatham Islands, southwestern side of neck of Taruwhenua Peninsula CH/f257 and CH/f257A, western side of base of Taruwhena Peninsula, CH/f587, Whenuatara (= Tarawhenua) Peninsula, west of Flowerpot Bay, CH/f345, eastern Pitt Island, CH/f11 and Flowerpot Harbour, Pitt Island CH/f466.

Stratigraphic range.-Maungataniwha Sandstone (upper Piripauan to Haumurian stages, upper Campanian to Maastrichtian, Upper Cretaceous); Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous); ?Kahuitara Tuff (Upper Cretaceous).

Geographic distribution.-Eastern North Island, east coast of South Island and possibly the Chatham islands.

Discussion.-*Cucullaea* (*Cucullastis*) *zealandica* is closely related to and probably the ancestor of the Early Paleocene species, *C*. (*Cucullastis*) *barbara* Finlay and Marwick, 1937 (p. 20, Pl. 1, Figs.11, 14, 15, 16; Fleming, 1966, Pl. 5, Figs. 80-82, Pl. 6, Fig. 83; Suggate, 1978, Fig 7.2-3; Speden and Keyes, 1981, Pl. 24, Fig. 3), from the Wangaloa Formation of South Island. The pronounced medial concavity along the ventral margin of *C*. (*Cucullastis*) *zealandica* is not as well-developed as in *C*. (*Cucullastis*) *barbara* and also the outline of *C*. (*Cucullastis*) *zealandica* is obliquely subtapezoidal and is unlike the subquadrate to subovate outline of *C*. (*Cucullastis*) *barbara*. The outline of *C*. *argentina* Feruglio, 1936 (pp. 100-101, Pl. 12, Figs. 4, 5), is superficially similar to *C*. (*Cucullastis*) *zealandica*, but the generally poor preservation of both species prevents a more detailed comparison. Zinsmeister and Macellari (1988, p. 263) stated that the type specimens of *C*. *argentina* housed at the University of Bologna, Italy, are poorly preserved casts and "should not have been used to define a valid species". Wilckens (1910, p.31, Pl. 2, Figs. 12, 13) erected the species *C*. *grahamensis* for a group restricted to the Late Cretaceous of Snow Hill Island, Antarctic Peninsula. As in the case of *C*. *argentina*, *C*. *grahamensis* was based on a single, poorly preserved specimen in a concretion, so that comparisons with other *Cucullaea* species are extremely difficult. Chavan *in* Routhier (1953, p. 59, Pl. 3, Fig. 5a-5b) and Freneix (1958, pp. 195-196;

1960, pp. 18-20, Pl. 1, Fig. 2) figured a species from the Late Cretaceous of New Caledonia that they considered to be closely related to *C.* (*Cucullastis*) *zealandica*, but this species has been more recently found not to be conspecific and not closely related to *C.* (*C.*) *zealandica*. The New Caledonia species was given a new name, *Cucullaea* (*Idonearca*) *gadjica* Freneix, 1980 (pp. 85-86, Pl. 2, Fig. 4). *Cucullaea* (*Cucullastis*) *zealandica* is not closely related to other Late Cretaceous cucullaeid bivalves around the southern circum-Pacific and the subgenus represents a highly provincial group along the eastern sector of the then fragmenting Weddellian Province, and also a somewhat unsuccessful group as it became extinct sometime during the Paleocene. *Cucullaea* (*Cucullastis*) *zealandica* was probably suspension feeder and shallow burrower of low mobility (Warren and Speden, 1978, p. 50, Tab. 5; Crampton and Moore, 1990, p. 346).

CUCULLAEA sp.

Plate 5 Figures 8, 11

Cucullaea sp., Woods, 1917, p. 20, Figs. 2, 3; Crampton and Moore, 1990, Fig. 8B.

Figured specimens.-TM 2457 (IGNS; Woods, 1917, Pl. 7, Fig. 3); TM 2458 (IGNS; Woods, 1917, Pl. 7, Fig. 2); TM 6867 (IGNS; Crampton and Moore, 1990, Fig. 8B).

Localities.-Haumuri Bluff, South Island, O32/f8025 [S55/f25], O32/f9027 [S25/f27]; Te Hoe River area, western Hawke's Bay, North Island V18/f8500, V19/f6909, Mangahouanga Stream float *3 of Crampton and Moore (1990).

Statigraphic distribution.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Maungataniwha Sandstone (Piripauan to Haumurian? stages, upper Campanian to Maastrichtian?, Upper Cretaceous).

Geographic distribution.-Eastern North Island and central eastern South Island.

Discussion.-Virtually no new data are available for this problematic species, except for a geographic and possibly geologic range extension. *Cucullaea* sp. of Woods, 1917, was reported by Crampton and Moore (1990, p. 340, Fig. 8B) to be present also in the western Hawke's Bay area, but their material was equally poorly preserved as the original material collected from Haumuri Bluff. The relationship of *Cucullaea* sp. to the New Zealand Late Cretaceous species *C*. (*Cucullastis*) *zealandica* and *C*. cf. *C*. *antarctica* is uncertain, but sculptural features of *C*. sp. indicate that this species is distinct from other Cretaceous *Cucullaea* species around the southern circum-Pacific. Wilckens (1920a, p. 263) in a review of the Upper Cretaceous bivalves of New Zealand (see translation by Marwick, 1921, p. 46) regarded *Cucullaea* sp. as probably conspecific with *C*. (*Cucullastis*) *zealandica*, but this synonymy is not supported here. Wilckens (1920a, p. 263) also believed that *Cucullaea* sp. is related to *C*. *grahamensis* Wilckens, 1910 (p. 31, Pl. 2, Figs. 12, 13) from the Late Cretaceous of Snow Hill Island, Antarctic Peninsula.

Genus *AUSTROCUCULLAEA* Zinsmeister and Macellari, 1988

Austrocucllaea Zinsmeister and Macellari, 1988, pp. 259-261.

Type species.-(by original designation) *Austrocucullaea oliveroi* Zinsmeister and Macellari, 1988.

Biogeographic element.-Paleoaustral, as interpreted here.

Discussion.-The "relatively long dorsally converging anterior pseudolateral teeth" of Austrocucullaea suggests placement within Cucullaeidae and the similarity of this genus with Indogrammatodon Cox, 1937, is superficial (Zinsmeister and Macellari, 1988). The denticulate ventral margin of Austrocucullaea also serves to distinguish this group from Indogrammatodon.

The previous sole record of Austrocucullaea from the upper units 8 and 9 (upper Maastrichtian) of the Lopez de Bertodano Formation of Seymour Islands, Antarctic Peninsula, is expanded herein to include the latest Cretaceous (probably Maastrichtian) of North Island, New Zealand.

AUSTROCUCULLAEA n. sp. cf. A. OLIVEROI Zinsmeister and Macellari, 1988

Plate 7 Figures 1, 4

Dimensions.-TM 7472 (IGNS) length 43.0 mm, height 37.0 mm.

Figured specimen.-TM 7472 (IGNS).

Material.-One specimen.

Locality.-Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6909.

Stratigraphic range.-Maungataniwha Sandstone (probably Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Western Hawke's Bay for certain.

Discussion.-A specimen (TM 7472 (IGNS)) labelled as Cucullaea (Cucullastis) zealandica Woods, 1917, at IGNS is not conspecific. This specimen represents a probable new species of the hitherto Maastrichtian Antarctic genus Austrocucullaea Zinsmeister and

Macellari, 1988, and is strikingly similar to *A. oliveroi* of Seymour Island. *Austrocucullaea* n. sp. cf. *A. oliveroi* differs from the Antarctic species in having finer primary radial riblets and more numerous secondaries and also more curved, sloping umbones. As only one example of the New Zealand species without an exposed hinge is available to me, I defer giving it a new name pending more material.

Genus *NORDENSKJOELDIA* Wilckens, 1910

Nordenskjöldia Wilckens, 1910, pp. 26-30; *Nordenskjoldia* Wilckens, Freneix, 1958, p. 22, error; *Nordenskjoldia* Wilckens, Vokes, 1980, p. 16, error; *Nordenskjoldia* Wilckens, Zinsmeister and Macellari, 1988, p. 259, error; *Nordenskjoldia* Wilckens, Aguirre-Urreta and Olivero, 1992, p. 212, error. As ruled by ICZN (1985, Article 32, Section d, Part i(2)), in a name published before 1985, based on a German word with a diacritic mark, the umlaut sign is deleted from a vowel and the letter "e" is to be inserted after that vowel.

Type species.-(by original designation) *Arca disparilis* d'Orbigny, 1846 (non Reeve, 1844) (= *Grammatodon subdisparilis* Nicol, 1954).

Biogeographic element.-Paleoaustral as inferred here.

Discussion.-The familial placement of *Nordenskjoeldia* was debated recently by Zinsmeister and Macellari (1988, p. 259) who decided that this genus is more appropriately placed within the Cucullaeidae and not the Parallelodontidae as assigned by Newell *in* Moore (1969, p. N258). Freneix (1960, pp. 22-23) regarded *Nordenskjoeldia* as a member of the Cucullaeidae, but in a later paper (Freneix, 1980, pp. 82-83) decided to assign the genus to the Parallelodontidae. The main diagnostic features of *Nordenskjoeldia* are short and dorsally converging (above the hinge line) anterior pseudolateral teeth and a denticulate margin which are more characteristic of the Cucullaeidae and not the Parallelodontidae (Zinsmeister and Macellari, 1988, p. 259). In agreement with Zinsmeister and Macellari (1988), *Nordenskjoeldia* is placed in the Cucullaeidae.

Freneix (1960, p. 23) reviewed the Cretaceous distribution of *Nordenskjoeldia*. The group has been reported from Upper Cretaceous rocks of South India, Madagascar, South Africa, Antarctic Peninsula, New Zealand, and New Caledonia. In New Zealand *Nordenskjoeldia* ranges from Late Campanian? to Maastrichtian and is represented by one species, *N. woodsi* Wilckens, 1920a. A Late Cretaceous cucullaeid species previously assigned by workers to *Nordenskjoeldia*, *N. hectori* (Woods, 1917), is reassigned to *Indogrammatodon*. Newell *in* Moore (1969, p. N258) in contrast recorded *Nordenskjoeldia* only from India and Madagascar and Zinsmeister and Macellari (1988, p. 259) recorded the group from Antarctica, Madagascar and New Caledonia. *Nordenskjoeldia*, an apparently short-lived bivalve taxon, had a fairly broad, austral distribution during the Late Cretaceous, but became extinct by Maastrichtian time. The group has not been reported to my knowledge in Cretaceous rocks of southern South America along the extreme western sector of the Weddellian Province.

Nordenskjoeldia was inferred to have been an epibyssate, nonsiphonate, infaunal, suspension feeder and a shallow burrower of low mobility (Warren and Speden, 1978, p. 50, Tab. 5; Freneix, 1981, p. 27, Fig. 3; Macellari, 1988, pp. 41-42).

NORDENSKJOELDIA WOODSI Wilckens, 1920a

Plate 7 Figures 3, 7

Nemodon? sp., Woods, 1917, p. 19, Pl. 6, Figs. 5a-b.

Nordenskjöldia woodsi Wilckens, 1920, p. 263 (not *N. woodsi* Marwick, 1921, as cited by Freneix, 1980, p. 18).

Nordenskjoldia woodsi Wilckens, 1920, Marwick, 1921, p. 46; Marwick and Fleming *in* Wellman, 1959, p. 138.

Dimensions.-Holotype TM 2455 (IGNS) length 57.5 mm incomplete, height 43.0 mm incomplete.

Type.-Holotype TM 2455 (IGNS; Woods, 1917, Pl. 6, Fig. 5).

Figured specimen herein.-TM 2455 (IGNS).

Material.-One poorly preserved specimen.

Localities.-"*Ostrea* bed, McKay's Creek, Middle Waipara", GS 149 (Woods, 1917, p. 19), M34/f7254, South Island.

Stratigraphic range.-Conway Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Discussion.-Wilckens (1920a) in a review of the Late Cretaceous bivalve fauna of New Zealand reassessed a species commented on by Woods (1917, p. 19), but left in open nomenclature, *Nemodon*? sp., and proposed a new name, *Nordenskjoeldia woodsi*, based on similarities of this species with *N. japetica* (Forbes) from the Late Cretaceous of South India, *N. nordenskjoeldi* Wilckens from the Late Cretaceous of the Antarctic Peninsula, and *N. disparilis* (d'Orbigny), the type species of *Nordenskjoeldia*. As a side note, Darragh and Kennedy (1991, p. 19) treated *N. japetica* as a species assignable to *Grammatodon* (*Nanonavis*), and not *Nordenskjoeldia*, but no discussion was made. The differences of these four species of *Nordenskjoeldia* are mainly in overall outline and orientation of hinge teeth. (See Marwick (1921) for a review and partial translation of Wilckens (1920)). It is interesting to note that Woods (1917, p. 19) compared his *Nemodon*? sp. with *Arca japetica* Forbes (= *Nordenskjoeldia*) and cited earlier Wilckens' (1910) paper in which Wilckens stated explicitly that *A. japetica* is a *Nordenskjoeldia* (p. 30), but he dismissed or inadvertently missed Wilckens' discussion of the group. As far as I am aware, no new material of *N. woodsi* has come to light, so the species can only considered as very rare in the New Zealand fauna.

Genus *INDOGRAMMATODON* Cox, 1937

Indogrammatodon Cox, 1937, p. 194.

Type species.-(by original designation) *Cucullaea virgata* J. de K. Sowerby, 1840.

Biogeographic element.-Indo-Pacific/Tethyan? as inferred here.

Discussion.-*Indogrammatodon* is reported from the New Zealand Cretaceous for the first time. Most workers have assigned *Indogrammatodon* Cox to the Parallelodontidae (Newell *in* Moore, 1969, pp. N257-N258; Freneix, 1980, p. 82; Vokes, 1980, p. 16), but Zinsmeister and Macellari (1988, p. 259) as discussed earlier queried the distinctiveness of the Cucullaeidae and Parallelodontidae, the limits of which are not well defined. Subtle morphological features separate *Nordenskjoeldia* Wilckens from *Indogrammatodon*, namely external sculpture and degree of asymmetry of the shell (translated from Freneix, 1980, p. 84). At this time Indogrammatodon seems more appropriately placed in Cucullaeidae.

Indogrammatodon is known from the Jurassic of India, Africa and Southwest Pacific (Newell *in* Moore, 1969), Late Cretaceous (Campanian) of New Caledonia, and Middle Jurassic (Marwick, 1953, pp. 89-90; Stevens and Fleming *in* Suggate *et al*., 1978, p. 713) to Late Cretaceous (Maastrichtian) of New Zealand. Indogrammatodon was an epibyssate, infaunal, suspension feeding bivalve that preferred silty substrates (Freneix, 1981, p. 27, Fig. 3), but as shown by its presence in Upper Cretaceous sandstones of South Island, New Zealand, could also tolerate coarser facies.

INDOGRAMMATODON HECTORI (Woods, 1917)

Plate 7 Figures 2, 5

"*Arca*" *hectori* Woods, 1917, p. 19, Pl. 6, Figs. 6a, 6b.

Nordenskjoldia hectori (Woods, 1917), Marwick and Fleming *in* Wellman, 1959, p. 138; Warren and Speden, 1978, p. 50, Tab. 5.

Indogrammatodon hectori (Woods), Stilwell *in* Aitchison et al., 1993, p. 50.

Dimensions.-Holotype TM 2456 (IGNS) length 38.5 mm, height 31.5 mm, width of single valve 10.5 mm.

Types.-Holotype TM 2456 (IGNS; Woods, 1917, Pl. 6, fig. 6).

Figured specimen.-TM 2456 (IGNS).

Localities.-"*Ostrea*" bed, Boby's Creek, Waipara", South Island, GS 277, M34/f7257 [S68/f257] (type); North face of Haumuri Bluff, South Island, O32/f8025 [S55/f25]; ?North Branch of Waianakarua

River, South Island, J42/f082.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Conway Formation (doubtfully Loburn Mudstone), ?Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-East coast of South Island from South Marlborough to possibly Waianakarua River, North Otago.

Discussion.-Indogrammatodon hectori (Woods, 1917) is a relatively rare cucullaeid species in the Late Cretaceous of New Zealand and is many times less abundant than Cucullaea (Cucullastis) zealandica Woods, 1917. Woods (1917, p. 19) was uncertain of the generic placement of I. hectori and tentatively assigned the species to "Arca", based on the species close external similarity to Arca disparilis d'Orbigny, 1846 (See Atlas volume, 1847, Pl. 8, Figs. 37, 38 (Woods, 1917, footnote, p. 19)), which was earlier designated by Wilckens (1910, p. 30) as the type species of Nordenskjoeldia (A specimen of Grammatodon (Nordenskjoeldia) subdisparilis Nicol, 1954, refigured by Newell in Moore, 1969, p. N258, Fig. C6-3a, 3b was considered by Newell as conspecific with N. disparilis (d'Orbigny (1846)). Indogrammatodon hectori is distinguished from N. disparilis from the Late Cretaceous of India, N. nordenskjoeldi Wilckens, 1910 (pp. 26-30, Pl. 2, Figs. 8a-8c, 9a-9b, 10, 11; Zinsmeister and Macellari, 1988, p. 259, Fig. 4.8-12) from the Late Cretaceous of the Antarctic Peninsula, and N. moindouensis Freneix, 1980 (pp. 83-84, Pl. 2, Fig. 3, See also Freneix, 1960, p. 22, Pl. 1, Fig. 4, Nordenskjoeldia sp.) from the Late Cretaceous of New Caledonia in having a less convex ventral margin and stronger, spaced primary radial ribs. Freneix

(1980, p. 18, translated from the French) thought that *I. hectori* appeared more closely related to *Indogrammatodon* Cox, a Jurassic to Late Cretaceous genus, than to *Nordenskjoeldia*, a relationship that is supported here. The overall outline and sculpture of *I. hectori* is similar to the type species of *Indogrammatodon*, *I. virgatus* (J. de C. Sowerby, 1840) (refigured by Newell *in* Moore, 1969, p. N258, Fig. C6-4a-c) and *I. lormandi* Freneix, 1960 (p. 20, Pl. 1, Fig.3; Freneix, 1980, pp. 83-84, Pl. 2, Figs. 1-2) from the Campanian of New Caledonia with its subquadrate shell, poorly defined posterior, umbonal ridge and narrow, widely spaced, radial costae, but *I. hectori* lacks the more pronounced commarginal sculpture of the above, compared species. No hinges of *I. hectori* are available for study.

As a sidenote *I. hectori* may be present in Upper Cretaceous deposits of the Katiki Formation, Waianakarua River, North Otago, but the specimens available are poorly preserved (Stilwell *in* Aitchison *et al.*, 1993, p. 50).

Superfamily LIMOPSACEA Dall, 1895

Family LIMOPSIDAE Dall, 1895

Genus *LIMOPSIS* Sassi, 1827

Limopsis Sassi, 1827, p. 476.

Type species.-(by original designation) *Arca aurita* Brocchi, 1814.

Synonyms.-Numerous; see Newell *in* Moore (1969, p. N265) and Abbott (1974, p. 425).

Biogeographic element.-Cosmopolitan (Newell *in* Moore, 1969, p. N265).

Discussion.-The presence of *Limopsis* in the New Zealand Late Cretaceous record is confirmed for the first time. Previously, Marwick and Fleming *in* Wellman (1959, p. 138) recorded *Limopsis*? sp. from the Haumurian Stage (Maastrichtian) of Kaipara, Northland, but their identification was tentative. Crampton amd Moore (1990, p. 346) reported *Limopsis* sp. from the Maungataniwha Sandstone (Upper Cretaceous) of western Hawke's Bay, North Island, but the identification was deemed "not confirmed" as this species was cited on earlier fossil lists and was not available for their re-examination. Although the record of *Limopsis* is new for the Cretaceous of New Zealand, members of the group were quite common throughout the early Cenozoic to Recent of New Zealand. The only major time gap for *Limopsis* s. s. in New Zealand is the group's apparent absence in the Paleocene to Early Eocene as no species have been reported. However, well-preserved specimens of a Mangaorapan to Heretaungan (Lower to Middle Eocene) species identified as *L*. aff. *waihaoensis* Allan, 1926, have recently been recognised in the "Pentland Hills" section, South Canterbury. This absence is most likely a reflection of the poor "deep-water" molluscan record of this time period.

Around the rim of the southern circum-Pacific, Late Cretaceous *Limopsis* species have been recorded elsewhere only from Seymour Island, Antarctic Peninsula (Wilckens, 1910; Zinsmeister and Macellari, 1988). The genus is not known from the Cretaceous of New Caledonia, Australia, or South America, but interestingly an unrecorded species is known from the middle Paleocene of southeastern Australia and *Limopsis* is known from the Tertiary of South America.

Limopsis s. s. is characterized by an obliquely ovate shape, sculpture without radial ornamentation and the inner margin is not crenulate (Newell *in* Moore, 1969, p. N265; cf. Abbott, 1974, p. 425), but many New Zealand Cenozoic species with some radial sculpture have been assigned to *Limopsis* s. s. (see Beu and Maxwell, 1990, for list and figures of various *Limopsis* taxa). *Limopsis griffini* n. sp. has very weakly developed radial sculpture and lacks a crenulate margin. Although intermediate in form, these limopsid species probably do not represent a new group or subgenus of *Limopsis*, but probably are variants within *Limopsis* s. s. and should probably be treated as such, pending further work. *Limopsis griffini* n. sp. seems much more closely related to *Limopsis* s. s. than to *Limopsis* (*Pectunculina*) which has very strong radial ribs and a crenulate margin.

Subgenus *LIMOPSIS* Sassi, 1827

LIMOPSIS s. s. *GRIFFINI* n. sp.

Plate 7 Figures 6, 9-10, 12

Diagnosis.-Shell average sized for genus, obliquely subquadrate to subovate, thin; antero- and posterodorsal margins nearly straight; shell mostly smooth except for weak, moderately crenulated commarginal growth lines and yet weaker radial striae; differs from *Limopsis antarctica* Wilckens which has a greater height to length ration, a less oblique shell, and a shorter dorsal margin compared to *L. griffini* n. sp.

Description.-Shell of average size for genus, thin, obliquely subquadrate to subovate, moderately inflated; height to length ratio slightly greater than one; umbones moderately prominent but small, projecting, subcentral, slightly curved; dorsal margins mostly straight, sloping gently from umbones; anterdorsal margin short, straight, subhorizontal merging with subangular anterodorsal-anterior margin; anterior margin moderately convex, more rounded ventrally; posterodorsal margin moderately long, straight, very gently sloping merging with obtusely angulate posterodorsal-posterior margin; posterior margin gently convex; ventral margin convex; shell mostly smooth or polished, commarginal sculpture of indistinct, crenulated grooves of different widths, stronger more ventrally; radial sculpture weak, of indistinct threads, stronger at intersection of radial threads and commarginal crenulations; radial sculpture not visible on umbones; sculpture at anterodorsal and posterodorsal margins with a near beaded appearance; anterior adductor scar situated near lower end of hinge, elongate ovate?; ventral margin smooth.

Dimensions.-Holotype L 3870 (from AU 2574) (AU) length 10.0 mm, height 10.5 mm; paratype Ge 7612 (AIM) length 5.0 mm, height 3.5 mm incomplete; paratype Ge 7617 (AIM) length 6.0 mm incomplete, height 6.0 mm incomplete; paratype Ge 7689 (AIM) length 5.0 mm, height 5.5 mm; paratype TM 7513 (IGNS) length 11.0 mm, height 11.0 mm.

Types.-Holotype L3870 (from AU 2574) (AU); paratypes Ge 7612, Ge 7617, Ge 7689 (All AIM), TM 7513 (IGNS).

Figured specimens.-Holotype L 3870 (AU); paratypes Ge 7612 (AIM), Ge 7617 (AIM), TM 7513 (IGNS).

Material.-13 calcified, mostly disarticulated, incomplete specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9909 (type), Q08/f9626; north side of promontory between Opu and Whakapirau creeks, Northland, Q08/f9639; concretion on shore, northeastern side of Bull Point, Kaipara, Northland, Q08/f9626; shore of Otamatea River, 0.8 km north of Batley, Northland, Q08/f9636; ?Batley, Kaipara, Northland, Q08/f9023; northeastern shore of Kawitu Estuary, Hokianga, Northland, O05/f9596; ?"small stream" (unnamed), Porangahau, North Island, V24/f6484; ?Te Rata Stream, North Island, Y16/f203; ?Clark Creek, Manu Creek S. D., North Island, Z14/f8492 and Z14/f8493; ?Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6909.

Stratigraphic range.-Unspecified horizon with Unit 4 of Evans (1985), formation unspecified, "Northland Allochton", and ?Whangai Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous); ?Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Species known for certain from several localities in Northland only; specimens of *Limopsis* from Manghouanga Stream may also represent this species.

Discussion.-*Limopsis griffini* n. sp. is apparently not closely related to a coeval species, *L. antarctica* Wilckens (1910, pp. 31-32, Pl. 2, Figs. 14, 15; also figured by Zinsmeister and Macellari, 1988, p. 263, Fig. 8.1), from the Antarctic Peninsula. The latter Antarctic species has a greater height to length ratio, a less oblique shell, and a shorter dorsal margin compared to *L. griffini* n. sp. Only the faint commarginal and radial ornamentation of the two above species are comparable. Zinsmeister and Macellari (1988, p. 263) were faced with a similar dilemma in revising the taxonomy of *Limopsis antarctica* as only the holotype of this species showed any signs of radial ornamentation (a general feature of *L.* (*Pectunculina*) and not *Limopsis* s. s.), as additionally collected material revealed no evidence of radial ornamentation whatsoever. Zinsmeister and Macellari's material of *L. antarctica* also lacked the crenulate margin that is present in species of *L.* (*Pectunculina*). The weak radial ornamentation, coupled with a smooth margin, forced their assignment of *L. antarctica* to *Limopsis* s. s., not *L.* (*Pectunculina*), a decision that is followed here for *Limopsis griffini* n. sp. Although no hinges were available for study, *L. griffini* n. sp. is clearly distinguishable by external features from contemporaneous and penecontemporaneous *Limopsis* species. Freneix (1972, pp. 71-72, Pl. 1, Fig. 10a-b, text-figs. 2-3) described a limopsid species, *L.* (*L.*) *atlantica*, from the Late Albian of "Bassin côtier de Tarfaya (Maroc méridional)". *Limopsis atlantica* appears quite similar to *L. griffini* n. sp. in sculpture and outline, but *L. griffini* n. sp. has a slightly less oblique shell, more numerous commarginal crenulations, and more inflated umbones, compared to *L. atlantica*. *Limopsis griffini* n. sp. seems most closely related to Paleogene taxa, such as *L. waihaoensis* Allan, 1926 (p. 346, Pl. 77, Figs. 8a-b; recently refigured by Beu and Maxwell, 1990. p. 114, Pl. 7, Figs. c, d; Maxwell, 1992, p. 62, Pl. 2, Figs. d-g) from the Late Eocene of New Zealand (except for slight differences in outline and sculpture), and *L. waihaoensis* may be a lineal descendent of *L. griffini* n. sp. In general outline, *L. griffini* n. sp. is not unlike a Tertiary species *L. insolita* (Sowerby, 1846) (refigured in Ortmann, 1902, p. 91, Pl. 25, Fig. 6) from the Patagonian beds, southern South America. Limopsis species are today generally deep-water, and L. griffini n. sp. is interpreted to have lived on the mid to outer shelf of "greater New Zealand" during the latest Cretaceous.

Etymology.-Species named after M. Griffin, Museo de La Plata, Argentina, for his work on the fossil bivalve and gastropod faunas of southern South America.

Family GLYCYMERIDIDAE Newton, 1922

Subfamily GLYCYMERIDINAE Newton, 1922

Genus GLYCYMERITA Finlay and Marwick, 1937

Glycymerita Finlay and Marwick, 1937, p. 22.

Type species.-(by original designation) Glycymeris concava Marshall, 1917.

Biogeographic element.-Indo-Pacific/Tethan (cf. Fleming, 1967, Appendix 1, p. 115).

Discussion.-Glycymerita was well-established in the South Pacific by late Campanian time. Early Cretaceous species from Europe and Japan formerly referred to Glycymerita may actually belong to Glycymeris (Hanaia) (Toshira, 1971, p. 233). Beu and Maxwell (1990, p. 78) in a review (see also Tashiro, 1971, p. 228) of the type species of Glycymerita, G. concava Marshall, 1917, stated that this genus ranges in New Zealand from the Late Cretaceous to Late Pliocene (Waipipian Stage) and is known elsewhere from California and Europe, essentially that stated by Newell in Moore (1969, p. N267). In New Zealand, Glycymerita first appears in upper Campanian sediments of South Island. The geographic range of Glycymerita is actually more extensive than that reported by

Newell *in* Moore (1969) and Beu and Maxwell (1990). In a review of Late Cretaceous glycymeridids from Japan, Toshiro (1971) stated that *Glycymerita* species flourished in the Late Cretaceous of Japan with several taxa having been recorded. Elder and Saul (1993) figured previously described *Glycymerita* species from the Campanian of California, North America (see Pl. 1, Figs. 3-4). Frassinetti and Covacevich C. (1983-1984, pp. 118-124) reported species of *Glycymerita* from the Miocene of central Chile and also noted the presence of the group in Patagonia. Zinsmeister (1981, p. 1092) revised a previously described species of *Glycymeris* from the Eocene of Santa Cruz Province, southern Argentina, and reassigned the species to *Glycymerita*, extending the geographic range of the group. Del Rio (1992) recently described a Middle Miocene species of *Glycymerita* from Chubut, Argentina. In a seldom cited and relatively unknown work entitled (translated from Russian) "Atlas of the Fauna of the Paleogene and Neogene of the Northeastern U. S. S. R.", Devyatilova and Volobueva (1981) recorded eight species of *Glycymerita* from the Tertiary (see pp. 36-39, Pls. 11, 12). Glycymeridid taxa, usually indicators of warm-temperate environments, are conspicuously absent in the Late Cretaceous record of Antarctica and also from the inferred warm temperate early Paleogene record of Antarctica (Stilwell and Zinsmeister, 1992, p. 43). *Glycymerita* is unknown from New Caledonia and Australia. Fleming (1967, p. 115) considered *Glycymerita* to be a warm-water, Indo-Pacific genus which is followed here.

The most prominent features of *Glycymerita* are a subquadrate, inflated shell; prominent umbo; long, robust hinge; and also strong, radial sculpture (Finlay and Marwick, 1937, p. 22; Newell *in* Moore, p. N267; Tashiro, 1971, p. 228; cf. Beu and Maxwell, 1990, p. 78). Although *Glycymerita* is usually assigned as a subgenus of *Glycymeris*, *G*. (*Glycymerita*), the above features are sufficiently different from *Glycymeris* s. s. to warrant its elevation to generic rank and also because the family is a conservative one (Beu and Maxwell, 1990, p. 78).

GLYCYMERITA SELWYNENSIS (Woods, 1917)

Plate 7 Figures 11, 13-19

Pectunculus selwynensis Woods, 1917, p. 20. Pl. 7, Figs. 4-7.

Glycymeris selwynensis (Woods), Marwick, 1923, p. 63.

Glycymeris (*Glycymerita*) *selwynensis* (Woods, 1917), Finlay and Marwick, 1937, p. 22; Marwick and Fleming *in* Wellman, 1959, p. 138; Warren and Speden, 1978, p. 50, Tab. 5.

Supplementary description.-Shell moderately small for genus, thick, subquadrate, well-inflated; umbones prominent, central; anterodorsal margin short, gently sloping, gently convex; anterior margin slightly concave adjacent to intersection of anterodorsal and anterior margin; anterior margin convex overall; posterodorsal margin longer than anterodorsal margin, gently sloping, gently convex, merging towards a slightly oblique, truncated, posterior margin; ventral margin well-rounded, convex; radial sculpture predominant, of about 35 flattened, strong, equally spaced ribs, that become somewhat obsolete on some specimens at anterodorsal and posterodorsal margins; commarginal sculpture extremely fine; details of hinge not known; inner margin very strongly crenulate.

Dimensions.-TM 7475 (IGNS) from GS 2157, length 23.5, height 21.5 mm, width of paired valves 17.0 mm; TM 7476 (IGNS) length 22.0 mm, height 21.0 mm.

Types and previously figured specimens.-Lectotype TM 2464 (IGNS; Woods, 1917, Pl. 7, Fig. 7); TM 2461 (IGNS; Woods, 1917, Pl. 7, Fig. 6); TM 2462 (IGNS; Woods, 1917, Pl. 7, Fig. 4); TM 2463 (IGNS; Woods, 1917, Pl. 7, Fig. 5).

Figured specimens herein.-TM 2461-TM 2464, TM 7475, TM 7476 (all IGNS).

Material.-Three specimens.

Localities.-Selwyn Rapids beds of Selwyn River, Canterbury, South Island (GS 23), L35/f6017 (type); Selwyn River Rapids, South Island (GS 589), L35/f6510; north face of Haumuri Bluff, South Island, O32/f9529 [S56/f529], O32/f8025 [S55/f25]; east wing of Haumuri Bluff, O32/f9031 [S56/f31]; ?Gorries Creek, Canterbury, South Island, N34/f42; ?north flowing tributary into Ruatohuna Stream, south of Ruatahuna, W18/f7601; north face of Haumuri Bluff, southern Marlborough, South Island, O32/f9529; ?Waitangi River, Bay of Islands, North Island, P05/f9491.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds (Upper Cretaceous) Conway Formation? (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Eastern central South Island.

Discussion.-Marshall (1917, p. 459) was the first to note the close relationship of Glycymerita selwynensis (Woods, 1917) (then an undescribed form) to G. concava (Marshall, 1917) (p. 459, Pl.

36, Fig. 42). Marwick (1923, p. 63) commented further on the relationship of the above species in his review of *Glycymeris* species in the Tertiary of New Zealand. The ancestor-descendent relationship of *G. selwynensis* to *G. concava* seems fairly clear and the most noticeable and profound change is the great increase in shell size from the Campanian to Paleocene. The average length and height doubled during this time period. As specimens of *G. selwynensis* are known from the upper Maastrichtian and *G. concava* is reported from inferred lower Danian rocks, this change would have occurred in a relatively short period of time, of which there is no record in New Zealand. This hypothesis may in the future be weakened, however, by more information on a second, very poorly preserved, unnamed species, *Pectunculus* sp. of Woods, 1917 (most likely a *Glycymerita*), as this species is comparable in size to *G. concava*.

Glycymerita selwynensis is morphologically very similar to several Late Cretaceous species assigned to this genus from Japan and California (see Tashiro, 1971, for figured, representative taxa from these areas) which suggests that species of the genus were well established around the Pacific by this time and perhaps earlier radiated from shallow European waters. The relationship of *G. selwynensis* to a second species *Glycymerita* sp. from the Late Cretaceous of New Zealand (Waimate and Haumuri Bluff), figured in this work (also see Woods, 1917, p. 20, Pl. 7, Fig. 8), is unclear due to very poor preservation and no new data. *Glycymerita* sp. is much larger than *G. selwynensis*. *Glycymerita selwynensis* was probably an infaunal non-siphonate suspension feeding, shallow burrowing bivalve of low mobility (Warren and Speden, 1978, p. 50, Tab. 5) and most records of Glycymerita are from the inferred inner or middle shelf (Beu and Maxwell, 1990, p. 78).

Order MYTILOIDA Fèrussac, 1822

Superfamily MYTILACEA Rafinesque, 1815

Family MYTILIDAE Rafinesque, 1815

Discussion.-The bivalve family Mytilidae has troubled molluscan systematists, neontologists and especially paleontologists, for decades with its numerous groups of various forms and the minute amount of information available on Cretaceous taxa is no exception to this problematic group. In a recent study of Late Cretaceous bivalves of northwestern Australia, Darragh and Kendrick (1991, p. 15) underscored the extent of what is known about Cretaceous mytilids and commented, "As a group, the Cretaceous mytilines appear to need revision and the systematic relationships of our species with those described previously remain unclear." For many Cretaceous mytilid bivalves, Mytilus has been used as a taxonomic "grabbag" and until a rigorous revision is made of this group little improvement can be expected. Unfortunately, the Cretaceous record for Mytilus-like bivalves in New Zealand is generally poor with only one species known and in this case the species seems more closely related to Lycettia, instead of the Mytilus (s. l.) sp. assignment given by Crampton and Moore (1990) (refer to discussion of Lycettia cf. L. foaensis below.). The record for Modiolus is better for the Cretaceous of New Zealand, but even then at least three species names have been previously assigned and, in my opinion, these names discussed below should be used with caution and are more appropriately, in some instances, assignable to different genera such as *Inoperna* and *Lycettia*. One possible record of the Crenellinae, *Arcoperna*? sp., derived the Maugataniwha Sandstone (Upper Cretaceous) and reported by Crampton and Moore (1990, p. 346), is not discussed here.

Subfamily MYTILINAE Rafinesque, 1815

Genus *LYCETTIA* Cox, 1937

Lycettia Cox, 1937, p. 345.

Type species.-(by original designation) *Mytilus lunularis* Lycett, 1857).

Synonym.-*Cuneolus* Stephenson, 1941 (Soot-Ryen *in* Moore, 1969, p. N273).

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-*Lycettia* is characterised externally by smooth, nacreous, falcate shells with a sharp carina parallel to and extending along the ventral margin and terminal beaks (Soot-Ryen *in* Moore, 1969, p. N273). The genus was moderately widespread in the Jurassic and the geographic distribution of *Lycettia* is extended further for the Late Cretaceous by its presence in New Zealand. Two species of *Lycettia*, *L*. cf. *foaensis* Freneix, 1980, and *L*. *lanceolata* Sowerby, are reported here from the New Zealand Cretaceous. Previously *Lycettia* was known in the Late Cretaceous only from Texas (Soot-Ryen *in* Moore, 1969, p. N273) and New Caledonia (Freneix, 1980, pp. 87-88). The inferred mode of life for *Lycettia* was a sessile, epibyssate, suspension-feeding habit (Freneix, 1980, p. 88).

LYCETTIA cf. L. FOAENSIS Freneix, 1980

Plate 8 Figure 6

cf. Lycettia foaensis Freneix, 1980, pp. 87-88, Pl. 2, Figs. 6-7.

Decription.-Shell moderately small, moderately inflated, arcuate mytiliform; beaks terminal; anterodorsal margin mostly straight, merging towards a dorsal margin that is strongly convex medially; ventral margin concave resulting in a gently arcuate general outline of the shell; umbonal ridge moderately developed, paralleling the ventral margin; shell mostly smooth except for closely spaced commarginal growth lines and more pronounced, unequally spaced growth pauses.

Dimensions.-TM 7477 (IGNS) length 22.5 mm, height 15.0 mm, width of single valve 6.0 mm.

Figured specimen.-TM 7477 (IGNS).

Material.-One, disarticulated specimen.

Locality.-Float *3 of Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6909 (Crampton and Moore, 1990).

Stratigraphic range.-As float within Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Presently limited to western Hawke's Bay, North Island.

Discussion.-The exact taxonomic placement of Lycettia cf. L. foaensis is problematic with available material, but the species seems closely related to a Late Cretaceous New Caledonian form erected by Freneix in 1980, except that the New Zealand species has a slightly more convex dorsal margin and the shell is less elongate. Although this species most likely represents a new group, the erection of a new species is deferred here until more material has been discovered. *Lycettia* cf. *L. foaensis* is only reminiscent morphologically to the geographically widespread species, *M. edulis* Linné, 1758 (refigured by Soot-Ryen *in* Moore, 1969, p. N271, Fig. C16, 2a-2b), the type of *Mytilus*. The former Cretaceous New Zealand species is much less elongate, has a medially convex dorsal margin, and also has a concave ventral margin that yields an overall arcuate outline, unlike *M. edulis* or any other Cretaceous species assigned to *Mytilus*. The absence of radial ornamentation and crenulated margins precludes its placement within the *Septifer* group, of which it otherwise closely resembles only in outline. There is little doubt that *L.* cf. *L. foaensis* belongs in the Mytilinae and its relationship to *Lycettia* seems probable as it is similar to the type species of *Lycettia*, *L. lunularis* (Lycett, 1857) (refigured by Newell and Soot-Ryen *in* Moore, 1969, p. N273, Figs. 1a-1b) from the Jurassic of England, but the New Zealand species has a more arcuate outline and is less elongate.

Other described southern hemisphere Cretaceous mytiline taxa include "*Mytilus*" (= *Lycettia*?) *decipiens* Wilckens, 1905 (p. 32, Pl. 5, Figs. 8, 9) from the Late Cretaceous of southern Patagonia, "*Mytilus*" *primigenius* Stinnesbeck, 1986 (pp. 167-168, Pl. 2, Figs. 1-2) from the Maastrichtian of central Chile, "*Mytilus*" sp. from the Maastrichtian of northwestern Australia (Darragh and Kendrick, 1991, pp. 14-16, Fig. 1B-1G), and "*M.*" *arrialoorensis* Stoliczska, 1871 (p. 381, Pl. 23, Figs. 2-3, 5), from the Campanian to Maastrichtian of South India.

LYCETTIA LANCEOLATA (Sowerby, 1823)

Plate 8 Figures 1-5, 7

Mytilus edentulous Sowerby, 1823, vol. 5, p. 55, Pl. 439, Fig. 1.

Mytilus lanceolatus Sowerby, 1823, vol. 5, p. 55, Pl. 439, Fig. 2.

Dreissensia lancelolata (Sowerby, 1823), Woods, 1900, pt. 2, p. 110, Pl. 18, Figs. 13-15, Pl. 19, Figs. 1-11 (see list of synonymies from 1823 to 1900); Woods, 1917, p. 24, Pl. 10, Figs. 6a-6b.

Dreissensia cf. lanceolata (Sowerby), Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5.

Dimensions.-TM 7478 (IGNS) (GS 5) length 43.5 mm incomplete, height 22.0 mm; TM 7480 (IGNS) (GS 9835) length 46.5 mm, height 21.0, width of paired valves 16.0 mm; TM 7479 (IGNS) length 20.0 mm incomplete.

Figured specimens.-TM 2498 (IGNS; Woods, 1917, Pl. 10, Fig. 6); TM 7480 (IGNS), TM 7479 (IGNS), TM 7478 (IGNS).

Material.-Three specimens.

Localities.-Okarahui Stream, Haumuri Bluff, southern Marlborough, South Island, O32/f8790 [S55/f790]; north face of Haumuri Bluff O32/f9530 [S56/f530], O32/f9529 [S56/f529], O32/f8025 [S56/f25] O32/f9026 [S56/f26], O32/f9027 [S56/f27], O32/f9028 [S56/f28].

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous).

Geographic distribution.-Known only from southern Marlborough, east coast, South Island.

Discussion.-The Dreissenidae and Lycettia are difficult to differentiate as the two groups are strongly convergent, but

Lycettia has a nacreous shell unlike genera within Dreissenidae (Newell *in* Moore, 1969, p. N273). The presence of nacre in the New Zealand species excludes its placement within *Dreissena*. The first appearance of the monofamilial Dreissenacea, a mostly freshwater group, was in the Eocene (see Nuttall (1990) for an in-depth review of the superfamily), and the Cretaceous age and marine environment of Okarahia Sandstone strengthens the claim that this species is not a *Dreissena*, but a *Lycettia*. Freneix (1980, p. 21) treated the discussed Late Cretaceous New Zealand species as conspecific with *Lycettia lanceolata*, a position held here. *Lycettia* cf. *feoensis*, also from the New Zealand Cretaceous differs from *L. lancelolata* in being smaller with a much less pronounced carina and strong, commarginal growth pauses. The New Zealand species is virtually indistinguishable from those variable (mainly in degree of concavity of the ventral margin and overall outline) specimens of *L. lanceolata* figured by Woods (1900, p. 110, Pl. 18, Figs. 13-15, Pl. 19, Figs. 1-11) in his monograph on the Cretaceous bivalves of England and cannot be separated here based on available material.

Genus *SEPTIFER* Récluz, 1848

Septifer Récluz, 1848, p. 275.

Type species.-(by subsequent designation, Stoliczka, 1871) *Mytilus bilocularis* Linné, 1758.

Biogeographic element.-Cosmopolitan (tropical, subtropical seas) (Soot-Ryen *in* Moore, 1969, p. N274).

Discussion.-*Septifer* is a long-ranging, Triassic to Recent mytilid bivalve having a cosmopolitan distribution in tropical to subtropical seas (Soot-Ryen *in* Moore, 1969, p. N274).

Brachidontes and *Hormomya* can be distinguished from *Septifer* only the latter genus having an umbonal septum; otherwise, these groups are nearly indistinguishable externally (cf. Keen, 1958, p. 50; cf. ibid., p. N274). Numerous mytilid specimens, mostly decorticated, were collected by the author recently in an Upper Cretaceous bioherm at Oyster Hill, Malvern Hills, Canterbury, South Island. These specimens appear to agree externally with *Septifer* and along with the inferred Cretaceous age, suggest placement with this Mesozoic to Recent group. The presence of an umbonal septum is unknown as the all available material of this species is articulated.

SEPTIFER? *EURYCRENULATA* n. sp.

Plate 8 Figures 8, 10

Diagnosis.-Radial sculpture quite strong, crenulations broad and well-developed along dorsal margin; differs from *Septifer torquatus* (Marshall) in having fewer, broader radial crenulations.

Description.-Shell small, mytiliform; beaks nearly terminal; dorsal margin long, broadly convex; posterior margin narrowly rounded; ventral margin mostly straight; sculpture of strong, raised, rounded, somewhat irregular, radial crenulations, more developed along dorsal margin; internal features unknown.

Dimensions.-Holotype OU 40942 length 9.5 mm, height 5.5 mm; paratype OU 40943 length 10.5 mm, height 5.5 mm.

Types.-Holotype OU 40942, paratype OU 40943.

Figured specimens herein.-OU 40942, OU 40943.

Type locality.-Oyster Hill, Malvern Hills, Canterbury, South

Island, L35/f67.

Material.-Two nearly complete specimens, numerous fragments and steinkerns.

Stratigraphic range.-Selwyn Rapids Beds? (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Discussion.-Septifer? eurycrenulata n. sp. has fewer, broader, radial crenulations compared to the type of Septifer, S. bilocularis Linné, 1758 (figured by Soot-Ryen in Moore , 1969, p. N274, Fig. C18-2) from the Recent of the Indo-Pacific, and S. torquatus (Marshall, 1918) (p. 271, Pl. 21, Figs. 3, 3a; figured and redescribed by Beu and Maxwell, 1990, pp. 215-216, Pl. 23, Figs. d-e) from the Miocene of North and South islands, New Zealand. In general outline, S.? eurycrenulata n. sp. closely approximates S. zeteki Hertlein and Strong, 1846 (Keen, 1958, p. 50, Fig. 87) from the Recent of lower California to Ecuador, but sculpturally the two species are very distinctive. Septifer dichotomus Gabb, 1864 (p. 186, Pl. 30, Fig. 261) from the Cretaceous of California may be a related form, but this species has a more trigonal shell and more regular radial ribs, compared to S.? eurycrenulata n. sp.

Etymology.-Species named from the Greek "eurys" (= broad) and Latin "crenulatus" (crenate) for the broad, radial crenulations, characteristic of the group.

Subfamily MODIOLINAE Keen, 1958

A rigorous revision of the New Zealand Cretaceous species previously assigned to Modiolus is not possible at this time due to the lack of material. An appropriate and thorough review of modioline bivalves can be accomplished in reality only with numerous specimens as the group is highly variable at intraspecific and interspecific levels.

Genus MODIOLUS Lamarck, 1799

Modiolus Lamarck, 1799, p. 87.

Type species.-(by subsequent designation, Gray, 1847) Mytilus modiolus Linnè, 1758.

Synonyms.-Modiola Lamarck, 1801; Perna Adams and Adams, 1858; Nudiola Monterosato, 1917; Eumodiolus von Ihering, 1900 (Soot-Ryen in Moore, 1969, p. N278; cf. Abbott, 1974, p. 434).

Biogeographic element.-Cosmopolitan (Soot-Ryen in Moore, 1969, p. N278).

Discussion.-The ubiquitous modioline genus Modiolus, an ancient group extending back into the Devonian, is well-represented in Upper Cretaceous rocks around the southern circum-Pacific, as noted by its presence in southern South America, Antarctic Peninsula, New Zealand and possibly Chatham Islands. In New Zealand latest Cretaceous Modiolus species have been reported from Haumuri Bluff, South Island (Woods, 1917; Fleming in Wellman, 1959; Warren and Speden, 1978), northern Hawke's Bay, North Island (Crampton, 1988), and western Hawke's Bay, North Island (Crampton and Moore, 1990). A large temporal gap exists between the Cretaceous and Recent as the group has not been reported from the New Zealand Tertiary apart from a range extension of a widespread extant form Modiolus areolatus (Gould, 1850) (refigured by Powell, 1979, p. 373, Pl. 72, Fig. 3) to the Opoitian Stage (Lower Pliocene). The diagnostic features of Modiolus include a large, inflated shell like Mytilus, but the beaks are not terminal; the "rounded beaks are situated slightly short of the narrowly rounded anterior margin" (Powell, 1979, p. 373). The hinge is edentulous. Species of Modiolus are difficult to distinguish from those of Xenostrobus Wilson, 1967, on external morphological grounds alone; details of anatomy are needed for differentiation. Many New Zealand species previously assigned to Modiolus have been reallocated to Xenostrobus. The Late Cretaceous species of Modiolus were inferred to have been endobyssate, nonsiphonate suspension feeders (Warren and Speden, 1978, p. 50, Tab. 5). Large, inferred endobyssate clumps of Modiolus thomsoni (Zinsmeister, 1984) were noted in the middle units of the La Meseta Formation (mid to upper Eocene) of Seymour Island, Antarctic Peninsula during the 1986-1987 expedition to the Antarctic Peninsula (personal observation). Earlier Jurassic forms were also interpreted to have been byssate, semi-infaunal species living attached to buried shell debris (McKerrow, ed., 1978, p. 246).

MODIOLUS cf. M. TYPICUS Forbes, 1846

Plate 8 Figures 9-14, 16

cf. Mytilus (Modiolus) typicus Forbes, 1846, p. 152, Pl. 14, Fig. 4.

Modiola sp. cf. typica Forbes, Woods, 1917, Pl. 9, Fig. 7; Pl. 10, Figs. 4a-4b. See Woods (1917) for numerous other citations of this species from 1866 to 1906 which will not be listed here.

Modiolus cf. typicus Forbes, Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5.

Supplementary description.-Shell medium-sized, moderately inflated, thin, elongated modioliform; beaks small, subterminal;

anterodorsal margin very short, narrowly rounded; posterodorsal margin long, broadly convex, nearly straight near beak, merging with narrowly rounded posterior margin; ventral margin straight to slightly concave medially; umbonal ridge poorly to moderately developed; surface generally smooth with spaced, moderately developed commarginal growth undulations and very faint radial microsculpture.

Dimensions.-TM 7481 (IGNS) (from GS 14271) length 32.5 mm, height 17.0 mm, width of single valve 6.0 mm; TM 7483 (IGNS) length 9.5 mm, height 6.0 mm.

Figured specimens herein.-TM 2496 (IGNS; Woods, 1917, Pl. 9, Fig. 7); TM 2497 (IGNS; Woods, 1917, Pl. 10, Fig. 6); TM 7481, TM 7483 (IGNS); OU 40944.

Material.-One, well-preserved, disarticulated specimen and two others; TM 7483 (IGNS), a believed juvenile, may also represent this species.

Localities.-Western Hawke's Bay, North Island, V19/f182-182a, Mangahouanga Stream float *3 (of Crampton and Moore, 1990); ?northern Hawke's Bay, North Island W18/f08a-08b; Paparoa River, Kaipara, Northland, Q08/f9011; Mikonui and Oaro streams near Haumuri Bluff, southern Marlborough, South Island ?O32/f8774A [?S55/f774a], O32/f8787 [S55/f787], and north face of Haumuri Bluff, ?O32/f9530 [?S56/f530], O32/f8025 [S55/f25].

Stratigraphic range.-Maungataniwha Sandstone (Piripauan to Haumurian stages, upper Campanian to Maastrichtian, Upper Cretaceous); Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); ?unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland?, Eastern North Island to north eastern South Island.

Discussion.-The exact placement of *Modiolus* cf. *M*. *typicus* is uncertain, but seems to be more closely related to the South Indian species than to coeval similar species from the James Ross Basin of the Antarctic Peninsula. Subtle differences separate *Modiolus pontotocensis* del Valle and Medina (1980) (pp. 53-54, Pl. 2, Figs. 2-4) from the Late Cretaceous of Vega and James Ross islands, Antarctic Peninsula, and *M*. cf. *M*. *typicus* from New Zealand. The above mentioned Antarctic species has a slightly less convex posterodorsal margin and more concave ventral margin, but othersise this species is very similar to *M*. cf. *M*. *typicus*. *Modiolus* cf. *M*. *typicus* is not closely related to the older *M*.? *kaikourensis* (Woods, 1917) (p. 8, Pl. 2, Figs. 3-5) from the Arowhanan Stage (lower Upper Cretaceous) of New Zealand, which has a smaller, wider, greatly inflated shell of a different outline and apparently terminal beaks which would most likely preclude its placement within *Modiolus*. As a side note, Crampton and Moore (1990, p. 346) reported the presence of *M*.? *kaikourensis* in the Maungataniwha Sandstone of the North Island, possibly extending the geologic range of the species into the latest Cretaceous. The widespread Recent species *Modiolus americanus* (Leach, 1815) (figured by Crouch, 1826, p. 18, Pl. 11, Fig. 1, as *M*. *tulipa* Lamarck, 1819 (synonym of *M*. *americanus*)) is reminiscent of *M*. cf. *typica*, but the latter species has a less convex dorsal margin and more terminal beaks. The relationship of _M_. cf. _typicus_ to specimens OU 40944 from Oyster Hill (L35/f67) and TM 7482 (IGNS) from GS 9666 is uncertain, but the strong umbonal ridge present on both specimens suggest that these specimens do not represent _M_. cf. _typicus_.

Subfamily LITHOPHAGINAE Adams and Adams, 1857

Discussion.-The lithophagine record in the New Zealand Cretaceous consists of _Inoperna_ and possibly _Lithophaga_. Although Marwick and Fleming _in_ Wellman (1959, p. 138) listed questionably the latter genus from Kaipara, Northland, its existence there unfortunately cannot be substantiated here even with the large amount of fossil material available to me from Northland.

Genus _INOPERNA_ Conrad in Kerr, 1875

Inoperna Conrad in Kerr, 1875, Appendix A, p. 5.

Type species.-(by subsequent designation, Stephenson, 1923) _Modiolus_ (_I_.) _carolinensis_ Conrad, 1875.

Synonym.-_Pharomytilus_ Rollier, 1914 (Soot-Ryen _in_ Moore, 1969, p. N278).

Biogeographic element.-Cosmopolitan (Soot-Ryen _in_ Moore, 1969, p. N278).

Discussion.-_Inoperna_ is reported from the New Zealand Late Cretaceous for the first time. _Inoperna_, a cosmopolitan group which ranges from the Early Jurassic to Late Cretaceous, is easily distinguished from other lithophagine genera by having a very elongate, narrow shell with nearly parallel dorsal and ventral margins.

INOPERNA sp. aff. _I_. _FLAGELLIFERA_ (Forbes, 1846)

Plate 8 Figure 15

aff. Modiola flagellifera Forbes, 1846, Woods, 1917, p. 24, Pl. 10, Fig. 5

aff. Modiolus (Inoperna) flagelliferus (Forbes), Dartevelle and Freneix, 1959, p. 47.

aff. Inoperna flagellifera (Forbes), Freneix, 1960. p. 12.

Modiolus cf. flagellifer (Forbes), Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5; Crampton and Moore, 1990, p. 346.

Inoperna sp. affin. flagellifera (Forbes), Freneix, 1980, pp. 20-21, Pl. 2, Fig. 5.

Figured specimen.-TM 2495 (IGNS; Woods, 1917, Pl. 10, Fig. 5).

Localities.-Mangahouanga Stream float *3 of Crampton and Moore (1990), western Hawke's Bay, North Island, V19/f6909; north face of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 [S55/f25].

Stratigraphic range.-Maungataniwha Sandstone (Upper Cretaceous); Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous).

Discussion.-This species from the Late Campanian of New Zealand is considered here to be conspecific with a Campanian species from New Caledonia, Inoperna aff. I. flagellifera (Forbes, 1846) (figured by Freneix, 1980, p. 20, Pl. 2, Fig. 5), but as in the New Caledonian species the paucity of material prevents an accurate assessment of the group. Although incomplete, Woods (1917, Pl. 10, Fig. 5) figured a specimen from Haumuri Bluff which he assigned to Modiola flagellifera, which is clearly assignable to *Inoperna* in having nearly parallel dorsal and ventral margins and strong, commarginal sculpture.

Superfamily PINNACEA Leach, 1819

Family PINNIDAE Leach, 1819

Genus *PINNA* Linné, 1758

Pinna Linné, 1758, p. 707.

Type species.-(by subsequent designation, Children, 1823) *Pinna rudis* Linné, 1758.

Synonyms.-Refer to Cox and Hertlein *in* Moore (1969, p. N283) and Abbott (1974, p. 437) for extended lists too numerous to list here.

Biogeographic element.-Indo-Pacific/Tethyan (cf. Cox and Hertlein *in* Moore, 1969, p. N283; Fleming, 1967, Appendix 1, p. 115).

Discussion.-A widespread group around the southern circum-Pacific during the Late Cretaceous, *Pinna* species are known from New Caledonia (Freneix, 1960, 1980), New Zealand (Woods, 1917; Warren and Speden, 1978; Marwick and Fleming and Fleming *in* Wellman, 1959; Moore *et al*., 1988; Crampton and Moore, 1990), Chatham Islands (Campbell *et al*., 1993) Cockburn Island, Antarctic Peninsula (Stilwell and Zinsmeister, 1987b), Snow Hill Island, Antarctic Peninsula (Wilckens, 1910), Seymour Island, Antarctic Peninsula (Zinsmeister and Macellari, 1988), southern South America (Wilckens, 1905; Riccardi, 1988), and southern India (Stoliczka, 1871). *Pinna* is today a mostly warm, shallow water, semi-infaunal, endobyssate bivalve that prefers sandy to mixed sand-mud facies and lives with its apex deeply buried (cf. Abbott, 1974, p. 437; cf. Macellari, 1988, p. 42). The geologic range of the genus is Early Carboniferous to Recent (Cox and Hertlein in Moore, 1969, p. N283).

The New Zealand Late Cretaceous species, referred herein as Pinna sp., is typically poorly preserved preventing an accurate assessment. All previous records of Pinna in the New Zealand Cretaceous have been left in open nomenclature, as will be done here.

PINNA sp.

Plate 9 Figures 1,3

Pinna sp., Woods, 1917, p. 28, Pl. 15, Fig. 1; Wilckens, 1920a, p. 264; Marwick and Fleming and Fleming in Wellman, 1959, p. 138 and p. 141; Warren and Speden, 1978, p. 50, Tab. 5; Moore et al., 1988, p. 59, Tab. 1; Crampton and Moore, 1990, p. 346, Tab. 1.

Dimensions.-TM 7484 (IGNS) length 66.5 mm incomplete.

Previously figured specimen.-TM 2535 (IGNS; Woods, 1917, Pl. 15, Fig. 1).

Figured specimens herein.-TM 2535 (IGNS), TM 7484 (IGNS) (GS 589).

Material.-Two specimens.

Localities.-Selwyn Rapids, Canterbury, South Island (GS 589), L35/f6008; Haumuri Bluff, southern Marlborough, South Island, O32/f8795 [S55/f795]; east wing of Haumuri Bluff O32/f9027 [S56/f27]; Waiau River float *1 and Mangahouanga Stream float *3 (of Crampton and Moore, 1990), western Hawke's Bay, North Island, V19/f6508, V19/f6909; Lake Waikaremoana, Urewera National Park, North Island W18/f27; Green Island, Otago, South Island, I44/f8489; southwestern side of neck of Taruwhenua Peninsula, Pitt Island, Chatham Islands CH/f257A; Whenuatara (= Taruwhenua)

Peninsula, west of Flowerpot Bay, Pitt Island, CH/f345; west side of base of Whenuatara Peninsula, Pitt Island, CH/f587.

Stratigraphic range.-Selwyn Rapids Beds (Upper Cretaceous) Conway Formation? (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Maungataniwha Sandstone (Upper Cretaceous); Kahuitara Tuff (Upper Cretaceous).

Geographic distribution.-Eastern central North Island to eastern central South Island and Pitt Island.

Discussion.-*Pinna* sp. is relatively rare in Upper Cretaceous sediments of New Zealand, where it is also usually poorly preserved. The geographic distribution of *Pinna* sp. has been extended greatly since Woods (1917, p. 28) to include localities in eastern North Island and Pitt Island, Chatham Islands. The exact taxonomic placement of *Pinna* sp. is uncertain, but the apical angle of nearly 20° of *Pinna* sp. is not too far removed from a similar species from the Maastrichtian of Seymour Island, Antarctic Peninsula, *P. freneixae* Zinsmeister and Macellari, 1988 (p. 265, Fig. 3.16) which has an apical angle ranging from 23 to 26°.

Superfamily AMBONYCHIACEA? Miller, 1877

Family INOCERAMIDAE Giebel, 1852

Discussion.-Late Cretaceous New Zealand species previously assigned to *Inoceramus* are in a state of flux. A systematic and biometric study of Cretaceous Inoceramidae, including New Zealand taxa, has been undertaken recently by J. S. Crampton, Cambridge University (now at IGNS, Lower Hutt), and other than geographic range extensions for the group, little new data will be presented here. Descriptions of the Northland species figured will not be given.

Crampton (1988c) in a taxonomic review of the families Isognomonidae, Inoceramidae, and Retroceramidae discussed the difficulties surrounding the differentiation between fossil Isognomonidae and Inoceramidae, based on external features. The primary feature separating the two latter groups is the "shell structure underlying the ligament area" (p. 965) and where the ligaments are attached. The ligament is attached to the prismatic shell layer in Inoceramidae, and to the inner shell layer in the Isognomonidae (Crampton, 1988c, p. 965). Crampton supported the view of evolution of Inoceramidae from Atomodesma based on current data, and suggested that this family be removed from Pteriacea and referred to Ambonychiacea (p. 986).

Latest Cretaceous (Piripauan to Haumurian stages) species referred to Inoceramus include I. australis Woods (1917, pp. 27-28, Pl. 13, Figs. 1-3, I. pacificus Woods (1917, p. 28, Pl. 14, Figs. 1-2), I. matotorus Wellman (1959, p. 155, Pl. 10, Fig. 1), I. sp. A (Crampton, 1988c, p. 991, Pl. 90, Fig. 11), and I.? sp. B (Crampton, 1988c, p. 991, Pl. 90, Fig. 14). A further New Zealand Late Cretaceous species discovered in collections housed at the Auckland Institute and Museum by the author may be assignable to Tenuipteria, an unusual and controversial group known hitherto only from the latest Cretaceous of the northern hemisphere (J. S. Crampton, personal communication, 1992).

Genus INOCERAMUS Sowerby, 1814

Inoceranus Sowerby, 1814, p. 448.

Type species.-(by monotypy) *Inoceramus cuvierii* Sowerby, 1814.

Synonyms.-See Cox *in* Moore (1969, p. N314) for extensive list.

Biogeographic element.-Cosmopolitan (Cox *in* Moore, 1969, p. N314).

Discussion.-Numerous, poorly preserved *Inoceramus* specimens have been recovered from Upper Cretaceous marine sediments throughout New Zealand. As a result of preservational deficiencies, these specimens have been left in open nomenclature within *Inoceramus*. Those localities are numerous and include (see Appendix A for locality and stratigraphic details): CH/f319, CH/f333, K34/f9096, N02/f127, N02/f9636, O04/f7589, O05/f9498, O05/f9524, O05/f9572, O05/f9573, O06/f7571, O32/f8113, O32/f8117, O32/f8791, O32/f9029, O32/f9041, O32/f9541, P04/f9494, P05/f158, P30/f198, Q08/f9009, Q08/f9011, Q09/f9501, R16/f6610, S28/f20, S28/f114, T26/f19, T26/f6546, T26/f7478, T26/f8068, T26/f9522, T27/f30, T27/f6490, T27/f8930, U25/f6613, U26/f6461, V19/f6503, V19/f6508, V19/f6511, V19/f6645, V19/f6649, V22/f8722, V24/f6484, W17/f7531, X16/f9534, X17/f7483, Y14/f7548, Y15/f55, Y16/f41, Y16/f62, Y17/f9721, Y17/f9722, Y20/f7472, Z15/f7497, O05/f9505, O06/f7574, O32/f8116, O32/f8795, O32/f8793, O32/f9506, O32/f9502, U25/f6473, V18/f8510, V19/f185, O32/f9030, O32/f9533, P05/f9539, V23/f6455, O32/f9031.

INOCERAMUS sp.

Plate 9 Figures 4, 6-7

Dimensions.-Ge 8081.4 (AIM) length 15.3 mm, height 21.7 mm; Ge 8081.5 (AIM) length 10.0 mm, height 15.5 mm; Ge 8081.6 length 12.0 mm, height 21.1 mm.

Figured specimens.-Ge 8081.4, Ge 8081.5, Ge 8081.6 (all AIM).

Material.-Three specimens. Two other poorly preserved specimens may represent this species.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Discussion.-Inoceramus species are the most geographically widespread and widely cited bivalves in the Late Cretaceous record in New Zealand and have been reported from many marine deposits. Inoceramus is known from Northland, east coast of North Island, eastern South Island and West Coast. A complete review of all known records of Late Cretaceous New Zealand Inoceramus has not yet been accomplished, but a list of most known localities is included here.

The figured specimens of Inoceramus are generally not well-preserved, but seem not to be conspecific to I. australis Woods, 1917, or I. pacificus Woods, 1917, and therefore may be I. matotorus Wellman, 1959; however, no good material of I. matotorus exists and the status of this species can only be considered as uncertain (J. S. Crampton, personal communication, 1992). The specimens may also be members of the Tenuipteria group, but more study is needed.

INOCERAMUS AUSTRALIS Woods, 1917

Plate 9 Figures 2, 5, 8-15

Inoceramus australis Woods, 1917, pp. 27-28, Pl. 12, Figs. 17-19, Pl. 13, Figs. 1-3; Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-2; Speden in Suggate, ed., 1978, p. 363, Fig. 6.6-2; Speden and Keyes, 1981, p. 54, Pl. 22,

Fig. 2; Crampton, 1988c, p. 989, Pl. 90, Fig. 13.

Types.-Lectotype TM 2738 (IGNS; Woods, 1917, Pl. 3, Fig. 3; Speden *in* Suggate *et al.*, ed., 1978, Fig. 6.6-2; Warren and Speden, 1978, Fig. 25-2; Speden and Keyes, 1981, Pl. 22, Fig. 2); TM 6703 (IGNS; Crampton, 1988c, Pl. 90, Fig. 13).

Figured specimens herein.-TM 2738, TM 2745-2748, TM 6703 (all IGNS).

Localities.-Because the list of *I. australis* localities is quite extensive, only the fossil record numbers will be given. Refer to Appendix for description of localities and stratigraphic information corresponding to fossil record numbers: O32/f8025, O32/f8026, O32/f8514, O32/f8763, O32/f8790, O32/f8847, O32/f9027, O32/f9505, P04/f42, ?P04/f9564, P05/f9647, P29/f8596, P29/f9739, ?P29/f9744, P30/f6589, P30/f6618, Q08/f9023, ?S28/f8593, T26/f6537, T26/f7477, T26/f9513, T27/f6010, T27/f6011, T27/f8674, ?U25/f6462, U25/f6509A, U25/f8723, ?V23/f6487, V23/f6550, V24/f6028, ?W18/f8, W18/f13, W18/f26, W18/f27, W18/f7601, W22/f8544, X16/f87, X16/f7513, ?X16/f7523, ?X16/7619, X16/f7627, X16/f7707, Y14/f7522, Y14/f7526, Y14/f7535, Y14/f7546, Y14/f7547, Y14/f7548, Y14/f7552, Y14/f7554, Y14/f7839, ?Y14/f7849, Y15/f7530, Y15/f7561, Y16/f6618, Y16/f7521, Y16/f9620, ?Z15/f41, Z15/f6571, Z15/f6577.

Stratigraphic range.-See Appendix A for formation names and ages for the above fossil record numbers.

INOCERAMUS PACIFICUS Woods, 1917

Plate 10 Figures 1, 5

Inoceramus multiplicatus Hector, 1877, p. xii; Hector, 1886, p.

17.

Inoceramus pacificus Woods, 1917, p. 28, Pl. 14, Figs. 1, 2; Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-1; Speden in Suggate, ed., 1978, p. 363, Fig 6.6-1; Speden and Keyes, 1981, p. 54, Pl. 22, Fig. 1; Crampton, 1988c, p. 991.

Types.-Lectotype TM 2739 (IGNS; Woods, 1917, Pl. 14, Fig. 2; Speden in Suggate et al., ed., 1978, Fig. 6.6-1; Warren and Speden, 1978, Fig. 25-1; Speden and Keyes, Pl. 22, Fig. 1).

Figured specimens.-TM 2739 (IGNS), TM 2750 (IGNS).

Localities.-As with I. australis, only a list of fossil locality numbers will be presented for I. pacificus. Refer to Appendix for locality and stratigraphic information relevant to fossil record numbers: ?O29/f9863, O32/f8511, ?O33/f8596, ?P05/f240, ?P29/f8596, ?P29/f9150, P29/f9151, P29/f9691, P29/f9695, P29/f9740, P29/9745, ?P30/f6593, P30/f6622, P30/f6897, ?P30/f7154, P30/7157, Q07/f9543, Q09/f7666, ?R10/f9512, S28/f8593, T26/f7479, ?T26/f9514, ?T26/f9531, T27/f9, T27/f11, T27/f12, T27/f13, T27/f331, T27/f6009, ?T27/f6506, ?T27/f6510, ?T27/6721, T27/f6723, U24/f16, U24/f17, U24/f19, U24/f20, U24/f7482, ?U24/f9503, U24/9505, U24/f271, U25/f6458, ?U25/f6462, U25/f6469, U25/f6509, U25/f6514, U25/f6608, U25/f6609, ?U25/f7498, U25/7498A, ?U25/8717, U25/f8718, U25/f8719, U26/f54, V22/f157, ?V23/f72, ?V23/f6494, V23/f6550, ?W16/f9516, ?W17/f7470, W18/f10, W18/f26, W18/f27, W18/f30, X16/f53, X16/f88, ?X16/f7508, ?X16/7509, ?X16/7510, ?X16/f7511, ?X16/f7512, X16/f7708, Y14/f7525, Y14/f7527, Y14/f7534, Y14/f7537, Y14/f7538, Y14/f7546, Y14/f7547, Y14/f7552, Y14/f7553, Y14/f7554, Y15/f68, Y15/f91, Y15/f7490, Y15/f7523, Y15/f7529, Y15/f7546, Y15/f7551, ?Y15/f7560, Y15/f7575, Y16/f14, Y16/f15, Y16/f38, Y16/f6750, Y16/6753, ?Y16/f7520, ?Z15/f6485, Z15/f6537, Z15/f6538, ?Z15/f6539, Z15/f6579, Z15/f6850, Z15/f6581, O32/f8694, O32/f8509, O32/f8787, O32/f9035, O32/f9504, O32/f9529, ?P04/f9497, ?Q08/f9668, U25/f270, ?V18/f8500, O32/f8026, O32/f8025, O32/f8774A, ?O32/f9026.

INOCERAMUS MATOTORUS Wellman, 1959

Plate 10 Figures 2, 10

Inoceramus sp., Wellman, 1956, p. 352.

Inoceramus matotorus Wellman, 1959, p. 155, Pl. 10 (Pl. 23 in figure caption), Fig. 1; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 26-1; Speden *in* Suggate *et al*., ed, 1978, p. 363, Fig. 6.6-7; Speden and Keyes, 1981, p. 54, Pl. 22, Fig. 7; Crampton, 1988c, p. 990.

Type and previously figured specimen.-Holotype TM 2110 (IGNS; Wellman, Pl. 10, Fig. 1; Speden *in* Suggate *et al*., ed, 1978, Fig. 6.6-7; Speden and Keyes, 1981, Pl. 22, Fig. 7); TM 5381 (IGNS; Warren and Speden, 1978, Fig. 26-1).

Figured specimens herein.-TM 2110 (IGNS), TM 5381 (IGNS).

Localities.-As with the previous *Inoceramus* species, only fossil record numbers will be given. K34/f9558, ?N02/f9585, ?N02/f9586, O32/f107, P04/f9493, P05/f9502, P29/f9503, ?P29/f9693, ?P29/f9738, ?P29/f9741, ?P29/f9746, P30/f7159, P30/f7579, P30/f7580, ?Q29/f8737, T26/f6546, ?T27/f30, T27/f34, U25/f6584, U25/f8047, ?V19/f26, ?W18/f8A, X17/f7674, ?Y14/f107, Y14/f7522, Y14/f7553, Y14/8007, Y14/f8008, Y14/8009, Y14/f8010, Y14/f8011,

?Y15/f17, Y15/f9522, Y16/f7234, Y16/f7489, Y17/f9720, ?Y17/f9723, Y19/f6502, Z14/f106, Z15/f6722, Z15/f7482, Z15/f7504, O32/f8849, ?O32/f8850, ?P05/f9499, V19/f181A, ?Y16/f6617, O32/f8851, P05/f9491.

Order PTERIOIDA Newell, 1965

Suborder PTERIINA Newell, 1965

Superfamily PTERIACEA Gray, 1847

Family ISOGNOMONIDAE Woodring, 1925

Genus ISOGNOMON Solander *in* Lightfoot, 1786

Isognomon Solander *in* Lightfoot, 1786, pp. 9, 41, 52, 115, 137.

Type species.-(by tautonomy) *Ostrea isognomon* Linné, 1764 (see Crampton, 1988c, p. 974).

Synonyms.-Numerous, see Cox *in* Moore (1969, p. N322).

Biogeographic element.-Cosmopolitan (Cox *in* Moore, 1969, p. N322; Kauffman, 1973, p. 359).

Discussion.-A review of *Isognomon* was recently accomplished by Crampton (1988c), including new Cretaceous and Paleogene species from New Zealand and Chatham Islands. Only one species *Isognomon* sp. of Crampton (1988a, p. 22, Pl. 1, Fig. 1) has been reported from the latest Cretaceous of greater New Zealand, but a species was described recently from Chatham Islands, *I*. *rekohuensis* Crampton, 1988c.

ISOGNOMON sp.

Plate 10 Figure 7

Isognomon sp., Crampton, 1988a, p. 22, Pl. 1, Fig. 1.

Figured specimen.-TM 6857 (IGNS).

Locality.-Headwaters of Waikokopu Stream, approximately 400 m southwest of Whakatakaa Hut, Urewera National Park, North Island, W18/f8A.

Stratigraphic range.-Maungataniwha Sandstone (Piripauan to Haumurian Stages, upper Campanian to Maastrichtian, Upper Cretaceous).

Geographic distribution.-Known only from a single locality in northern Hawke's Bay, North Island.

Distribution.-No discussion of this species was made by Crampton (1988a) who first figured the species. The affinities of this *Isognomon* species are uncertain. *Isognomon* sp. has a much narrower shell compared to a coeval species *I. rekohuensis* Crampton, 1988c (pp. 978-981, Pl. 89, Fig. 1a-e), from the Chatham Islands; these two species appear not to be conspecific. More material is needed to make a more accurate assessment.

Superfamily PECTINACEA Rafinesque, 1815

Family ENTOLIIDAE von Teppner, 1922

Genus *ENTOLIUM* Meek, 1865

Entolium Meek, 1865, p. 478.

Type species.-(by original designation) *Pecten demissus* Phillips, 1829 (as illustrated by Quenstedt, 1858) (= *Entolium corneolum* (Young and Bird, 1828).

Biogeographic element.-Cosmopolitan (Hertlein *in* Moore, 1969, p. N347; Kauffman, 1973, p. 359).

Synonyms.-*Protamusium* Verrill, 1897; *Protamussium* Paris and Richardson, 1915; *Protomusium* Stewart, 1930; *Etolium* McLearn, 1949 (Hertlein *in* Moore, 1969, p. N346).

Discussion.-*Entolium* is a cosmopolitan group which ranged from Middle Triassic to Late Cretaceous (Hertlein *in* Moore, 1969, p.

N347). Dhondt (1971, p. 6) placed Entolium in the Amusiidae: Entoliinae, whereas Hertlein in Moore (1969, p. N346) and Waller (1984, p. 219) believed that the genus more appropriately belongs in Entoliidae as a distinct family, a position supported here. In the southern hemisphere, Cretaceous species of Entolium are widely distributed and have been widely cited, including records in New Caledonia, Australia, New Zealand, Chatham Islands, and Antarctic Peninsula.

The smooth, shining, subequivalve, suborbicular, acline shell and auricles of the left valve projecting above the hinge line are diagnostic features of Entolium (Newell and Hertlein in Moore, 1969, p. N347; Dhondt, 1971, p. 6) and separate this group from other genera within the Entoliidae. The affinities of the Late Cretaceous New Zealand species assigned to Entolium have been unsettled for some time and a review of this taxon is appropriate.

ENTOLIUM MEMBRANACEUM (Nilsson, 1827)

Plate 10 Figures 9, 11-16

Pecten membranaceum Nilsson, 1827, p. 23, Pl. 9, Fig. 16 (lower left figure). Study of an original copy of Nilsson (1827) indicates that he inadvertently placed two Fig. 16s on Plate 9.

Pecten (Syncyclonema) membranaceus Nilsson, Woods, 1917, pp. 25-26, Pl. 11, Figs. 3-5.

Pseudamussium s. l. sp., Marwick, 1928, p. 446.

Entolium membranaceum (Nilsson), Dhondt, 1971, pp. 27-36, Pl. 1, Figs. 2a-b (with synonymies from 1799 to 1962); Stevens in Suggate et al., 1978, p. 352, Tab. 6.2; Crampton and Moore, 1988,

p. 346.

Entolium aff. membranaceum (Nilsson), Warren and Speden, 1978, p. 50, Tab. 5; Moore et al., 1988, p. 59, Tab. 1.

Dimensions.-Ge 7652.2 (AIM) length 31.5 mm, height 32.5 mm; L 3871 (AU) (from AU 2577) length 30.0 mm, height 32.0 mm.

Previously figured specimens.-TM 2515 (IGNS; Woods, 1917, Pl. 11, Fig. 3; Warren and Speden, 1978, Fig. 26-11); TM 2516 (IGNS; Woods, 1917, Pl. 11, fig. 5); TM 2517 (IGNS; Woods, 1917, Pl. 11, Fig. 4).

Figured specimens herein.-TM 2515-2517 (IGNS); Ge 7652.2, right valve, (AIM); L 3871 (AU) (from AU 2577); L 3877 (AU) may represent this species.

Material.-21 specimens.

Localities.-Weka Creek, Weka Pass, southern Canterbury, M34/f7264; Kaiwara River, left bank, N33/f9811; Haumuri Bluff, southern Marlborough, O32/f8850, O32/f9506, O32/f8851; north face of Haumuri Bluff, southern Marlborough, O32/f107, O32/f9541, O32/f8849, O32/f9530, O32/f9529, O32/f9533; east wing of Haumuri Bluff, O32/f9025, O32/f9029, O32/f9032, O32/f9030, O32/f9031; Te Hoe River, western Hawke's Bay, North Island, V19/f184; ?Lower Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6508; ?Hook Stream, North Island, V19/f6645; Argyle Road, North Island, V22/f18; Birch Hollow, southern Canterbury, M34/f1; western Branch of Haematite Stream, South Island, N32/9822; Okarahui Stream, South Island, O32/f8790; Tributary of Okarahia Stream, southern Marlborough, O32/f8787; Batley, Kaipara, Northland, Q08/f9023; Bull Point, Kaipara, Northland, Q08/f9626; north side of promontory between Opu and Whakapirau Creeks, Kaipara, Northland, Q08/f9639; Mikonui Stream, South Island, O32/f8788; near Kekerengu River, Marlborough, P30/f8702; northwest side of Rocky Side, southwest of neck of Taruwhena Peninsula, Pitt Island, Chatham Islands, CH/f257A; Rocky Side, Whenuatara Peninsula, west of Flowerpot Bay, CH/f345; northern Pitt Island, CH/f466; west side of base of Taruwhenua Peninsula, CH/f587.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Tarapuhi Grit, Conway Formation, Whangai Formation, "Saurian Sands", unspecified horizon within Unit 4 of Evans (1985) ("Northland Allochthon"), formations unspecified (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Kapuitara Tuff, ?Silverstream Formation, Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Widespread in New Zealand, from Northland to southern Marlborough, and also Chatham Islands.

Discussion.-*Entolium membranaceum* is one of the most widespread Cretaceous bivalves of New Zealand, if not the globe, with known localities covering many areas of the North Island, South Island and Chatham Islands. In Europe, including Senonian stratotypical regions, *E. membranaceum* is known from "Bassin de Mons" (Belgium--early Maastrichtian), "Environs d'Aix-la-Chapelle (RFA)"--early Campanian, "Environs de Norwich" (England--Late Campanian to Maastrichtian), and "Maastricht (Pays-Bas)"--Maastrichtian (Dhondt, 1985a). The type locality for *E. membranaceum*, as designated by Dhondt (1971, p. 31), is Köpinge (Sweden) (upper Campanian). Woods (1917, pp. 25-26) believed that this New Zealand species, represented by material from Haumuri Bluff, agreed well with *E. membranaceum*. Marwick (1928, p. 446), however, in a revision of New Zealand Pectinidae reviewed this species and decided as no figures or specimens of typical "*P. membranaceus*" were available to him, this group from New Zealand, unlike supposed *P. membranaceus* from Stoliczka's figures of Indian specimens, should perhaps either be given a new generic name or for the time being be placed in *Pseudamussium* s. 1. Well-preserved specimens of *E. membranaceum* are rare. A superior specimen from Northland (Ge 7652.2; AIM) retains its original shell and polish. Specimens of the New Zealand species agree relatively well with figured individuals of *E. membranaceum*, which was widespread in Europe.

Dhondt (1971), in a review of Cretaceous European boreal species of *Entolium*, discussed the taxonomic problems associated with this species, including the difficulties of differentiating between *E. membranaceum*, *E. orbiculare* (Sowerby, 1817) which became extinct by the late Cenomanian, and *Syncyclonema nilssoni* (Goldfuss, 1835). *Entolium membranaceum* is believed to have evolved from *E. orbiculare* because the former species replaced the latter in the late Cenomanian (Dhondt, 1971, p. 21). The difficulties surrounding the identification of these three species listed above has plagued workers for 150 years. *Entolium orbiculare* (see figure of well-preserved specimen in British Museum (Natural History) **British Mesozoic Fossils**, ed. 4, 1972, Pl. 56, Fig. 2) has macroscopical commarginal ridges on left valves and auricles that are more dorsally elevated, compared to *E. membranaceum* (Dhondt, 1971, p. 21); these features of *E.*

orbiculare exclude the New Zealand species from this group, although some specimens referable to *E. orbiculare* approach the New Zealand species fairly well (see Woods, 1902, Pl. 27, Fig. 11). Values of the apical angle overlap in the specimens of *E. membranaceum* and *E. orbiculare* measured by Dhondt. It is very surprising that Dhondt studied 429 specimens of *E. membranaceum* and only figured two poor examples of this species (Pl. 1, 2a-b). Dhondt also listed, as questionable (see p. 30), Woods' (1917) synonymy of the Late Cretaceous New Zealand species with *E. membranaceum*. Warren and Speden (1978, p. 50, Tab. 5) cited the species, present at Haumuri Bluff, as *E.* aff. *membranaceum*. The variability of *E. membranaceum* can be pronounced mainly with respect to hinge line and strength of commarginal growth lines. The New Zealand species has unequal growth pauses, but otherwise appears to be well within the range of variability of *E. membranaceum*. As an aside, Feruglio (1936, pp. 247-248, Pl. 25, Fig. 3) described *Pecten wichmanni* from the latest Cretaceous of Salamanqueano, Patagonia, southern South America. There is little doubt that *Pecten wichmanni* belongs in *Entolium* and the specimen figured is nearly identical to New Zealand specimens here referable to *E. membranaceum*.

Family PECTINIDAE Rafinesque, 1815

Discussion.-Little new information will be presented for New Zealand Cretaceous pectinids, except for descriptions of two new species, previously unpublished locality information for known species, and some remarks on other taxa. These newly described species are *Chlamys* (*Lyriochlamys*?) *conwayensis* n. sp. from the

Conway River area, southern Marlborough, and Camptonectes (s. l.) n. sp.?. The Cretaceous Pectinidae of New Zealand requires extensive revision and attention, which is beyond the scope of this work. Several taxa, including probable new species, are present in the Upper Cretaceous rocks of New Zealand. In Northland, Bull Point in Kaipara, believed pectinid fragments are present in monotypic concentrations in Maastrichtian rocks that crop out extensively in the region (see Pl. 11 Fig. 11, Ge 7602.4 (AIM)). James S. Crampton, presently of Institute of Geological and Nuclear Sciences, Lower Hutt, has planned a review of this group (personal communication, 1989) which is underway. Pectinid taxa previously reported from various localities in New Zealand include Aequipecten sp. (Warren and Speden, 1978; Crampton, 1988; Campbell et al., 1993) (see Plate 11 Figures 2-3), Camptonectes selwynensis (Finlay, 1927) (Marwick, 1928, see review, p. 446, of the problems associated with the name of this species; Fleming and Marwick and Fleming in Wellman, 1959; Warren and Speden, 1978), "Camptonectes" n. sp.?; Camptonectes n. sp. (Crampton, 1988, Pl. 1, Fig. 2; Moore et al., 1988; possibly Chatham Islands, Campbell et al., 1993), Eburneopecten sp. (Campbell et al., 1993), Mixtipecten amuriensis (Woods, 1917) (Fleming in Wellman, 1959; Warren and Speden, 1978; possibly Chatham Islands, Campbell et al., 1993; Stilwell in Aitchison et al., 1993), Chlamys sp. (Marwick and Fleming in Wellman, 1959; s. l., Moore et al., 1988), and Neithea grangei (Murdoch, 1924) (Marwick and Fleming in Wellman, 1959).

Genus CAMPTONECTES Agassiz in Meek, 1864

Camptonectes Agassiz in Meek, pp. 28, 39.

Type species.-(by subsequent designation, Stoliczka, 1871) Pecten lens J. Sowerby, 1818).

Synonyms.-Campstonectes von Teppner, 1922; Campitonectes Salisbury, 1939; Camponectes Vyalov and Korobkov, 1939 (Hertlein in Moore, 1969, p. N352).

Biogeographic element.-Cosmopolitan (Hertlein in Moore, 1969, p. N352; Kauffman, 1973, p. 359).

Discussion.-Camptonectes was a geographically widespread and long ranging Mesozoic (Early Jurassic to latest Cretaceous) pectinid bivalve that became extinct at the end of the Maastrichtian (Hertlein in Moore, 1969. p. N352). In New Zealand the genus ranges from Middle Jurassic to latest Cretaceous (see Stevens in Suggate et al. (1978, Fig. 4.61-1) for Jurassic species). Two, and possibly a third, Late Cretaceous species of Camptonectes are found in New Zealand marine rocks; these are the fairly widespread species Camptonectes selwynensis (Woods, 1917), Camptonectes n. sp. (Crampton, 1988a, p. 23, Tab. 1, Pl. 1, Fig. 2) from northern Hawke's Bay, and the large, rare Camptonectes n. sp.? from Ocean View, Otago that may be a gerontic specimen of C. n. sp. of Crampton (1988a).

CAMPTONECTES SELWYNENSIS (Finlay, 1927)

Plate 11 Figures 4-5, 7-8, 10-11, 14, 16, 19

Pecten (Camptonectes) hectori Woods, 1917, p. 26, Pl. 11, Figs. 6-9, Pl. 12, Fig. 1 (name preoccupied).

Pecten woodsi Morgan in Wilckens, 1922, p. 32, footnote.

Pecten (Camptonectes) selwynensis Finlay, 1927, p. 526; Marwick, 1928, p. 446; Marwick and Fleming in Wellman, 1959, p. 138;

Fleming in Wellman, 1959, p. 141; Stevens in Suggate et al., 1978, p. 352, Tab. 6.2 (replacement name).

Dimensions.-TM 7485 (IGNS) length 37.5 mm, height 40.5 mm; TM 7486 (IGNS) length 11.0 mm, height 13.0 mm; TM 7567 (IGNS) length 8.0 mm, height 9.5 mm.

Type and previously figured specimens.-Lectotype TM 2508 (IGNS; Woods, 1917, Pl. 11, Fig. 6); TM 2509 (IGNS; Woods, 1917, Pl. 11, Fig. 7); TM 2510 (IGNS; Woods, 1917, Pl. 12, Fig. 1); TM 2511 (IGNS; Woods, 1917, Pl. 11, Fig. 9); TM 2512 (IGNS; Woods, 1917, Pl. 11, Fig. 8).

Figured specimens herein.-TM 2508-2510 (IGNS), TM 2512 (IGNS); TM 7485 (IGNS) (from GS 6173); TM 7486 (IGNS) (from GS 4607); TM 7567 (IGNS).

Material.-Four well-preserved specimens and fragments.

Localities.-?Green Island, Otago, I44/f8489; McKay's Creek, Middle Waipara, southern Canterbury, M34/f7254; Weka Creek, Weka Pass, southern Canterbury, M34/f7264; Ashley County, Middle Waipara, Canterbury, M34/f7305; ?Hawkswood, Marlborough, O32/f8113; Mikonui Stream, southern Marlborough, O32/f8511; Waimarama-Mangakuri coastline, Hawke's Bay, North Island, V22/f9613; ?headwaters of Waikokopu Stream, North Island, W18/f8A; ?east slope of Barron's Hill, Otago, I44/f8510; Selwyn River, Malvern Hills, Canterbury, L35/f6008; lower Conway rail cutting, southern Marlborough, O32/f8792, O32/f8793; Okarahui Stream, southern Marlborough, O32/f8790; Conway River, southern Marlborough, O32/f8513; ?near bend of "Matsumoto" Stream, tributary of Okarahia Stream, southern Marlborough, O32/f8787; Haumuri Bluff, southern Marlborough, O32/f9506; north face of

Haumuri Bluff, O32/f9529, ?O32/f9030; west wing of Haumuri Bluff, southern Marlborough, O32/f8025; tributary of Mikonui Stream, southern Marlborough, O32/f8788; just south of Mikonui Stream, southern Marlborough, O32/f8774; Huarau Point, southern Hawke's Bay, V22/f9613; Porangahau Main Highway, one mile north of junction of Mangaorapa Road, V24/f6028.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Tarapuhi Grit, Conway Formation, Waipara Greensand, ?Brighton Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Widespread in New Zealand from North Island to southeastern South Island.

Discussion.-The correct name of this species has been in a state of confusion since its erection in 1917 and a review is needed here. An early review of this problem was made by Marwick (1928, p. 446). Morgan *in* Wilckens (1922, p. 32) renamed this species as *Pecten woodsi* as *P. hectori* was preoccupied by *P. hectori* Hutton, 1873. However, overlooked and later corrected by Finlay *in* Marwick (1928, p. 446), *P. woodsi* was preoccupied by *P. woodsi* Woldrich, 1918; this species was then unknown to Morgan. A year earlier, Finlay (1927, p. 526), realizing that *P. hectori* was occupied renamed this species as *P.* (*Camptonectes*) *selwynensis*. *Camptonectes selwynensis* has been used by various workers ever since. Boreham (1965, pp. 24-26) in a revision of Hutton's bivalve species from his "Catalogue of Tertiary Mollusca and Echinodermata (1873)" erected a new genus, *Kaparachlamys* with *P. hectori* Hutton, 1873 as type species. *Camptonectes selwynensis* should still be used because this name is a replacement name for a junior homonym (see I. C. Z. N. (1985, Articles 52 and 60 (a))). Thus, Pecten hectori Woods, 1917, is irrevocably a junior homonym of P. hectori Hutton, 1873.

Camptonectes selwynensis seems closely related to a coeval form from Pondoland, referred to as Camptonectes sp. by Woods (1906, pp. 297-298, Pl. 35, Figs. 12-13). Well-preserved specimens of the New Zealand species are relatively uncommon and their thin shells are usually found as partially or wholly decorticated. Camptonectes selwynensis ranged from Late Campanian to Maastrichtian in New Zealand.

CAMPTONECTES n. sp.?

Plate 11 Figure 9

Description.-Shell large for genus, suborbicular, only slightly inflated, moderately robust; apical angle approximately 95°; anterior auricle of left valve well-developed, moderately large; byssal sinus of left valve apparently strong, not well-preserved; commarginal sculpture virtually absent; radial sculpture of moderately strong, oblique, divergent, curved, spaced ribs of subequal strength; ribs raised, well-rounded in cross-section; anterior auricle sculpture of approximately 12 subhorizontal costae that bear closely spaced raised scales or nodules; new radial costae arise by either bifurcation or intercalation, the latter pattern predominating on the medial portion of disc and towards ventral margin.

Dimensions.-OU 40954 length approximately 73.0 mm incomplete; height approximately 93.0 mm; length of anterior portion of hinge margin about 26.0 mm.

Figured specimen.-OU 40945.

Material.-One, incomplete left valve.

Locality.-Approximately 300 m west of coal mine, Ocean View, eastern Otago, South Island, I44/f280.

Stratigraphic range.-Creamery Road Member of Brighton Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known for certain only from the Brighton area, Otago, South Island.

Discussion.-The affinity of this probable new species seems to lie with the Camptonectes group more than any other, but the presence of strong, radial ribs may preclude its placement within Camptonectes s. s. The type of Camptonectes, C. lens (Sowerby, 1818) (refigured by Hertlein in Moore, 1969, pp. N351-N352, Fig. C74-1a, 1b) from the Late Jurassic of England has very fine radial sculpture, unlike the New Zealand species which has relatively coarse, radial ribs. Although large, Camptonectes n. sp.? also approaches smaller examples of the Cretaceous European species C. virgatus (Nilsson, 1827) (pp. 22-23, Pl. 9, Fig. 15) (A. Dhondt, pers. commun., 1992). Otherwise, the divergent pattern of intercalating and bifurcating ribs present in the New Zealand species seem consistent with Camptonectes s. s. A possible juvenile (Plate 11 Figure 6) figured by Crampton (1988, p. 22, Pl. 1, Fig. 2) as Camptonectes n. sp. from the Maungataniwha Sandstone (Piripauan Stage, upper Campanian) may represent this species. Camptonectes selwynensis (Finlay, 1927), also from the latest Cretaceous of New Zealand, is not a close relative of Camptonectes n. sp.?, as the former species has very fine, radial sculpture unlike the strong, radial sculpture of C. n. sp.?

Genus CHLAMYS Röding, 1798

Chlamys Röding, 1798, p. 161.

Type species.-(by subsequent designation, Herrmannsen, 1847) Pecten islandicus Müller, 1776.

Synonyms.-See extended list by Hertlein in Moore (1969, p. N355).

Biogeographic element.-Cosmopolitan (Hertlein in Moore, 1969, p. N355; Kauffman, 1973, p. 359).

Discussion.-No systematic work has been done on Cretaceous Chlamys-like bivalves of New Zealand and the affinities of reported species are uncertain. A species of Chlamys, affinity uncertain, was reported by Marwick and Fleming in Wellman (1959, p. 138) from Maastrichtian rocks of Kaipara, Northland. Warren and Speden (1978, p. 33, Tab. 3) reported Chlamys sp. from the Late Cretaceous of Haumuri Bluff. Moore et al. (1988, p. 59, Tab. 2) included Chlamys (s. l.) sp. as present in the breccia facies of Maungataniwha Sandstone (Upper Cretaceous), Urewera National Park. Two species of Chlamys are present in the Upper Cretaceous Kahuitara Tuff of Chatham Islands (Campbell et al., 1993). Only one species, Chlamys (Lyriochlamys) conwayensis n. sp. will be described here. The affinities of this new species are somewhat tentative, but a relationship with the widespread Chlamys (Lyriochlamys) group seems probable.

Subgenus LYRIOCHLAMYS Sobetski, 1977

Lyriochlamys Sobetski, 1977, p. 47.

Type species.-(by original designation) Pecten fissicosta Etheridge, 1881.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

CHLAMYS (LYRIOCHLAMYS) CONWAYENSIS n. sp.

Plate 11 Figure 15

Diagnosis.-Small- to medium-sized, suborbicular, robust, height a bit greater than length; umbonal angle of approximately 92°; sculpture of 22, undivided, subequal, strong, rounded, costae with poorly developed scales on left valve; ctenolium moderately developed with at least 7 small teeth; microsculpture reticulate.

Description.-Shell small- to medium-sized, robust, suborbicular, height a bit greater than length; left valve slightly inflated; umbonal angle of about 92°; dorsal margin moderately long, slightly elevated; anterodorsal and posterodorsal margins moderately concave merging towards subtruncated to moderately rounded anterior and posterior margins; anterior and posterior auricles unequal, thickened, subtruncated, anterior auricle moderately long, twice the length of posterior one; anterior auricle with narrow radial grooves; byssal sinus of left valve moderately developed; ctenolium moderately small with about seven, narrow, elongated teeth; left valve sculpture of about 22, strong, unequal, subequally spaced, undivided, slightly rounded costae with poorly developed scales becoming weaker towards umbo and well-spaced commarginal growth pauses; microsculpture finely reticulate, becoming obsolete towards umbo.

Dimensions.-Holotype TM 7487 (IGNS), length 15.0 mm, height 17.0 mm.

Type.-Holotype TM 7487 (IGNS).

Type locality.-Railway cutting, north side of Conway River mouth, southern Marlborough, South Island, O32/f8124.

Figured specimen.-TM 7487 (IGNS).

Material.-One well-preserved left valve.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous).

Geographic distribution.-Known only northeastern South Island.

Discussion.-The presently restricted Campanian new species *Chlamys* (*Lyriochlamys*) *conwayensis* n. sp. agrees well with the Cretaceous European type species *C*. (*L*.) *fissicosta* (Etheridge, 1881 (see Woods, 1902, p. 163, Pl. 30, Figs. 3-8; Sobetski, 1977, pp. 47-50, Pl. 3, Figs. 9-11) and a similar, slightly younger species, *C*. (*Microchlamys*) *propesalebrosa* Darragh and Kendrick, 1991 (pp. 55-58, Fig. 16A-E), from the Maastrichtian Miria Formation of northwestern Australia. *Chlamys* (*L*.) *conwayensis* n. sp. has a more developed ctenolium with several teeth, more widely spaced radial ribs and more developed reticulate microsculpture, compared to *C*. (*L*.) *fissicosta*. I originally allocated tentatively the New Zealand species to *C*. (*Microchlamys*), based on the poorly developed scales on radial costae (possibly an artefact of preservation) and its closeness to the Australian species *C*. (*M*.) *propesalebrosa*. The Australian species has a slightly shorter hinge line, less thickened auricles, a smaller ctenolium and more equal radial costae compared to the left valve of *C*. (*L*.) *conwayensis* n. sp. The presence of reticulate microsculpture of *C*. (*M*.) *propesalebrosa* cannot be deduced from the figures of this species by Darragh and Kendrick, but is noted in their diagnosis and description. The radial rib pattern of only marginally interlocking ribs and flattened shell of *C.* (*M.*) *propesalebrosa* is not consistent with *C.* (*Microchlamys*), type species *Pecten pulchellus* Nilsson, 1827 (p. 22, Pl. 9, Fig. 12; Sobetski, 1977, pp. 57-59, Pl. 4, Fig. 9) from the latest Cretaceous of Europe; *C.* (*Microchlamys*) is characterised by its interlocking rib pattern and small gibbous shell, quite distinct from *C.* (*Lyriochlamys*) which has a pattern of marginally interlocking ribs which branch on the right valve and intercalate on the left (cf. Waller, 1991, pp. 13-14). (In error, Waller (1991) misinterpreted Sobetski's (1977) designation of *Microchlamys* and *Lyriochlamys* as subgenera of *Chlamys* by treating them as genera.) *Chlamys* (*Lyriochlamys*) *conwayensis* n. sp. and *C.* (*M.*) *propesalebrosa* are more appropriately placed in *C.* (*Lyriochlamys*).

Waller (1991, p. 14) was of the opinion that "... *Lyriochlamys* and *Microchlamys*, barely survived the great extinction event at the end of the Cretaceous and evolved into the modern *Chlamys* and *Palliolum* groups, respectively" (see fig. 8 depicting the phylogeny of Entoliidae and Pectinidae plotted against time).

Genus *MIXTIPECTEN* Marwick, 1928

Mixtipecten Marwick, 1928, p. 456.

Type species.-(by original designation) *Pecten* (*Aequipecten*) *amuriensis* Woods, 1917.

Synonym.-*Mixtopecten* Tucker-Rowland, 1938 (Hertlein *in* Moore, 1969, p. N359).

Biogeographic element.-Paleoaustral, as interpreted here.

Discussion.-*Mixtipecten* was presumed to be an endemic, monotypic genus known only for certain from the Late Cretaceous of the New Zealand region, including Chatham Islands, until its report in Maastrichtian rocks of Central Chile by Stinnesbeck (1986), who redescribed *Pecten chilensis* d'Orbigny, 1847, as *Chlamys* (*Mixtipecten*) *chilensis* (pp 170-172, Pl. 2, Figs. 8-13). Diagnostic features of *Mixtipecten* include a small shell, a nearly flat right valve with weak radial ribs, and convex left valve with deep, byssal notch, large auricles and numerous narrow, primary ribs. Hertlein *in* Moore (1969, p. N359) and Stinnesbeck (1986, p. 170) regarded this group as a subgenus of *Chlamys*, but morphological differences between *Chlamys* s. s. and *Mixtipecten* suggest that, indeed, *Mixtipecten* should be retained at generic rank.

MIXTIPECTEN AMURIENSIS (Woods, 1917)

Plate 11 Figures 12-13, 17-18, 21; Plate 12 Figures 1-5, 8-10, 13, 26

Pecten (*Aequipecten*) *amuriensis* Woods, 1917, pp. 26-27, Pl. 12, Figs. 2-9.

Mixtipecten amuriensis (Woods, 1917), Marwick, 1928, p. 446-447; Fleming *in* Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5; Stevens *in* Suggate *et al*., 1978, p. 352, Tab. 6.2; Stilwell *in* Aitchison *et al*., 1993, Fig. 4d.

?*Mixtipecten* cf. *amuriensis* (Woods), Campbell *et al*., 1993, Tab. 4.3.

Chlamys (*Mixtipecten*) *amuriensis* (Woods, 1917), Hertlein *in* Moore, 1969, pp. N359-N360, Fig. C82-3a, 3b; Stinnesbeck, 1986, p. 171.

Dimensions.-TM 7488 (IGNS) (GS 5) length of left valve 11.0 mm, height 11.0 mm; TM 7568 (IGNS) length 13.5 mm, height 12.5 mm; TM 7569 (IGNS) length 8.5 mm, height 9.0 mm; OU 40657 length 20.0 mm, height 21.5 mm; OU 41265 length 6.5 mm, height 6.5 mm.

Type and previously figured specimens.-Lectotype (as designated here) TM 2524 (IGNS; Woods, 1917, Pl. 12, Fig. 7; Hertlein *in* Moore, 1969, Fig. C82-3a; Warren and Speden, 1978, Fig. 26-9); TM 2519 (IGNS; Woods, 1917, Pl. 12, Fig. 2); TM 2520 (IGNS; Woods, 1917, Pl. 12, Fig. 3); TM 2521 (IGNS; Woods, 1917, Pl. 12, Fig. 4; Hertlein *in* Moore, 1969, Fig. C82-3b; Warren and Speden, 1978, Fig. 26-10); TM 2522 (IGNS; Woods, 1917, Pl. 12, Fig. 5); TM 2523 (IGNS; Woods, 1917, Pl. 12, Fig. 6); TM 2525 (IGNS; Woods, 1917, Pl. 12, Fig. 8); TM 2526 (IGNS; Woods, 1917, Pl. 12, Fig. 9); ?TM 2527 (IGNS; Woods, 1917, Pl. 12, Fig. 10); ?TM 2528 (IGNS; Woods, 1917, Pl. 12, Fig. 11).

Figured specimens.-TM 2519-2528, TM 2524, TM 7488, TM 7568, TM 7569 (all IGNS), OU 40657, OU 41265.

Material.-26 specimens.

Localities.-East wing of Haumuri Bluff, southern Marlborough, O32/f9032, O32/f9026, O32/f9027; west wing of Haumuri Bluff, O25/f8025 (type); southeast of Black Grit reef, Haumuri Bluff, southern Marlborough, O32/f9542; Mikonui Stream, southern Marlborough, O32/f8694; lower Conway Rail cutting, southern Marlborough, O32/f8793; near bend of "Matsumoto" Stream, tributary of Okarahia Stream, southern Marlborough, O32/f8787; north face of Haumuri Bluff, O32/f9529, O32/f9030; Haumuri Bluff, O32/f9028; tributary of Mikonui Stream, O32/f8788; just south of Mikonui Stream, O32/f8774A; North Branch of Waianakarua River, Otago, J42/f218; ?eastern Pitt Island, CH/f11, ?CH/f319.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Tarapuhi Grit, Conway Formation, Katiki Formation, ?Kahuitara Tuff (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-north and central eastern South Island to possibly Chatham Islands.

Discussion.-The geographic distribution of *Mixtipecten amuriensis* in New Zealand was extended recently by Stilwell *in* Aitchison *et al*. (1993) to include the Waianakarua River area, Otago. Previously, the species was known only from the Marlborough area. Possibly, *M*. *amuriensis* extended to the Chatham Islands (Campbell *et al*., 1993), but identification of this species was tentative. In New Zealand, *M*. *amuriensis* is present in upper Campanian to Maastrichtian rocks.

Few pectinid species are morphologically similar to *M*. *amuriensis*. A coeval Maastrichtian species, *Chlamys* (s. l.) *cracenticostata* Darragh and Kendrick, 1991 (pp. 62-65, Fig. 17A-O) from the Miria Formation of northwestern Australia, compares well with *M*. *amuriensis* and may be a member of this group. Height to length ratios of these two species are similar, approximately 1:1. The Australian species has finer radial sculpture, more numerous radial ribs, and a slightly lower umbonal angle of 100° compared to *M*. *amuriensis* which has an umbonal angle of approximately 105°. The shape of the auricles are also somewhat different in these species as is also the degree of depth of the byssal notch. As a sidenote, the strongly divergent sculpture of specimens of *C*. (s. l.) *cracenticostata* figured by Darragh and Kendrick (for example, left valves, Fig. 17-B and 17-M) may be of interspecific rather than intraspecific significance or may be simply a reflection of intraspecific ontogenetic differences. Unfortunately, no specimens of _M_. _amuriensis_ are available with cardinal crura preserved for comparison with other taxa.

Mixtipecten _amuriensis_ is closely related to a Chilean species, _M_. _chilensis_ (d'Orbigny) from the Quiriquina Formation. The differences between these two species can only be considered slight at the most. _Mixtipecten_ _chilensis_ has somewhat variable radial ribs that appear "beaded" and more rounded auricles compared to _M_. _amuriensis_ which has smoother radial ribs and somewhat sharper auricle margins. See Stinnesbeck (1986, p. 172, Fig. 15) for interesting autecological reconstruction of the "stabilisierende Funktion des vorderen Aurikel" or stabilising function of the anterior auricle of the right valve with respect to current motion and center of rotation of _Mixtipecten_ _chilensis_.

Subfamily NEITHEINAE Sobetski, 1960

Genus _NEITHEA_ Drouet, 1824

Neithea Drouet, 1824, p. 186.

Type _species_.-(by subsequent designation, Chenu, 1862) _Pecten_ _aequicostatus_ Lamarck, 1819.

Synonyms.-_Neithaea_ Gray, 1840; _Neitea_ d'Orbigny, 1846; _Mithea_ Anderson, 1902; _Neitha_ Preston, ,1925; _Nerithea_ Grant and Gale, 1931 (Hertlein _in_ Moore, 1969).

Biogeographic _element_.-Cosmopolitan (Hertlein _in_ Moore, 1969, p.

N371; Kauffman, 1973, p. 359).

Discussion.-Neithea was more or less a cosmopolitan group during the Late Cretaceous and the origin of the group occurred sometime during the Early Cretaceous. The European species of Neithea were monographed recently by Dhondt (1973) who also reviewed the taxonomy of the group. Note also earlier, shorter reviews of Neithea by Freneix and Lefevre (1967, pp. 772-774) and Freneix (1972, pp. 78-80). Hertlein in Moore (1969, p. N371) gave a general geologic range of Neocomian to Senonian, although as pointed out by Harland et al. (1982, pp. 30-31) these informal sub-epochs over the years have meant different things to different people. As indicated by records in the southern hemipshere and Europe, Neithea does range into the Maastrichtian after which time the group became extinct. Recently, Darragh and Kendrick (1991, p. 69) reported the presence of Neithea in the Maastrichtian of northwestern Australia, where it was only known previously from the Neocomian. In New Zealand, Neithea is known only from the Maastrichtian from one small area near Dunedin, Otago, where it is relatively rare.

NEITHEA GRANGEI (Murdoch, 1924)

Plate 12 Figures 6-7

Pecten n. sp., Grange, 1921, p. 163.

Chlamys grangei Murdoch, 1924, p. 159, Pl. 9, Fig. 1.

Neithea grangei (Murdoch), Marwick in Ongley, 1939, p. 55; Marwick and Fleming in Wellman, 1959, p. 138.

Nerithea grangei (Murdoch), Stevens, 1965, p. 36.

Dimensions.-OU 40947 length 16.0 mm incomplete, height 18.5 mm ;

OU 40946 length 11.0 mm, height 12.0 mm.

Types.-Holotype TM 7452 (IGNS; Murdoch, 1924, Pl. 9, Fig. 1); paratype TM 7453 (IGNS; unfigured).

Type locality.-Precise locality not given by Murdoch (1924), but probably east slope of Barrons Hill, Brighton, Otago, South Island, I44/f8510.

Figured specimens herein.-OU 40946 and OU 40947.

Material.-Two specimens, one well-preserved.

Localities.-East slopes of Barrons Hill, Brighton, South Island, I44/f8510.

Stratigraphic range.-Brighton Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Only known at present from a small area in eastern Otago, South Island.

Discussion.-*Neithea grangei* is the only described species of this genus from New Zealand and is usually overlooked in the literature. A questionable occurrence of the group was noted by Stevens and Fleming *in* Suggate (1978, p. 714) in the Korangan Stage (upper Aptian). The original description of *Neithea grangei* in a paper on Tertiary Mollusca has not helped this rare taxon gain significance in the scientific community. Murdoch (1924, p. 159) did not compare his new species with any other taxa and other than his description wrote very little. This species is most likely conspecific with *Pecten* n. sp. recorded by Grange (1921, p. 163) in his report on the geology of the Green Island Coalfield, as Grange's specimen also has a quite pronounced medial, principal, radial rib characteristic of the species. Marwick *in* Ongley (1939, p. 55) was the first to recognise that Chlamys grangei is not a Chlamys, but probably a Neithea based on Murdoch's unclear figure. The holotype of Neithea grangei was presumably collected from what has been recently been named the Creamery Road Limestone Member (McKellar, 1990, p. 19) of the Brighton Formation. A second example, OU 40946, has a much more subdued medial rib, compared to the holotype, suggesting that this characteristic feature given in the description by Murdoch is a variable one in the species. A specimen was also taken from the Barrons Hill Lens, also a member of the Brighton Formation. Neithea sp. (Darragh and Kendrick, 1991, pp. 69-70, Fig. 19A) from the upper Maastrichtian Miria Formation, the inferred temperate species N. regularis (Schlotheim, 1813) from the Coniacian to the Campanian of North America to the Russian Platform (reviewed and refigured by Dhondt, 1985b, p. 41, Fig. 1d-f, 1h-i), and N. quinquecostata (Sowerby, 1814) (figured by Woods, 1908, p. 298, Pl. 35, Fig. 14; also see European examples figured by Dhondt, 1973, Fig. 2a-c) from the Late Cretaceous of Pondoland, South Africa, are similar to Neithea grangei, except that the New Zealand species has a less inflated shell, a much stronger medial, radial rib and more numerous principal radial costae. Most European Cretaceous forms of Neithea have inflated umbones, unlike N. grangei which are only slightly inflated. Neithea grangei appears not to be closely related to European species and probably arose from an unknown Austral species. No Late Cretaceous species of Neithea have been reported from Antarctica, southern South America or New Caledonia.

Superfamily ANOMIACEA Rafinesque, 1815

Family ANOMIIDAE Rafinesque, 1815

Genus ANOMIA Linné, 1758

Anomia Linné, 1758, p. 700.

Type species.-(by subsequent designation, Schmidt, 1818) Anomia ephippium Linné, 1758.

Synonyms.-Echion Poli, 1791; Echinoderma Poli, 1795; Fenestella Röding, 1798; Operculella Montersorato, 1915 (Keen in Moore, 1969, p. N383).

Biogeographic element.-Indo-Pacific/Tethyan as inferred here (should be treated as cosmopolitan?).

Discussion.-Anomia was first recognized in the New Zealand Cretaceous by Warren and Speden (1978, p. 50, Tab. 5). This New Zealand Late Cretaceous species is hitherto undescribed or figured. The New Zealand range of the genus is Late Campanian to Recent. Only two species are represented in the fossil record during this time period; these are Anomia sp. from the Late Cretaceous (Piripauan to Haumurian? stages), and the very long-ranging species A. trigonopsis Hutton, 1877, from the mid Eocene (Bortonian Stage) to Recent. Previously, no Anomia species have been reported from New Zealand Paleocene rocks, but a mid to upper Teurian (mid to Upper Paleocene) species has recently been identified by the author from Kaiwhata River, southern North Island and is described below in the section on Paleocene New Zealand bivalves.

The mode of life of Anomia is one of attachment to either rock or wood surface by means of fused byssal threads into a calcified plug which passes through a notch in the right valve

(Abbott, 1974, p. 451). The outer surface of Anomia species can be shaped according to a shell's ornamentation to which it is attached and thus "mimic" the rib pattern of the host (Powell, 1979, p. 383). A specimen from Haumuri Bluff (TM 7489, IGNS) figured in Plate 12 (herein) reveals xenomorphic sculpture of a large, wide groove extending from dorsal to ventral margin, indicating possible attachment of the upper valve to a coarsely ribbed bivalve, such as Inoceramus. The large range of morphological variation in Anomia renders species-level separation difficult; as an example, there are vitually no morphological differences between A. trigonopsis Hutton, 1877 (figured by Beu and Maxwell, 1990, pp. 179-180, Pl. 18, Figs. a-b) and the Recent type species A. ephippium Linné, 1758 (figured by Crouch, 1826, p. 21, Pl. 13, Fig. 1; Wye, 1991, p. 257, central figure top row).

ANOMIA n. sp.?

Plate 12 Figures 11-12, 16-17

Description.-Shell of small to moderate size for genus, thin, subcircular, very weakly inflated; umbo very small, subcentral, slightly curved; height to length ratio slightly greater than 1:1; dorsal margin of left valve nearly flat merging towards moderately rounded anterodorsal and posterodorsal margins; ventral margin convex; commarginal sculpture irregular; radial sculpture of closely spaced threads, stronger dorsally near umbo and midway on disc.

Dimensions.-TM 7489 (IGNS) length 13.5 mm, height 15.0 mm; TM 7490 (IGNS) length 5.0 mm, height 4.5 mm.

Figured specimens.-TM 7489 (IGNS), TM 7490 (IGNS); Ge 8085 (AIM) may also represent this species.

Material.-Three specimens.

Localities.-Lower Conway rail cutting, southern Marlborough, South Island, O32/f8792; near bend of "Matsumoto" Stream, tributary of Okarahia Stream, southern Marlborough, O32/f8787; north face of Haumuri Bluff, southern Marlborough, O32/f9529; just south of Mikonui Stream, southern Marlborough, O32/f8774A; east wing, Haumuri Bluff, southern Marlborough, O32/f9027; ?Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); ?unspecified horizon within Unit 4 of Evans (1985), formation not specified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-At present restricted to southern Marlborough, South Island and possibly Northland.

Discussion.-*Anomia* n. sp.? seems closely related to a coeval Late Campanian to Maastrichtian species, *A. solitaria* Wilckens, 1905 (p. 29, Pl. 5, Fig. 3) from Baguales, southern Patagonia, except that the New Zealand species is more dorsally-ventrally elongated with more irregular, commarginal growth pauses. Comparison of *Anomia* n. sp.? with a much younger New Zealand species, *A. trigonopsis* Hutton, 1877, indicates only a distal relationship for these taxa. The high variability of known *Anomia* species forces here only a tentative assignment at this time, as a large number of specimens are needed to deduce relationships.

Order LIMOIDA Waller, 1978

Superfamily LIMACEA Rafinesque, 1815

Family LIMIDAE Rafinesque, 1815

Discussion.-Only one species of limid was recorded by Woods (1917) in the latest Cretaceous bivalve fauna of New Zealand, but since that writing several other limid groups have come to light in the Cretaceous record. Species of Limidae in the New Zealand Cretaceous include Limea (Pseudolimea) woodsi (Suter, 1921), Limatula sp. of Fleming, 1978, Seymourtula antarctica (Wilckens, 1910), Regalalima cf. R. marlburiensis (Woods, 1917) (= Acesta (Plicacesta) n. sp.? herein), Acesta warreni n. sp., and possibly others.

Genus LIMEA Bronn, 1831

Limea Bronn, 1831, p. 623.

Type species.-(by monotypy) Ostrea strigilata Brocchi, 1814.

Subgenus PSEUDOLIMEA Arkell in Douglas and Arkell, 1932

Pseudolimea Arkell in Douglas and Arkell, 1932, p. 160.

Type species.-(by original designation) Plagiostoma duplicata J. de C. Sowerby, 1827.

Synonyms.-Limoarca von Münster, 1832; Limnoarca Paetel, 1875 (Cox and Hertlein in Moore, 1969, p. N391).

Biogeographic element.-Cosmopolitan (Cox and Hertlein in Moore, 1969, p. N391).

Discussion.-Fleming (1978, p. 37) in a review of fossil and Recent species of Limatula in the southwestern Pacific was the first to recognize the presence of the widespread Triassic to Late Cretaceous limid subgenus Limea (Pseudolimea) in the Cretaceous of New Zealand. Limea (Pseudolimea) did not survive the Cretaceous-Tertiary transition. In New Zealand, specimens of this group have been collected from rocks ranging from upper Campanian to Maastrichtian age. In a recent paper on Late Cretaceous *L.* (*Pseudolimea*) species of Europe, Dhondt (1989, pp. 106-107) recognized only subtle differences, namely in shape of the ribs, between *Limea* and *Pseudolimea*, which were hitherto treated as not directly related. Differentiation of the two genera is slight enough that *Pseudolimea* appears to be in fact phylogenetically closely related to *Limea* s. s. and can more appropriately be considered as a subgenus of *Limea*, although some authors (e. g. Darragh and Kendrick, 1991, p. 20; Campbell *et al*., 1993, Tab. 4.3) continue to treat the two genera as separate. As Dhondt pointed out, placing *Pseudolimea* as a subgenus of *Limea* makes "phylogenetic sense", as this group would then fill a gap from the oldest subgenus *L.* (*Eolimea*) from the mid Triassic to much younger Cenozoic groups. Separation of *L.* (*Pseudolimea*) from other groups is based on "its obliquity and relative width from *Limatula* Wood, 1835; its strongly developed ribs and suborbicular shape from *Limatulella* Sacco, 1898; and its smallness and absence of gape from *Limaria* Link, 1807" (Dhondt, 1989, p. 107). Hinge details distinguish *L.* s. s. from *l.* (*Pseudolimea*). *Limea* s. s. has narrow, oblique, unequal hinge teeth located in angles at the ends of the hinge margin whereas *L.* (*Pseudolimea*) has fewer to no teeth which are only slightly oblique occupying dorsal angles (Cox and Hertlein *in* Moore, 1969, pp. N389, N391). Typical *Limea* (*Pseudolimea*) also has a more elongated and compressed ligament pit compared to *Limea* s. s. It is quite probable that *Limea* is a polyphyletic group, but detailed studies of hinge features, etc. are needed to confirm this hypothesis (Kilburn, 1990, p. 223).

The inferred paleodepth of European Cretaceous L. (Pseudolimea) species ranged from nearshore to possibly 250 m as indicated by Campanian-Maastrichtian "Schreibkreide" assemblages (Dhondt, 1989, p. 106). Specimens taken from the Okarahia Sandstone and Tarapuhi Grit in South Island indicate "medium to shallow" and "intertidal or directly subtidal" depths (Warren and Speden, 1978, p. 19 and p. 23 respectively) for the Late Cretaceous New Zealand species L. (Pseudolimea) woodsi (Suter, 1921).

LIMEA (PSEUDOLIMEA) WOODSI (Suter, 1921)

Plate 12 Figures 15, 19, 21-22, 24-25

Lima (Limatula) huttoni Woods, 1917, p. 27, Pl. 12, Figs. 12-16.

Lima (Limatula) woodsi Suter, 1921, p. 3, footnote (replacement name for L. (L.) huttoni, preoccupied).

Limatula woodsi (Suter), Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5.

Pseudolimea woodsi (Suter), Fleming, 1978, p. 37.

Dimensions.-TM 7491 (IGNS) (GS 11359) length 3.5 mm, height 6.5 mm.

Type and previously figured specimens.-Lectotype TM 2532 (IGNS; designated by Fleming, 1978, p. 37, Pl. 12, Fig. 13 of Woods, 1917); TM 2530 (IGNS; Woods, 1917, Pl. 12, Fig. 14); TM 2531 (IGNS; Woods, 1917, Pl. 12, Fig. 12); TM 2534 (IGNS; Woods, 1917, Pl. 12, Fig. 16).

Figured specimens herein.-TM 2530-2534 (IGNS); TM 7491 (GS 11359).

Material.-Five specimens.

Localities.-West of Haumuri Bluff rail tunnel, southern Marlborough, South Island, O32/f8783; east wing of Haumuri Bluff, southern Marlborough, O32/f9025, O32/f9032, O32/f9030, O32/f9026, O32/f9027; west wing of Haumuri Bluff, O32/f8025 (type?); southeast of Trig G, southern Marlborough, O32/f8116; Okarahia Stream, southern Marlborough, O32/f8790; lower Conway rail cutting, southern Marlborough, O32/f8793; near bend of "Matsumoto" Stream, tributary of Okarahia Stream, southern Marlborough, O32/f8787; Haumuri Bluff, O32/f9504; north face of Haumuri Bluff, O32/f9529; west wing of Haumuri Bluff, O32/f8026; Ngaroma, Conway River, southern Marlborough, O32/f8862; tributary of Mikonui Stream, southern Marlborough, O32/f8788; Mangahouanga Stream, western Hawke's Bay, North Island, V19/f26, V19/f6909; lower Mangahouanga Stream, V19/f6508; east-flowing tributary of Mangahouanga Stream, V19/f181A; Hook Stream, North Island, V19/f6645; tributary of Waihoroihika Stream, Lake Waikaremoana, North Island, W18/f10; eastern Pitt Island, CH/f11; southwestern side of neck of Taruwhenua Peninsula, Pitt Island, CH/f257A; west of Flowerpot Bay, Whenuatara Peninsula, Pitt Island; northern Pitt Island, CH/f466; western side of base of Taruwhenua Peninsula, CH/f587.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Tarapuhi Grit, Conway Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Maungataniwha Sandstone, Kahuitara Tuff (Upper Cretaceous).

Geographic distribution.-Eastern North Island to northeastern South Island; Pitt Island, Chatham Islands.

Discussion.-*Limea* (*Pseudolimea*) *huttoni* (Woods, 1917) was at the naming of the species known from only two localities. Since 1917 the number of Late Cretaceous localities with this species has increased to nearly 30. As with other New Zealand Cretaceous taxa, the name of this species should be reviewed. Woods (1917, p. 27) originally named the discussed species *Lima* (*Limatula*) *huttoni*. As the name of this species was found to preoccupied by *Lima* *huttoni* Suter, 1914, Suter (1921, p. 3, footnote) renamed the species *Lima* (*Limatula*) *woodsi*. In a review of the limid genus *Limatula*, Fleming (1978, p. 37) realized that Woods' species was actually a *Pseudolimea*, not a *Limatula*, and left this species as *Pseudolimea* *woodsi* (Suter, 1921) because *L*. (*Limatula*) *huttoni* Woods, 1917, is a primary homonym (see ICZN, Article 53 (c)).

Pseudolimea *flabellulina* Darragh and Kendrick, 1991 (pp. 20-23, Fig. 3 A-D), from the Miria Formation (Maastrichtian) of northwestern Australia bears resemblance to *L*. (*P*.) *woodsi*, but the latter New Zealand species has a more oblique shell and is more dorsoventrally elongated compared to the Australian and other Austral coeval species. The sculpture of *L*. (*P*.) *woodsi* is more like *Pseudolimea* sp. of Darragh and Kendrick, 1991 (pp. 23-24, Fig. 3E-F), also from the Miria Formation, but again the shell is narrower and more oblique. Fleming (1978, p. 37) rejected Finlay's (1927, p. 454) unwarranted claim that the Pliocene to Recent New Zealand species *Limatula* *maoria* Finlay, 1927 (refigured by Powell, 1979, p. 382, Pl. 73, Fig. 7 (unnumbered specimen; number inadvertently absent from Powell's figure) is a descendant of _L._ (_P._) _woodsi_.

Late Cretaceous species of _Limea_ (_Pseudolimea_) in the Austral Realm have been reported from New Zealand, Chatham Islands, Australia, southern India, and may be present in New Caledonia. _Pseudolimea_ sp. (Freneix, 1960, p. 24, Pl. 1, Fig. 5) was identified from Campanian rocks of New Caledonia, was later reassigned to _Limea_ _perlata_ Freneix, 1980 (p. 95-96, Pl. 3, Fig. 8).

Genus _LIMATULA_ Wood, 1839

Limatula Wood, 1839, p. 235.

Type _species_.-(by subsequent designation, Gray, 1847) _Pecten_ _subauriculata_ Montagu, 1808.

Synonyms.-Numerous, see Cox and Hertlein _in_ Moore (1969. p. N389).

Biogeographic _element_.-Cosmopolitan (Cox and Hertlein _in_ Moore, 1969, p. N389; Kauffman, 1973, p. 359).

Discussion.-Fleming (1978, p. 37) realized that two species are represented in Woods' (1917) figures of what is here called _Limea_ (_Pseudolimea_) _woodsi_ and singled out Fig. 15 (Pl. 12) as representing a distinct group. Fleming assigned this specimen to _Limatula_ (_Limatula_) sp. indet. and his assignment seems appropriate here.

LIMATULA sp. indet.

Plate 12 Figures 14, 20

Limatula (_Limatula_) sp. indet., Fleming, 1978, p. 37.

Dimensions.-TM 2533, length 5.5 mm, height 12.0 mm, width of single valve 3.3 mm; TM 7492 (IGNS) length 5.0 mm, height 8.0 mm.

Previously _figured_ _specimen_.-TM 2533 (IGNS; Woods, 1917, Pl. 12,

Fig. 15).

Figured specimens herein.-TM 2533 (IGNS), TM 7492 (IGNS).

Localities.-West wing of Haumuri Bluff, southern Marlborough, O32/f8025; ?McKay's Creek, Middle Waipara, South Canterbury, M34/f7254; ?Bull Point, Kaipara, Northland, Q08/f9626; Te Hoe River, western Hawke's Bay, North Island, V19/f184; ?Shag Point, Otago, North Island, J43/f6472; Mangahouanga Stream, North Island, V19/f6909.

Stratigraphic range.-Only Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous) and Maungataniwha Sandstone (Upper Cretaceous) for certain.

Discussion.-See Fleming (1978, p. 37).

Genus SEYMOURTULA Zinsmeister and Macellari, 1988

Seymourtula Zinsmeister and Macellari, 1988, p. 269.

Type species.-(by original designation) Lima (Limatula) antarctica Wilckens, 1910.

Biogeographic element.-Paleoaustral, as interpreted here.

Discussion.-Fleming (1978, p. 52, Fig. 26) figured a specimen that he considered to be conspecific with a Maastrichtian Antarctic species Limatula (Limatula) antarctica Wilckens, 1910 (pp. 16-17, Pl. 1, Fig. 8; see also Zinsmeister and Macellari, 1988, p. 269, Fig. 8.12-13). In a review of the Late Cretaceous bivalves of Seymour Island, Antarctic Peninsula, Zinsmeister and Macellari (1988, p. 269) proposed Seymourtula for a group of bivalves similar to Limatula, but distinguished from the latter by having a distinctly modioliform outline and a broad posterior margin. Limatula (L.) antarctica was designated as type species of Seymourtula by Zinsmeister and Macellari and hence, the New Zealand species, although not definitely conspecific with S. antarctica, should be reassigned to this genus.

Seymourtula is a paleoaustral genus, known for certain from the Campanian of New Caledonia and Maastrichtian of New Zealand and Antarctic Peninsula, suggesting possibly a migration route from the easternmost sector of the Weddellian Province to the western sector before the Maastrichtian. No Seymourtula species are known after the Maastrichtian. Seymourtula was most likely an epibyssate suspension feeder that attached itself to a hard substrate (Macellari, 1988, p. 43).

SEYMOURTULA cf. S. ANTARCTICA (Wilckens, 1910)

Plate 12 Figures 18, 23, 27

cf. Lima (Limatula) antarctica Wilckens, 1910, pp. 16-17, Pl. 1, Fig. 8.

cf. Limatula (Limatula) antarctica (Wilckens), Fleming, 1978, p. 52, Fig. 26; Palamarczuk et al., 1984, p. 401.

cf. Seymourtula antarctica (Wilckens), Zinsmeister and Macellari, 1988, p. 269, Fig. 8.12-13.

Dimensions.-TM 5556 (IGNS), length 11.0 mm, height about 20 mm, width of single valve 5.0 mm; OU 40948 from OU 11136 length 11.0 mm, height 18.5 mm; OU 40971 length 5.5 mm, height 10.5 mm.

Figured specimens.-TM 5556 (IGNS); OU 40948, OU 40971.

Locality.-Known only from McKay's Creek, Middle Waipara, South Island, M34/f7254 and Shag Point, Otago, South Island, J43/f6544.

Stratigraphic range.-?Conway Formation, Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from Middle Waipara and

Otago, South Island.

Discussion.-*Seymourtula* cf. *S*. *antarctica* seems closely related to the Antarctic form, but only a tentative assignment can be made at this time due to the absence of well-preserved material. Fleming (1978, p. 52) was more firm in his assignment of this species as *L*. (*L*.) *antarctica*, whereas Zinsmeister and Macellari (1988, p. 269) were uncertain about the affinities of this species. There is little doubt, however, that the Antarctic and New Zealand species are closely related, and future studies may indeed indicate a more firm relationship. *Seymourtula* *parisi* (Freneix, 1980) (pp. 93-94, Pl. 3, Figs. 3-4) from the Campanian of New Caledonia is also closely related to *S*. cf *S*. *antarctica*, but the New Zealand species has a more oblique shell.

Genus *ACESTA* H. and A. Adams, 1858

Acesta H. and A. Adams, 1858, p. 558.

Type *species*.-(by monotypy) *Ostrea* *excavata* Fabricius, 1779.

Synonym.-*Callolima* Bartsch, 1913 (Cox and Hertlein *in* Moore, 1969, p. N386).

Biogeographic *element*.-Cosmopolitan (Cox and Hertlein *in* Moore, 1969, p. N386; Kauffman, 1973, p. 359).

Discussion.-*Acesta* first appeared in the Jurassic in New Zealand (Marwick, 1953), then reappeared in the latest Cretaceous in the Maastrichtian (Haumurian Stage) where it ranged through to the Pliocene (Mangapanian Stage), and Recent (Beu, 1973, pp. 315-316; Beu and Maxwell, 1990, p. 91). Recently, *Acesta* was discovered to be present in the uppermost Maastrichtian to mid Paleogene of the Antarctic Peninsula (Zinsmeister and Macellari, 1988;

Stilwell and Zinsmeister, 1992), where it was previously known only from slightly older rocks of Snow Hill Island (Wilckens, 1910) and Ula Point, James Ross Island (Stilwell and Zinsmeister, 1987). Freneix (1960, p. 25; 1980, pp. 92-93) reported the presence of Acesta in Campanian rocks of New Caledonia. Acesta is also present in uppermost Cretaceous rocks of southern South America and was just recently found to be present in the Lefipan Formation, Chubut (Olivero et al., 1990, Tab. 1).

Cretaceous species of Acesta are inferred to have been sessile, epifaunal suspension feeders similar to life habits of Recent species. Most fossil species of New Zealand are found in greensand, limestone, and marl indicating deposition in deep water (Beu and Maxwell, 1990, p. 91), but the Cretaceous species described here is inferred to have been present in shallower water.

ACESTA WARRENI n. sp.

Plate 13 Figure 1

Acesta n. sp., Warren and Speden, 1978, p. 33, Tab. 3. (inadvertently misplaced in Table 3 under GS 9896; should be GS 9832).

Diagnosis.-Very large Acesta, moderately oblique, slightly ventricose, elongate-subovate; length, 72% of height; anterior and posterior margins subparallel; posterior auricle moderately long; radial sculpture somewhat wavy, stronger posteriorly.

Description.-Shell very large, elongate-subovate, equivalve, inequilateral, moderately inflated, slightly ventricose; length, 72% of height; auricles unequal in length, posterior auricle moderately long, straight, gently sloping; anterior and posterior margins subparallel; ventral margin narrowly rounded; commarginal sculpture of widely spaced, moderately pronounced growth pauses, becoming more bunched ventrally; radial sculpture of closely spaced, low, wavy ribs (approximately 7-9 per centimeter), more pronounced near posterior margin; central portion of valve mostly smooth except for growth pauses.

Dimensions.-Holotype TM 7493 (IGNS) (GS 9832) length 137.0 mm, height 190.0 mm.

Type.-Holotype TM 7493 (IGNS) (GS 9832).

Figured specimen herein.-TM 7493 (IGNS).

Type locality.-Outcrops along tunnel, just north of "Old Claverley" Stream at rail level, southern Marlborough, South Island, O32/f8795.

Material.-One specimen (right valve).

Stratigraphic range.-Conway Formation? (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Only known from southern Marlborough, South Island.

Discussion.-The Maastrichtian species *Acesta warreni* n. sp. is easily separated from other coeval latest Cretaceous species from the Austral Realm in having an elongate-subovate outline and a length which is 72% of height. A possible lineal descendant from the Paleocene of Chatham Islands, *Acesta* n. sp. (Beu and Maxwell, 1990, p. 91, Pl. 3i), has a broader shell with pronounced radial sculpture on the central and anterior portions of the shell, compared to *A. warreni* n. sp. which apparently lacks radial sculpture centrally and anteriorly and has an elongate shell with near subparallel anterior and posterior margins. Acesta warreni n. sp. has an outline reminiscent of a Paleocene species, A webbi Zinsmeister and Macellari, 1988 (pp. 267-268, Fig. 9.1-3), from the Sobral Formation of Seymour Island, Antarctic Peninsula, but the New Zealand species is more elongate, has a much larger shell, and much stronger radial sculpture. Acesta latens (Feruglio, 1936) (pp. 245-247, Pl. 25, Figs. 1-2) from the latest Cretaceous of Salamanqueano, Patagonia, southern South America has a smaller shell, is less elongate, and has much stronger radial ornamentation. Acesta warreni n. sp. is quite rare, with only specimen known.

Etymology.-Species named after G. Warren, NZGS (now IGNS), for his work on the stratigraphy and biostratigraphy of the Haumuri Bluff District, southern Marlborough.

Subgenus PLICACESTA Vokes, 1963

Plicacesta Vokes, 1963, p. 90.

Type species.-(by original designation) Lima smithi G. B. Sowerby, 1888.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-Acesta (Plicacesta) is characterised by strong radial ribbing on the central portion of the shell, whereas Acesta s. s. has superficial or for the most part weak radial riblets that are strongest laterally and grade into fine striae medially (Cox and Hertlein in Moore, 1969, p. N386). Lima marlburiensis Woods, 1917 (pp. 8-9, Pl. 3, Fig. 3) from the Ngaterian to ?Piripauan Stages (mid to ?Upper Cretaceous) of New Zealand and Regalilima cf. R. marlburiensis (Woods) (Piripauan Stage) figured by Crampton (1988a, Pl. 1, Fig. 3) seem more appropriately placed in

Acesta (Plicacesta). Regalilima has broad, flat ribs with incised interspaces unlike the specimen figured by Crampton (1988a), which has strong, raised, somewhat rounded radial riblets, very typical of A. (Plicacesta). The above two species are probably not conspecific.

The geologic range extends at least to the latest Cretaceous for A. (Plicacesta), the oldest recorded occurrence of the subgenus, in New Zealand and is also known from the Paleocene of Chatham Islands (Beu and Maxwell, 1990, p. 88). Previously the subgenus was known from Japan and North America Eocene to Recent (Cox and Hertlein in Moore, 1969, p. N386) and Eocene of southwestern Patagonia (Griffin, 1991, pp. 130-132).

ACESTA (PLICACESTA) n. sp.?

Plate 13 Figure 5

Regalilima cf. R. marlburiensis (Woods, 1917), Crampton, 1988a, Pl. 1, Fig. 3.

Figured specimen.-TM 6859 (IGNS).

Locality.-Headwaters of Waikokupu Stream, approximately 400 m southwest of Whakatakaa Hut, Urewera National Park, northern Hawke's Bay, North Island, W18/f8A.

Stratigraphic range.-Maungataniwha Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous).

Discussion.-Acesta (Plicacesta) n. sp.? seems to be distinct from Lima marlburiensis Woods, 1917, which may be a congener, but is doubtfully conspecific as details in rib morphology differ between the two species. Acesta (Plicacesta) n. sp.? is only known from one locality in northern Hawke's Bay.

Order OSTREOIDA Férussac, 1822

Suborder OSTREINA Férussac, 1822

Superfamily OSTREACEA Rafinesque, 1815

Family GRYPHAEIDAE Vialov, 1936

Subfamily EXOGYRINAE Vialov, 1936

Genus PLANOSPIRITES Lamarck, 1801

Planospirites Lamarck, 1801, p. 400.

Type species.-(by original designation) Planospirites ostracina Lamarck, 1801.

Synonym.-Planospirigenus Renier, 1807 (Stenzel *in* Moore, 1971, p. N1122).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-Planospirites is reported from the New Zealand Late Cretaceous record for the first time. A specimen labelled as "Exogyra cf. conica" is reclassified herein as a member of the apparently restricted, short-lived Maastrichtian exogyrine Planospirites. A similar or conspecific species was listed by Campbell *et al.* (1993, Tab. 4.3) as A. conica (Sowerby), present in the Upper Cretaceous Kahuitara Tuff of Chatham Islands. Planospirites, previously recorded from the Maastrichtian of Western Europe only, has an oval and very inequivalve shell with a very flat right valve and basin-shaped left valve. In contrast, Amphidonte, a Late Cretaceous group recognised from the Russia and North America, is characterised by many chomata, less pronounced growth squamae and smooth shell (Stenzel *in* Moore, 1971, pp. N1119, N1122). The New Zealand species has a more-or-less planar left valve and moderately excavated right valve more akin to Planospirites than to Exogyra or Amphidonte. This group has not been reported from other coeval rocks around the southern circum-Pacific. A worn specimen with doubtful vestiges of chomata (eroded?) of Planospirites associated with Pseudoperna lapillicola Marwick, 1926d, was collected from Koranga. The poor preservation of this specimen forces only a preliminary assignment here, but it probably represents a new species.

PLANOSPIRITES sp.

Plate 13 Figures 2, 6

Dimensions.-TM 7494 (IGNS) length 11.5 mm, height 11.5 mm.

Figured specimen.-TM 7494 (IGNS).

Material.-One worn left valve.

Locality.-Exact locality not known, near waterfall below Fifty Stream, Koranga, North Island, possibly X17/f101.

Stratigraphic range.-Association with Pseudoperna lapillicola suggests a Haumurian age (Maastrichtian, uppermost Cretaceous), formation unknown.

Geographic distribution.-Known at present only from Koranga.

Discussion.-The species-level affinity of this small probable Planospirites species are uncertain. The relationship of Planospirites sp. to A. conica (Sowerby) reported by Campbell et al. (1993, Tab. 4.3) from the Upper Cretaceous Kahuitara Tuff, Pitt Island, Chatham Islands, is unknown. No specimens of this species are available to me at this time for comparison. The flat nature of the right valve of this problematic species is reminiscent of the Maastrichtian western Europe type species of

Planospirites, P. ostracina Lamarck, 1801 (figured by Stenzel in Moore, 1971, p. N1122, Fig. J96-2a, 2b), except that the New Zealand species has a somewhat deeper left valve.

Surprisingly, other gryphaeid taxa such as Pycnodonte, present in abundance elsewhere in the southern hemisphere Late Cretaceous record have not been recorded here in New Zealand. However, Pycnodonte was listed as tentatively present in the Kahuitara Tuff of Chatham Islands by Campbell et al. (1993, Tab. 4.3).

Family OSTREIDAE Rafinesque, 1815

Discussion.-Oyster debris, consisting of entire specimens and fragments, is fairly ubiquitous in marine Upper Cretaceous rocks of New Zealand and has been recorded from over 80 localities from the tip of Northland to eastern Otago. The fragmentary nature of material from some of these localities hinders identification. Localities with ostreid bivalves of uncertain affinity are listed here: Brighton, Otago, South Island, I44/f8490; Saurian Sands, Trelissik Basin, Canterbury, K34/f9096; north side of Broken River, Canterbury, K34/f9558; left bank of Acheron River, Canterbury, K35/f7509; Selwyn Rapids, Canterbury, L35/f6510; near Motumapau Point, arm of Parengarenga Harbour, Northland, N02/f9626; left bank of Kaiwara River, North Canterbury, South Island, N33/f9811; Gorries Creek, North Canterbury, N34/f42; Saurian Boulder, Waipara River, Canterbury, N34/f6313; Haumuri Bluff, southern Marlborough, O32/f8512, O32/f9506, ?O32/f9507, O32/f9529; Benmore Stream, Marlborough, P30/f7157; headwaters of Waikokopu Stream, North Island, W18/f8A; ?Birch Hill Road, Raukumara Peninsula, North Island, X16/f9161, X16/f9161B;

Okarahui Stream, southern Marlborough, O32/f8790; Mataikona River, Aohanga, southern Hawke's Bay, U25/f6473; near Trig G, Waipukurau, southern Hawke's Bay, V22/f8766; Ngaroma, Conway River, O32/f8862; and tributary of Uhakanekeneke River, Northland, P05/f9539.

At least two species are present in the Late Cretaceous New Zealand record and these species are revised here, Pseudoperna lapillicola (Marwick, 1926d) [Ostrea] and Crassostrea sp. [Ostrea cf. O. dichotoma Bayle, 1869]. In some areas these ostreid bivalves form bioherms, as in nearly forgotten localities such as "Oyster Hill", near Selwyn Rapids, revisited during the course of this work. Skeletal concentrations such as that found at "Oyster Hill" would fall under the category of mixed skeletal oyster bioherms or "biohermos osteros esqueletales mixtos" of Leanza and Hugo (1985) in their example of a Paleocene oyster bioherm from the Roca Formation La Pampa Province, Argentina, as other invertebrate debris is present "en sedimentos de distincta naturaleza" (within sediments of a different nature) (p. 143). At "Oyster Hill", composed of abundant Crassostrea bivalve shells, other molluscs include Aphrodina (Tikia), Modiolus sp., Septifer? eurycrenulata n. sp., Eriptycha, and turritellid? gastropods.

Subfamily OSTREINAE Rafinesque, 1815

Genus PSEUDOPERNA Logan, 1899

Pseudoperna Logan, 1899, p. 95 as Pseudo-perna (Vokes, 1980, p. 68).

Type species.-(by subsequent designation, Stenzel in Moore, 1971)

Ostrea congesta Conrad in Nicolet, 1843.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-The affinity of Ostrea lapillicola Marwick, 1926d, from the Maastrichtian of New Zealand needs reassessment. This species is not an Ostrea as it is quite unlike the type species, O. edulis Linné, 1758 (figured by Crouch, 1826, p. 21, Pl. 12, Fig. 8; Stenzel in Moore, 1971, p. 1138-1139, Fig. J109, J110, J111, J112, J113). The generic location of Ostrea lapillicola seems to lie with the short-ranging Late Cretaceous Pseudoperna group, which strikingly like the New Zealand species, is very small with an ovate to spatulate or irregular outline depending on degree of xenomorphism, has an apparently deep umbonal cavity and shallow resilifer groove in the left valve, and has poorly developed sculpture compared to many ostreid groups. The relationship of Pseudoperna congesta (Conrad, 1843), the type species, to O. lapillicola is a strong one and with additional study, these two species may be found to be conspecific. Ostrea lapillicola is herein reassigned to Pseudoperna. Stenzel in Moore (1971, p. 1132) reported the geologic range of Pseudoperna to be Coniacian to Santonian, but the genus extended to the Campanian of New Caledonia (Freneix, 1980, pp. 32-33) and Maastrichtian of New Zealand before apparently becoming extinct at the end of the Maastrichtian.

As a sidenote, Stenzel in Moore (1971, p. 1139) considered the Cretaceous to Recent genus Ostrea to be present worldwide, except in polar regions, but more recently Zinsmeister (1984) and Stilwell and Zinsmeister (1992) recorded the presence of the group in the Eocene of the Antarctic Peninsula, further extending the range.

PSEUDOPERNA LAPILLICOLA (Marwick, 1926d)

Plate 13 Figures 3-4, 7-10

Ostrea lapillicola Marwick, 1926d, pp. 381-382, Figs. 2-6; Marwick and Fleming in Wellman, 1959, p. 138; Speden and Keyes, 1981, p. 55, Pl. 22, Fig. 8; Speden in Suggate et al., 1978, p. 363, Fig. 6.6-8; Crampton and Moore, 1990, p. 346; Warren and Speden, 1978, p. 41, Fig. 26-3.

Dimensions.-TM 7495 (IGNS) length 14.0 mm, height 22.5 mm; TM 2506 (IGNS), TM 2507 (IGNS).

Types.-Holotype TM 2506 (IGNS; Marwick, 1926d, Figs. 4-6), paratype TM 2507 (IGNS; Marwick, 1926d, Figs. 2-3).

Figured specimens.-TM 2506, TM 2507, TM 7495 (all IGNS).

Localities.-Large meander in Birch Stream, Canterbury, South Island, M34/f9896; the Narrows, Hokianga River, North Island, O05/f9498, north side, O05/f9524; Penehu Point, north side of Hokianga Harbour, Northland, O05/f9573; Limestone Creek, southwest of Trig G, southern Marlborough, South Island, O32/f8114; north shore of Whangaroa Harbour, Northland, P04/f9494; Waihora Stream, southern North Island, T26/f19; Awakei Creek, tributary of Waitangi River, Northland, P05/f9502; Tangowhahine Stream, Northland, P07/f7570; Paparoa River, Kaipara Harbour, Northland, Q08/f9011; large tributary joining Kaiwhata River from east, Northland, T27/f6726; approximately 6 km north of mouth of Mataikona River, southeastern North Island, U25/f6613; ?Tangakuhe Stream, southeastern North Island, U24/f115; attached to Inoceramus, mouth of tributary of Pakowhai

River, southeastern North Island, U25/f8047; ?tributary of Marauhika Stream, north of Glenfallach Station, U25/f8722; head of Takiritini Stream, Tinui River, southeastern North Island, U25/f8991; Mangahouanga Stream, Hawke's Bay, North Island, V19/f26, V19/f187, V19/f6909B; lower Mangahouanga Stream, ?V19/f6508, V19/f6511; Hook Stream, Hawke's Bay, North Island, V19/f6649; east-flowing tributary of Mangahouanga Stream, V19/f181A; Elsthorpe Road, east of Tarui Station, central eastern North Island, V22/f8722; loose boulder conglomerate near Trig A, Pourerere, central eastern North Island, V23/f6490; small unnamed? stream, east of Trig 23, Porangahua, central eastern North Island, V24/f6484; Porangahua Beachblock, Porangahua, central eastern North Island; near head of east branch of Kahunui Stream, North Island; Waihau Bay on east coast towards Orete Point, Raukumara Peninsula, North Island, Y14/f7553; east bank of Waiorongomai River, Raukumara Peninsula, Y15/f55; west bank of Waiorongomai River, Y15/f7559; Tikihore Stream, Raukumara Peninsula, Y16/f41; Tarndale Road, Raukumara Peninsula, Y16/f49; ?tributary of Pakarae River, Raukumara Peninsula, Y17/f9722; 400 m up south-flowing tributary of Totaurangakautuku River, Raukumara Peninsula, Z14/f106; Clarke Creek, Taurangakautuku River, Raukumara Peninsula, Z14/f8492; ?right bank of Mata River, Raukumara Peninsula, Z15/f6722; Riparua and Tuparoa, Auckland, North Island, Z15/f7482 (type?); near Kaingake Point, north of Tuparoa, North Island, Z15/f7497; mid Waipara, Canterbury, South Island, M34/f7263; "The Narrows", south side of Motakione Peninsula, Northland, O05/f9505; Ngamahanga Point, north side of Hokianga Harbour, Northland, O06/f7574; north face of Haumuri

Bluff, southern Marlborough, South Island, O32/f8849, O32/f9529, O32/f9533; Haumuri Bluff, O32/f9506, O32/f8851; east wing of Haumuri Bluff, O32/f9030; Waitangi River, Bay of Islands, Northland, P05/f9499, P05/f9491.

Stratigraphic range.-Brighton Formation, Tarapuhi Grit, Maungataniwha Sandstone, Punakitere Sandstone, Tapuwaeroa Formation, Saurian Sands, Broken River Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous). *Pseudoperna lapillicola* is present in several unnamed Cretaceous formations and is considered to be a Haumurian (Maastrichtian) index taxon as this species is not known from rocks older than of Maastrichtian age in New Zealand.

Geographic distribution.-Widespread in New Zealand from Northland to eastern Otago.

Discussion.-Marwick (1926d, p. 381) recognized the presence of his species *Ostrea lapillicola* at only two localities. Since his writing, *O. lapillicola* (here reassigned to *Pseudoperna*) has been recorded from nearly 50 Maastrichtian localities from Northland to eastern Otago. I do not know of any occurrence of this species in Campanian rocks. As Marwick remarked, *P. lapillicola* may be related to a southern Patagonian Upper Cretaceous species, *O. vulselloides* Wilckens, 1905 (p. 30, Pl. 5, Figs. 5-7) (*Pseudoperna*?) and perhaps *O. congesta* Conrad from Missouri and other localities, which was subsequently designated as type species of *Pseudoperna* by Stenzel *in* Moore (1971) mentioned earlier. Freneix (1960, p. 31, Pl. 2, Fig. 4) assigned a Campanian New Caledonian species to *Liostrea*? cf. *L. congesta* and later (1980, pp. 98-99) reassigned this species, inferred previously to be closely related to *O. congesta* Conrad, to *Pseudoperna*. In error Marwick attributed *O. vulselloides* to Wilckens (1917). The presence of *Pseudoperna* in the Late Cretaceous of New Zealand and New Caledonia further strengthens faunal ties between these Gondwana "fragments" during this time.

Late Cretaceous ostreid species are known around the southern circum-Pacific from Western Australia (Feldtmann, 1963), New Zealand and southern South America (see Riccardi, 1988, p. 49, Tab. 7 for non-exhaustive list of ostreid taxa). Wilckens (1910) described *Ostrea seymouriensis* from the Late Cretaceous (Units four through nine (Maastrichtian), Lopez de Bertodano Formation, Zinsmeister and Macellari, 1988, p. 271) of Seymour and James Ross Island, Antarctic Peninsula. Freneix (1960, p. 32) believed that this Antarctic species should be assigned to *Liostrea* and two decades later in 1980 (p. 98) reassessed the affinity of this group again as a *Acutostrea* related to the type species, *A. acuticostris* (Nilsson). More recently Zinsmeister and Macellari (1988, pp. 269-271) redescribed *Ostrea seymouriensis* as *Pycnodonte* (*Phygraea*) *seymouriensis* in the Gryphaeidae, but made no mention of Freneix's review of the species as a member of the Ostreidae. The figures of this species by Wilckens (especially Pl. 1, Fig. 12b) and Zinsmeister and Macellari indicate a probable, but still tentative, relationship to *Pycnodonte* (*Phygraea*) rather than to *Acutostrea*, based on general outline and hinge morphology.

Genus *CRASSOSTREA* Sacco, 1897

Crassostrea Sacco, 1897, p. 15.

Type species.-(by original designation) *Ostrea* (*Crassostrea*) *virginica* (Gmelin, 1791).

Synonyms.-Numerous, see Stenzel *in* Moore (1971, p. N1128).

Biogeographic element.-Cosmopolitan (Stenzel *in* Moore, 1971, p. N1129; Kauffman, 1973, p. 359). *Crassostrea* was considered to be an Indo-Pacific element by Fleming (1967, p. 115) who was apparently unaware of the extensive distribution of this group.

Discussion.-*Crassostrea* is a cosmopolitan group, known from Late Cretaceous to Recent (Stenzel *in* Moore, 1971, p. N1129). Warren and Speden (1978, p. 50, Tab. 5) and Suggate *et al*. (1978, p. 352, Tab. 6.2) were the first to note the presence of *Crassostrea* in the Late Cretaceous record of New Zealand, *C*. cf. *C*. *dichotoma* (Bayle), a reassignment of this species to this group after Woods' (1917, pp. 24-25) preliminary identification. Not discussed by Woods (1917), there is little doubt that the "large *Ostrea*" noted by von Haast (1871, p. 10; 1872, p. 23) in the Malvern Hills area, including Oyster Hill, is what is here referred to as *Crassostrea* sp. The extensive distribution of *Crassostrea* during the Cretaceous, as is the case today, most likely reflects the oviparous nature of the group's reproduction allowing production of long-swimming veligers (Morton, 1979, p. 147).

CRASSOSTREA sp.

Plate 14 Figures 1-2, 4-6

Ostrea sp. cf. *dichotoma* Bayle, Woods, 1917, pp. 24-25, Pl. 10, Figs. 7a-b and Pl. 11, Fig. 1; Marwick *in* Ongley, 1939, p. 55; Marwick and Fleming *in* Wellman, 1959, p. 138.

Crassostrea cf. *dichotoma*, Warren and Speden, 1978, p. 50, Tab. 5.

Crassostrea sp., Suggate *et al*., 1978, p. 352, Tab. 6.2.

Dimensions.-OU 40949 length 70.0 mm, height 130.0 mm nearly complete.

Previously figured specimens.-Hypotypes, TM 2503 (IGNS; Woods, 1917, Pl. 11, Fig. 1) and TM 2504 (IGNS; Woods, 1917, Pl. 10, Fig. 7).

Figured specimens herein.-TM 2503 (IGNS), TM 2504 (IGNS), OU 40949, right valve.

Material.-Numerous specimens, mostly incomplete.

Localities.-Selwyn River, Malvern Hills, Canterbury, South Island, L35/f6017; Oyster Hill, Malvern Hills, Canterbury, L35/f67; Waipara Beds, Weka Creek, Canterbury, M34/f7264; Mid Waipara Coal Beds, Canterbury, M34/f7305; Boby's Creek, Waipara, North Canterbury, N34/f6257; Whakamaria Stream, Raukumara Peninsula, North Island, X16/f61; south of Selwyn River, Malvern Hills, Canterbury, L35/f6007; lower Conway rail cutting, southern Marlborough, South Island, O32/f8792; north face of Haumuri Bluff, southern Marlborough, O32/f9530.

Stratigraphic range.-Selwyn Rapids Beds (Upper Cretaceous); Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Broken River Formation, Whangai Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Raukumara Peninsula, eastern North Island to Canterbury, South Island.

Discussion.-Woods (1917, pp. 24-25) assigned this species to *Ostrea* cf. *O*. *dichotoma* Bayle, 1849 (see Coquand, 1869, p. 99, Pl. 27, Figs. 1-6, especially Fig. 1), as his available material was not well-enough preserved for accurate diagnosis. Specimen OU 40950 (Pl. 14 Fig. 2) from Acheron River may also represent this species. A second species, assigned to *Ostrea* sp. (see Pl. 14 Fig. 3, this work), was also reported by Woods (1917, p. 25, Pl. 11, Fig. 2, TM 2505 (IGNS)). No further data are available for this species. Difficulties in collection and preparation and the general fragmentary nature of the available material to this day prevents further discussion, except to acknowledge the seemingly firm assignment of this species to *Crassostrea* because it has a very high, slender shell with irregularly spaced growth squamae consistent with this group.

Subclass PALAEOHETERODONTA Newell, 1965

Order TRIGONOIDA Dall, 1889

Superfamily TRIGONACEA Lamarck, 1819

Family TRIGONIIDAE Lamarck, 1819

Discussion.-The Cretaceous Trigoniidae of New Zealand was recently monographed by Sir C. A. Fleming (1987) in his last major classic work, "New Zealand Mesozoic bivalves of the superfamily Trigonia". This monograph, already out of print and scarce as only 400 copies were printed in error due to miscalculation (and reckless cost cutting!), was published shortly before Sir Charles' death the same year. (In fact, the Management/Administrative Group were keen to cut out expenses and overlooked the fact that IGNS Library Exchanges would require quite a large number of copies (I. W. Keyes, pers. commun., 1993)).

Except for possible new species presented here from the Waianakarua River, Otago, South Island and northern Hawke's Bay, North Island and new fossil localities postdating Fleming's monograph, no thorough review of this group will be made. However, all Late Cretaceous species relevant to this work will be figured, including drawing's of the various taxa by R. C. Brazier in Fleming (1987) to unite and integrate these species for purpose of the systematic catalogue presented here.

At least fifteen species of trigoniid bivalves are known to date from the Piripauan (Mp) to Haumurian Stages (Mh) of New Zealand and Chatham Islands. These are: *Pterotrigonia* (*Pterotrigonia*) *pseudocaudata* (Hector, 1886) (Mp-Mh), the first Late Cretaceous trigoniid species to be described from New Zealand (Plate 14 Figures 7-9; Plate 15 Figures 1-8, 10); *Pterotrigonia* (*Pterotrigonia*) *waitangiensis* Fleming, 1987 (Mh) (Plate 15 Figure 9); *Pterotrigonia* (*P*.) n. sp. aff. *waitangiensis* Fleming of Crampton, 1988a and Moore *et al*., 1988 (Mp) (not figured); *Pterotrigonia* (*Ptilotrigonia*) *ultima* Fleming, 1987 (Mh) (Plate 15 Figures 11-13); *Pacitrigonia hanetiana hectori* (d'Orbigny, 1842), Fleming, 1987 (Mp) (Plate 16 Figures 1-10); *Pacitrigonia hanetiana woodsi* (d'Orbigny, 1842), Fleming, 1987 (Mp-Mh) (Plate 15 Figures 14-15); *Pacitrigonia sylvesteri* Marwick, 1932 (Mp-Mh) (Plate 16 Figures 11-13; Plate 17 Figures 1, 3, 10); *Oistotrigonia piripauana* Fleming, 1987 (Mp) (Plate 17 Figures 7-8, 13, 17); *Oistotrigonia ongleyi* Fleming, 1987 (Mh) (Plate 17 Figures 4-5); *Oistotrigonia waiparensis* (Woods, 1917) (Mh) (Plate 17 Figures 6, 9, 12); *Iotrigonia leda* Fleming, 1987 (Mp) (Plate 17 Figure 16); *Iotrigonia lenseni* Fleming, 1987 (Mh)

(Plate 17 Figure 2); Eselaevitrigonia sp. of Campbell et al., 1993 (Mp-Mh) (not figured); Eselaevitrigonia? n. sp.? of Stilwell in Aitchison et al. (1993) (Mh) (Plate 17 Figures 15, 18); and Trigonia n. sp. aff. marwicki Fleming, 1987 of Crampton (1988a) and Moore et al., 1988 (Mp) (Plate 17 Figure 14).

Pacitrigonia hanetiana (d'Orbigny) has since been recorded by Crampton and Moore (1988, p. 346, Append. 1) from the Maungitaniwha Sandstone (Upper Cretaceous) of western Hawke's Bay, Mangahouanga Stream float *3; Katiki Formation (Haumurian Stage, Maastrichtian) from the North Branch of the Waianakarua River, Otago by Stilwell in Aitchison et al., 1993, ?J42/f082, J42/f218; and South Branch of the Waianakarua River, ibid. J42/f127. Also present in the Maungataniwha Sandstone of western Hawke's Bay are Pacitrigonia sylvesteri Marwick, V19/f182-182A, Mangahouanga Stream float *3; Pterotrigonia pseudocaudata (Hector), V18/f8500, Waiau River float *1, Loony Stream float *2, V19/f182-182A, Mangahouanga Stream float *3, Te Hoe float *4; and Oistotrigonia waiparensis (Woods), ?V19/f184, V19/f186, V19/f196, Mangahouanga Stream float *3 (Crampton and Moore, 1988, p. 346, Append. 1).

Genus ESELAEVITRIGONIA Kobayashi and Mori, 1954

Eselaevitrigonia Kobayashi and Mori, 1954, p. 161.

Type species.-(by original designation) Trigonia meridiana Woods, 1917.

Biogeographic element.-Paleoaustral (cf. Fleming, 1987, p. 42 and as interpreted here).

Discussion.-Since the monograph on trigoniid bivalves by Fleming

(1987), a review of Late Cretaceous Antarctic species was published by Zinsmeister and Macellari (1988), including *Eselaevitrigonia regina* (Wilckens, 1910) and *Oistotrigonia pygoscelium* (Wilckens, 1910). *Pacitrigonia hanetiana* (d'Orbigny) was also reported in the Maastrichtian Quiriquina Formation of central Chile by Stinnesbeck (1986, pp. 172-174, Pl. 2, Figs. 14-16).

ESELAEVITRIGONIA? n. sp.?

Plate 17 Figures 15, 18

"*Eselaevitrigonia*" n. sp.?, Stilwell *in* Aitchison *et al*., 1993, p. 52, Figs. 4b, 4f.

Description.-Shell medium-sized, moderately thick, trigonal to trigonally subovate, slightly inflated; umbones small, situated more anteriorly; anterodorsal margin moderately long, straight, very steeply sloping at 60° from horizontal merging with well-demarcated, obtusely angled anterior margin; posterodorsal margin long, steeply sloping merging towards angular posterior margin; ventral margin broadly convex; posterior carina reduced to poorly developed; surface of shell smooth, except for low, moderately closely spaced commarginal ribs, slightly stronger near ventral margin.

Dimensions.-OU 40658, length 29.0 mm, height 24.0 mm nearly complete, width of paired valves, 12.5 mm.

Figured specimen.-OU 40658.

Material.-One, articulated specimen.

Locality.-North Branch of Waianakarua River, Otago, South Island, J42/f218.

Stratigraphic range.-Kaitiki Formation (Haumurian Stage, Maastrichtian Stage, uppermost Cretaceous).

Geographic distribution.-Restricted at present to Otago and possibly Chatham Islands.

Discussion.-The relatively smooth shell of only low, commarginal ribs suggests placement of this species within Eselaevitrigonia. The trigonal to trigonally subovate outline of Eselaevitrigonia n. sp.? seems more like E. regina (Wilckens, 1910) (recently refigured and reviewed by Zinsmeister and Macellari (1988, pp. 271-273, Fig. 12.1-7) from the Late Cretaceous of Antarctica, than to the type species, E. meridiana (Woods, 1917) (refigured by Fleming, 1987, pp. 42-43, Pl. 8, Figs. 1-3) from the Ngaterian Stage (Upper Albian? to Cenomanian) of New Zealand which is more produced posteriorly with widely spaced commarginal growth pauses. Although this species most likely represents a new species, the presence of only one, articulated, moderately preserved specimen prevents me from assigning a new name at this time.

Subclass HETERODONTA Neumayr, 1884

Order VENEROIDA H. and A. Adams, 1856

Superfamily LUCINACEA Fleming, 1828

Family LUCINIDAE Fleming, 1828

Subfamily MYRTEINAE Chavan, 1969

Genus MYRTEA Turton, 1822

Myrtea Turton, 1822, p. 133.

Type species.-(by monotypy) Venus spinifera Montagu, 1803.

Synonyms.-Cyrachaea Leach, 1819; Eulopia Dall, 1901; ?Notomyrtea Iredale, 1924 (Chavan in Moore, 1969, p. N499).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here. Kauffman (1973, p. 374) curiously designated Myrtea as endemic to New Zealand.

Discussion.-Before its presence was confirmed here in Upper Cretaceous rocks of New Zealand, Myrtea was only known for certain from the Paleocene to Recent. However, Beu and Maxwell (1990, p. 184) stated a range of Duntroonian (Upper Oligocene) to Opoitian (Lower Pliocene) for Myrtea in New Zealand, but included a "Wangaloan" (Lower Paleocene) species, M. microlirata (Finlay and Marwick, 1937), in their systematic checklist (p. 396). Chavan in Moore et al. (1969, p. N499) questionably listed Myrtea as present in Upper Cretaceous New Zealand rocks, whereas later Kauffman (1973, p. 374) in his review of Cretaceous Bivalvia designated this genus as endemic to New Zealand. Myrtea is also known from Oligocene to Recent of Europe, Australia, Asia and North America. Beu and Maxwell (1990) appeared not to have recognized the various subfamilies of Lucinidae reviewed and proposed by Chavan in Moore et al. (1969), but other recent authors such as Vaught (1989) recognized the various subfamilies.

MYRTEA CANTERBURIENSIS (Woods, 1917)

Plate 18 Figures 1-4, 6

Lucina canterburiensis Woods, 1917, p. 30, Pl. 16, Figs. 4, 5a-c; Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5, p. 41, Fig. 26-12; Speden in Suggate et al., 1978, p. 364, Fig. 6.7-3; Speden and Keyes, 1981, pp. 56-57, Pl. 23, Fig. 3.

"Lucina" canterburiensis Woods, Marwick and Fleming in Wellman, 1959, p. 138.

Supplementary description.-Shell medium-sized, moderately thin, subquadrate, slightly to moderately inflated; umbones orthogyrous, central to subcentral; anterodorsal margin straight to very slightly concave, moderately long, moderately sloping, merging towards subtruncated, very broad, gently rounded anterior margin; posterodorsal margin straight to also slightly concave, merging towards obliquely truncated, gently concave posterior margin; ventral margin broadly convex; posterior sulcus shallow; sculpture of more than 16, raised, well-spaced, commarginal lamellae, slightly stronger on anterior and posterior portions of disc, and secondary, fine, interlamellar threads.

Dimensions.-OU 40951 (from OU 10986) length 23.0 mm incomplete, height 26.0 mm.

Types.-Lectotype TM 2551 (NZGS; Speden and Keyes, 1981, p. 99; Woods, 1917, Pl. 16, Fig. 4), hypotype TM 2552 (NZGS; Woods, 1917, Pl. 16, Fig. 5), hypotype TM 5383 (NZGS; Warren and Speden, 1978, Fig. 26-12).

Figured specimens.-TM 2551 (IGNS), TM 2552 (IGNS), OU 40951.

Material.-Eight specimens, mostly incomplete.

Localities.-?Green Island, Otago, I44/f8489; Macilwaiths Coal Mine, Malvern Hills, Canterbury, South Island, L35/f6011; Selwyn River, Malvern Hills, L35/f6017, L35/f6008; ?Selwyn Rapids oyster bed, L35/f6510A; ?near Selwyn River, old army ammunition store around stables, L35/f6511; east wing, Haumuri Bluff, southern Marlborough, O32/f9032, O32/f9026; ?Glenfield, Stream, Marlborough, P29/f9744; west wing, Haumuri Bluff, southern Marlborough, O32/f8025, O32/f8026; ?Manurewera Point, Cape

Palliser area, southernmost tip of North Island, S28/f114; ?Batley, Kaipara, Northland, Q08/f9023; ?promontory between Te Opu and Whakapirau Creeks, Kaipara, Northland, Q08/f9639; ?Porangahau River, central eastern North Island, V23/f6455; Shag Point, Otago, J43/f159.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds, Whangai Formation, unspecified horizon within Unit 4 of Evans (1985) ("Northland Allochthon"), Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Possibly Northland to Otago, South Island.

Discussion.-The appropriate generic location of *Lucina canterburiensis* needs reappraisal. The subquadrate outline, orthogyrous beaks and well-spaced, narrow, raised commarginal lamellae are more akin to *Myrtea* than to *Lucina*, the type of which, *L. jamaicensis* (Spengler, 1784) (figured by Chavan *in* Moore, 1969, p. N493, Fig. E2-6), has a more subtrapezoidal to subcircular shell that is much smoother. Some fossil species of *Myrtea*, for example, *M. valdesculpta* Marwick, 1943, from the Early Miocene (Altonian Stage) of New Zealand, have "distant, narrow lamellae raised into subtriangular spines along the dorsal margin" (Beu and Maxwell, 1990, p. 182, Pl. 18, Fig. j, l). *Myrtea canterburiensis* seems phylogenetically more closely related to mid Tertiary species, such as *M. supraflexa* (Marwick, 1931) (p. 69, Figs. 86-87; see also Fleming, 1966, p. 160, Pl. 31, Figs. 316-317) from New Zealand than to a slightly younger

Early Paleocene species, M. microlirata (Finlay and Marwick, 1937, p. 29, Pl. 3, Fig. 9; also Fleming, 1966, p. 160, Pl. 31, Fig. 308) which is much smaller with radial striae and more curved beaks. The relationship to a coeval species and probable congener, L. scotti (Wilckens, 1910) (p. 57, Pl. 3, Figs. 2a-2b; reviewed and refigured by Zinsmeister and Macellari, 1988, p. 273, Fig. 9.5-6) from the Maastrichtian of the Antarctic Peninsula, is unclear, but the subcircular to subtrigonal outline is quite distinct from M. canterburiensis. A species similar to M.? scotti was recently reported by Stilwell and Zinsmeister (1987) from the Late Cretaceous of Cockburn Island, Antarctic Peninsula; the relationship of this unnamed species from Cockburn Island to M. canterburiensis is also unclear. None of the available material, mostly fragmentary, of M. canterburiensis reveals hinge details, so these features remain unknown. Warren and Speden (1978, p. 50, Tab. 5) inferred this species to be an infaunal, siphonate suspension feeder of low mobility.

MYRTEA CRETACEA n. sp.

Plate 18 Figures 5, 7-8, 10-11

?"Lucina" sp., Marwick and Fleming in Wellman, 1959, p. 138.

?Myrtea sp., Evans, 1985, p. 618, Tab. 1.

Diagnosis.-Small, polished, Myrtea with subcircular to subovate outline; anterior and posterior margins truncated; posterodorsal margin moderately sloping, straight; sculpture of commarginal rounded, spaced, low ribs and radial striations.

Description.-Shell small, thin, subcircular to subovate, slightly inflated to compressed; length to height ratio slightly greater than 1:1; beaks small, subcentral, moderately prosogyrous;

anterodorsal margin short, moderately sloping, slightly concave, merging towards straight, obliquely truncated anterior margin; posterodorsal margin moderately long, straight, gently to moderately sloping, merging towards slightly oblique, subtruncated posterior margin; anterior and posterior margins well-demarcated; ventral margin broadly convex with secondary concavity near intersection of posterior and posteroventral margins; escutcheon lanceolate; ligament on holotype and some paratypes preserved, external, "pencil-shaped", pointed posteriorly; shell polished, mostly smooth, except for spaced, low, slightly raised, rounded ribs, stronger ventrally and radial striations; hinge details obscurred.

Dimensions.-Holotype, Ge 8029 (AIM), length 7.0 mm, height 6.0 mm, width of paired valves, 2.5 mm; paratype, Ge 8626 (AIM), length 6.0 mm nearly complete, height 5.5 mm nearly complete; paratype Ge 6374 (AIM), length 11.5 mm, height 10.0 mm, width of paired valves, 4.3 mm; paratype Ge 7935 (AIM), length 9.0 mm, height 8.0 mm, width of paired valves, 3.5 mm; paratype Ge 6369 (AIM) length 11.5 mm, height 9.0 mm.

Types.-Holotype Ge 8029; paratypes Ge 8626, Ge 7935, Ge 6374, Ge 6369 (all AIM).

Figured specimens.-Holotype Ge 8029, paratypes Ge 6374, Ge 7935, Ge 6369 (all AIM).

Material.-Six, well-preserved, articulated specimens.

Localities.-Kaipara, Northland, Q08/f547 (type); Whakapirau Creek, Kaipara, Northland, Q08/f9637; Hukatere Peninsula, Kaipara Harbour, Q08/f9660; Te Opu, Kaipara, Q08/f9639; Bull Point, Kaipara, Q08/f9626.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Restricted at present to Kaipara, Northland.

Discussion.-This new lucinid species is tentatively assigned to *Myrtea*, based on its close if not lineal relationship with *M. microlirata* (Finlay and Marwick, 1937) from the Early Paleocene of New Zealand, its subcircular to subovate outline, external ligament and radial striations, all features consistent with this group. The disparity in form and sculpture between *Myrtea canterburiensis* which is subquadrate with strong commarginal sculpture and *M. cretacea* n. sp. which is nearly subovate with more subdued commarginal sculpture and radial striations suggests a much earlier origin for the *Myrtea* group, perhaps mid to even Early Cretaceous. *Myrtea cretacea* n. sp. is more broadly ovate with more strongly truncated anterior and posterior margins compared to *M. microlirata* (Finlay and Marwick, 1937) (p. 29, Pl. 3, Fig. 9; also Fleming, p. 160, Pl. 31, Fig. 308), but otherwise the two species are strikingly similar. Specimens of *M. cretacea* are generally exquisitely preserved with highly polished shells and external ligaments. One specimen inferred to be a member of this new species from Kaipara (Q08/f9639), housed at the Auckland Institute and Museum (Ge 6369) (see Plate 18 Figure 5), has stronger, raised commarginal ribs compared to the holotype, but this feature may be an enhanced one from slight erosion.

Family THYASIRIDAE Dall, 1901

Genus THYASIRA Leach in Lamarck, 1818

Thyasira Leach in Lamarck, 1818, p. 195.

Type species.-(by original designation) Amphidesma flexuosa Lamarck, 1818.

Synonyms.-Numerous, see Chavan in Moore (1969, p. N508).

Biogeographic element.-?Indo-Pacific/Tethyan as interpreted here.

Discussion.-Except for a little known Cretaceous Thyasira species first acknowledged by Marshall (1926, p. 207) in his study of the Late Cretaceous ammonites of New Zealand, Thyasira species have been well-studied around the globe, including several species around the southern circum-Pacifc. Part of this lack of knowledge of New Zealand Thyasira stems from the fact that Marshall's recognition of this group postdated by nearly a decade Woods' (1917) monograph on the bivalves. As stated before, virtually no thorough systematic work has been accomplished since this time and until now the affinity of this group has escaped proper assessment.

The life habits of Thyasira has been well studied and numerous workers have commented on the autecology of this group (Kauffman, 1967; Kauffman in Moore, 1969; McKerrow, ed., 1978; Freneix, 1980, 1981; Hickman, 1984; Evans, 1985; Reid and Brand, 1986; Macellari, 1988; Beu and Maxwell, 1990). Thyasira, a deep burrowing suspension feeder of low mobility, is most predominant in low-diversity faunal assemblages and can populate areas of oxygen-poor, hydrogen sulfide-rich waters and food-poor habitats unlike many other groups. Today this group is present in quiet, deep water on the continental shelf, typically in black mud, but can range into very deep water of more than 2000 m.

Chavan *in* Moore (1969, p. N508) reported the presence of *Thyasira* in Cretaceous to Recent areas of Europe, Pacific and Australia. In the southern hemisphere since Chavan's writing and earlier, Cretaceous species have come to light from New Caledonia, New Zealand, Antarctica and South America. The new New Zealand species can be referred to the subgenus *Thyasira* (*Conchocele* Gabb, 1866), an assignment supported by its large and oblique shell.

Subgenus *CONCHOCELE* Gabb, 1866

Conchocele Gabb, 1866, p. 27.

Type species.-(by original designation) *Conchocele disjuncta* Gabb, 1866.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

THYASIRA (*CONCHOCELE*) *BULLPOINTENSIS* n. sp.

Plate 18 Figures 9, 12-17

Thyasira cf. *townsendi* (White, 1990), Marshall, 1926, p. 207.

Thyasira n. sp. A, Marwick and Fleming *in* Wellman, 1959, p. 138.

Thyasira sp., ?Warren and Speden, 1978, p. 50, Tab. 5; Evans, 1985, p. 618, Tab. 1; ?Crampton and Moore, 1990, p. 346;

Diagnosis.-Medium- to large-sized *Thyasira* with moderately thick, moderately oblique, subtrigonal shell; short, oblique truncation at extreme anterior margin of shell; sulcus, broad, deep; sculpture of well-spaced commarginal folds or undulations and radial striations.

Description.-Shell medium-sized to large, moderately thick, inflated, stongly declivous from mid-point on disc to ventral margin, subtrigonal, moderately oblique; ratio of length to height approximately 1:1; beaks small, strongly prosogyrate; umbones prominent, well-rounded; anterodorsal margin moderately short, slightly concave, very steep, merging with short, obliquely truncated, anterior margin, well-demarcated from ventral margin; posterodorsal margin long, gently convex, steeply sloping, slightly more than anterodorsal margin; intersection of posterior and ventral margins subangular; ventral margin broadly convex; sulcus broad, deep extending along posterodorsal margin; margin of fold, sharp, blade-like, narrow, extending approximately 2.5 mm above sulcus on holotype; lunule poorly developed, flattened; very shallow sulcus parallel with lunule; shell ornamentation of low, slightly irregular, spaced, commarginal folds or undulations, more bunched near umbones and ventral margin, and radial striations; anterior adductor scar subpyriform? (specimen Ge 7706.1 (AIM)).

Dimensions.-Holotype, L 3872 (from AU 2576), length 48.0 mm, height 48.5 mm, width of paired valves 32.0 mm; paratype Ge 5954 (AIM) length 56.0 mm, height 58.0 mm, width of paired valves 34.0 mm; paratype Ge 6375 (AIM), length 11.5 mm, height 11.5 mm, width of paired valves 4.0 mm; paratype TM 7564 (IGNS) length 48.0 mm, height 55.5 mm, width of paired valves 33.0 mm.

Types.-Holotype, L 3872 (AU 2576); paratypes Ge 5954 (AIM), Ge 6375 (AIM), TM 7564 (IGNS).

Figured specimens.-L 3872 (AU 2576), Ge 5954 (AIM), Ge 6375 (AIM), TM 7564 (IGNS); Ge 6376 (AIM) may represent a juvenile.

Material.-Ten articulated specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626 (type); Te Opu, Kaipara, Northland, Q08/f9639; Batley, Kaipara, Q08/f9636, Q08/f9023; ?east of Trig G, southern Marlborough, South Island, O32/f8113; ?Limestone Stream, Ngaroma, southern Marlborough, O32/f8846, O32/f8846A; ?Conway River, Ngaroma, O32/f8862; Ngaumi State Forest, Totara Stream, southern tip of North Island, T27/f30; ?east wing of Haumuri Bluff, southern Marlborough, O32/f9032; north side of Tapuaeroa River, easternmost Raukumara Peninsula, North Island, Z15/f6500; ?Mangarua Stream, from Tapuwaeroa Valley Road, eastermost Raukumara Peninsula, Z15/f6572; ?Mangatutakawa Stream near junction of western Mata River, easternmost Raukumara Peninsula, Z15/f6573; Mangahmi Stream, easternmost Raukumara Peninsula, Z15/f9529.

Stratigraphic range.-?Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon", ?Te Mai Formation; ?Conway Formation (Haumurian stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known for certain from Kaipara, Northland and possibly to southern Marlborough, South Island.

Discussion.-Thyasira (Conchocele) bullpointensis n. sp. seems to be moderately closely related to a South American-Antarctic Late Cretaceous species, T. townsendi (White, 1890) (p. 14, Pl. 3, Figs. 1, 2; also figured by Weller, 1903, p. 67, Pl. 11, Figs. 2-3 (not p. 415, Pl. 1, Zinsmeister and Macellari, 1988, p. 273, error); Wilckens, 1910, p. 53, Pl. 2, Fig. 31a-c, Pl. 3, Fig. 1; Zinsmeister and Macellari, 1988, pp. 273-276, Fig. 9.7-8), but T. townsendi has a less inflated shell, an obliquely subquadrate outline with a narrower shell and hence a greater height to length ratio compared to T. bullpointensis n. sp. which is subtriangular in outline with a nearly 1:1 length to height ratio. Ornamentation of these two species is comparable, except that no radial striations, present in T. (C.) bullpointensis n. sp., are mentioned in the supplementary description of T. townsendi by Zinsmeister and Macellari (1988). Comparison of T. (C.) bullpointensis n. sp. with T. collignoni Freneix, 1980 (pp. 40-41, Pl. 5, Figs. 1, 2) from the Campanian of New Caledonia proves difficult in light of the very poor preservation of the figured New Caledonian species, although general outline of the two species in comparison is similar. Preservation of T. collignoni is so poor, in fact, that perhaps this species should assigned **nomen dubium** status as virtually no meaningful comparisons with other taxa can be made.

A review of large Cretaceous to Recent thyasirids formerly assigned to Thyasira should be undertaken due to the small size of the Recent Mediterranean type of Thyasira, T. flexuosa (Montagu, 1803). An assignment for some of these taxa to the relatively large, oblique thyasirid subgenus Conchocele may be more appropriate (A. G. Beu, pers. commun., 1993).

Several small apparently adult Thyasira specimens of subequal size were collected by the author recently in the Campanian? to Maastrichtian Katiki Formation of Shag Point, Otago (locality J43/f159), extending much further south the geographic range of this group in New Zealand. More than likely this group of specimens represents a distinct species from T. (C.)

bullpointensis n. sp. as these shells are much smaller with a more circular outline, but the preservation of this material, so typical of most fossils from this facies, prevents further analysis here.

Etymology.-Species named from its type locality, Bull Point, in Kaipara, Northland.

Superfamily CRASSATELLACEA Férussac, 1822

Family ASTARTIDAE d'Orbigny, 1844

Subfamily ASTARTINAE d'Orbigny, 1844

Genus ASTARTE J. Sowerby, 1816

Astarte J. Sowerby, 1816, p. 85.

Type species.-(by original designation) Venus scotica Maton and Rackett, 1807 (= Pectunculus sulcatus Da Costa, 1778, var. scotica Maton and Rackett, 1807).

Biogeographic element.-Cosmopolitan (Chavan in Moore, 1969, p. N562).

Discussion.-Astarte is here reported from the New Zealand Cretaceous for the first time and this new species represents the sole record of the genus and subfamily in the New Zealand Cretaceous and Tertiary fossil record. Previously, Astarte was recognised in Jurassic rocks of New Zealand only (Marwick, 1953, p. 107, see Pls. 10, Figs. 22, 25, Pl. 11, Figs. 13, 15). Two specimens (Ge 8608 (AIM) and Ge 8615 (AIM)) of Astarte n. sp. were collected from parautochthonous concretions in association with ammonites south of Puriri Point, Hukatere Peninsula, Kaipara Harbour, Northland (Q08/f9660) which are probably referable to Unit 4d (considered to be infaulted slivers) of Evans (1985), "Northland Allochthon". The association of these astartid specimens with Haumurian ammonites supports a latest Cretaceous age.

Chavan *in* Moore (1969, p. N562) reported a Middle Jurassic to Recent range and a cosmopolitan geographic distribution for *Astarte*, diagnostic features of which include a subquadrate outline, inequilateral shell, enlarged posterior end which is truncated, strong rounded commarginal ribs, remote lateral teeth and laminar oblique cardinals, impressed lunule and impressed escutcheon. *Astarte* n. sp. is morphologically similar to New Zealand Cenozoic species of *Placamen* Iredale, 1925, which is characterised by having thickened, spaced commarginal lamellae and deep, heart-shaped lunule (Keen *in* Moore, 1969, p. N688). Features of the New Zealand Cretaceous species are consistent with *Astarte* and any similarity with *Placamen* is deemed herein to be superficial.

ASTARTE n. sp.

Plate 18 Figures 18-19

Description.-Shell small to large for family, moderately thick, moderately inflated, subtrigonal; umbones prominent; anterodorsal margin short, straight to very slightly concave, moderately sloping, merging with well-rounded anterior margin; posterodorsal margin moderately long, convex, also moderately sloping, merging with fairly broad, well-rounded to obliquely truncated posterior margin; ventral margin well-rounded, convex; lunule moderately large, impressed, but not deep; escutcheon not well-defined in available material; sculpture of very thick, widely spaced, flattened lamellae that become more closely spaced ventrally and nearly coalesce on the umbones; fine, commarginal threads present between prominent ridges; hinge details unknown.

Dimension.-Ge 8608 (AIM) length 15.0 mm, height 14.0 mm; Ge 8615 (AIM) length 12.0 mm, height 11.5 mm, width of paired valves 8.0 mm.

Figured specimens.-Ge 8608 (AIM) and Ge 8615 (AIM).

Material.-Two specimens.

Locality.-South of Puriri Point, Hukatere Peninsula, Kaipara Harbour, Northland, Q08/f9660.

Stratigraphic range.-Unspecified horizon within Unit 4d? of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-*Astarte* n. sp. has a more obliquely truncated posterior margin, a more circular shell, and fewer more widely spaced commarginal ribs compared to the type species, *A. sulcata* (Da Costa, 1778) (see Tebble, 1966, p. 70, Text-fig. 12a-b; Chavan *in* Moore, 1969, p. N562, Fig. E64, Fig. 1a-c; Dance, 1990, p. 245, sole figure, second column). *Astarte* n. sp. is superficially similar to *Placamen* n. sp. of Beu and Maxwell (1990, p. 102, Pl. 5, Figs. n, o) from the Bortonian Stage (upper Middle Eocene) of Waihao River and Raincliff Stream, South Island, but the Late Cretaceous species is larger with a more broadly rounded posterior margin and more bunched, subcoalescing commarginal lamellae on the umbones compared to *P.* n. sp. of Beu and Maxwell (1990) which is smaller with a slightly angular posterior margin and apparently narrower, commarginal lamellae. The type species of *Placamen*, *P. placida* (Philippi, 1844) (see description and figure by Macpherson and Gabriel, 1962, pp. 348-350, Fig. 401) from Australia, including Tasmania, has more numerous, closely spaced commarginal lamellae compared to P. n. sp.

Subfamily ERIPHYLINAE Chavan, 1952

Genus ERIPHYLA Gabb, 1864

Eriphyla Gabb, 1864, p. 180.

Type species.-(by original designation) Eriphyla umbonata Gabb, 1864.

Synonym.-Mikayoella Hayami, 1965 (Chavan *in* moore, 1969, p. N568).

Biogeographic distribution.-Indo-Pacific/Tethyan as interpreted here. Kauffman (1973, p. 368) referred Eriphyla s. s. to his "Euramerican region" based on the known geographic distribution of the genus at that time.

Discussion.-Eriphyla s. s. and E. (Dozyia) are closely related astartid taxa, separated on the basis of minor differences in dentition, outline and shell thickness. Both taxa are restricted to the Cretaceous, but E. (Dozyia) is further restricted to the Senonian (Chavan *in* Moore, 1969, p. N569). Zinsmeister and Macellari (1988, p. 276) remarked that "...a number of Late Cretaceous bivalves have a nearly circular outline with elevated umbones; without information about the hinge, these bivalves are virtually impossible to separate". The two above subgenera are also difficult to distinguish without hinge details.

Subgenus ERIPHYLA Gabb, 1864

ERIPHYLA s. s. MERIDIANA Woods, 1917

Plate 19 Figures 1-10, 13, 16-18

Lucina americana Forbes, Hutton, 1877, p. 37 (attributed to Sowerby); Hector, 1886, p. 64, Fig. 8.

Lucina americana? Forbes, Park, 1910, p. 87, Fig. 44.

Astarte (Eriphyla) meridiana Woods, 1917, pp. 28-29, Pl. 15, Figs. 2-7; Wilckens, 1920b, p. 12, footnote.

"Eriphyla" meridiana Woods, Marwick and Fleming in Wellman, 1959, p. 138.

Eriphyla meridiana Woods, Fleming in Wellman, 1959, p. 141; Speden in Suggate et al., 1978, p. 412, Figs. 6.7-2; Warren and Speden, 1978, p. 39, Fig. 25-7; Speden and Keyes, 1981, p. 56, Pl. 23-2; **non** del Valle and Medina, 1980, p. 57, Pl. 3, Figs. 3-4; **non** Medina et al., 1981, p. 170; Moore et al., 1988, p. 59, Tab. 1; **non** Dozyia drygalskiana (Wilckens, 1910), Zinsmeister and Macellari, 1988, p. 276, Figs. 14.1-4; Crampton and Moore, 1990, p. 346, (Woods), error; Stilwell in Aitchison et al., 1993, p. 52, Fig. 4g-h.

Supplementary description.-Shell medium-sized, moderately thin, subcircular; umbones elevated, moderately prosogyrous, subcentral, more anterior; anterodorsal margin moderately short, concave, merging towards evenly rounded anterior and ventral margins; posterodorsal margin long, convex; slight angulation at extreme posterior of shell demarcating posterodorsal and ventral margins; escutchen sunken, deep; escutcheon narrow, moderately deep; commarginal ornamentation of closely spaced, slightly raised, ribs; hinge relatively narrow, anterior part of hinge slightly broader than posterior part; right valve with strong, slightly oblique, peg-like, subtrigonal cardinal tooth (3b), 3a fused with AIII, anterior lateral tooth AI moderately short, narrow, stronger ventrally; anterior cardinal (2b) in left valve strong, trigonal; posterior cardinal tooth (4b) weak, reduced, narrowly trigonal, more oblique; anterior lateral tooth on left valve (AII) moderately short, narrow; posterior lateral tooth (PII) short, only slightly raised; adductor scars well-developed, anterior adductor reniform, posterior adductor elongate-ovate; pedal retractor scars poorly represented on available material, possibly three, two below anterior part directly below hinge plate, and one directly below extreme posterior part of hinge; pallial line moderately developed, apex of line projecting upwards nearly perpendicular to hinge; inner margin smooth.

Types.-Hypotypes TM 2545 (IGNS; Woods, 1917, Pl. 15, Fig. 5); TM 2546 (IGNS; Woods, 1917, Pl. 15, Fig. 7); TM 2547 (IGNS; Woods, 1917, Pl. 15, Fig. 6); TM 2548 (IGNS; Woods, 1917, Pl. 15, Fig. 4); TM 2549 (IGNS; Woods, 1917, Pl. 15, Fig. 3); lectotype (designated herein) TM 2550 (IGNS; Woods, 1917, Pl. 15, Fig. 2; Speden *in* Suggate *et* *al*., ed., 1978, Fig. 6.7-2; Warren and Speden, 1978, Fig. 25-7; Speden and Keyes, 1981, Pl. 23, Fig. 2); OU 40659.

Dimensions.-TM 7496 (IGNS) (GS 13) length 27.0 mm, height 27.5 mm; TM 7497 (IGNS) (GS 13) length 30.0 mm, height 32.5 mm; TM 7498 (IGNS) (GS 13) length 30.5 mm, height 33.0 mm; OU 40952 length 30.0 mm, height 27.5 mm; OU 40953 hinge length 13.0 mm; OU 40659 length 34.0 mm, height 32.5 mm, width of paired valves 16.0 mm.

Figured specimens herein.-TM 2545-TM 2550, TM 7496, TM 7497, TM

7498, OU 40952, OU 40953, OU 40659.

Material.-10 well-preserved specimens, many with hinges revealed.

Localities.-North of Haumuri Bluff, southern Marlborough, South Island, O32/f9041, O32/f9530, O32/f9529; Haumuri Bluff, O32/f9035, O32/f9504, O32/f9505, O32/f9502; east wing, Haumuri Bluff, O32/f9026; west wing of Haumuri Bluff, O32/f8026, O32/f8025 (type); Okarahui Stream, southern Marlborough, O32/f8790; tributary of Mikonui Stream, O32/f8788; ?just south of Mikonui Stream, O32/f8774A; ?near Jedburgh Station, Cheviot, South Island, O33/f9044; ?Awakei Creek, tributary of Waitangi River, North Island, P05/f9502; Waitangi River, Northland, P05/f9491, ?P05/f9499; ?Maitaikona River, North Island, U25/f6473; Te Hoe River, western Hawke's Bay, North Island, V19/f129; V19/f130; ?Ruatahuna Stream, tributary of Whakatone River, North Island, W18/f14A; Waikokopu Stream, tributary of Waihoroihika River, W18/f26; ?east-flowing main branch of Waikokopu Stream, W18/f27; Mt. Pukeiwitahi, Lower Shag Valley, Otago, J43/f6494; North Branch of Waianakarua River, Otago, J42/f218; Selwyn River, Malvern Hills, Canterbury, L35/f6008; Selwyn Rapids, oyster beds, L35/f6510; ?Totara Point, Whangaroa Harbour, Northland, P04/f9497.

Stratigraphic distribution.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds, Katiki Formation, ?Herbert Formation, Maungataniwha Sandstone (Haumurian Stage, Maastrichtian, uppermost Cretaceous); formation names in Northland unknown (Upper Cretaceous).

Geographic distribution.-Northland to Otago, widespread.

Discussion.-There is little doubt that the figure of Hector

(1886, Fig. 28-8) of a left valve, referred by him to Lucina americana Forbes, represents the widespread New Zealand species Eriphyla meridiana Woods, 1917. Previous to this work no hinges of E. meridiana have been figured, but numerous external views of right and left valves were portrayed by Woods (1917). Without hinge details the generic placement of this species could be problematic, as discovered by del Valle and Medina (1980) and Zinsmeister and Macellari (1988) in their attempts at analysing relationships between coeval Antarctic and New Zealand astartid taxa. Del Valle and Medina (1980, p. 57, Pl. 3, Figs. 3-4) referred their species from the Late Cretaceous of Cape Lamb, Vega Island and Cape Morro, James Ross Island, Antarctic Peninsula, as conspecific with Eriphyla meridiana, but in their description (in Spanish) of the Antarctic material made no mention of hinge details, important in the proper assignment of this species to genera or subgenera within the Astartidae. More than likely the Antarctic species described by them is more closely related to Dozyia drygalskiana (Wilckens, 1910) (pp. 51-53, Pl. 3, Figs. 3a-b; redescribed by Zinsmeister and Macellari, 1988, p. 276, Fig. 14.1-4) from slightly younger marine beds from Seymour Island, Antarctic Peninsula, but again this is conjecture until details of the hinge are known. Zinsmeister and Macellari (1988) fell into the trap of their own mentioned caution of problematic, numerous circular Late Cretaceous bivalves and their identification by synonymising Eriphyla meridiana with Dozyia drygalskiana. Part of this problem in identification stems from interpretation of hinge details given by Woods (1917) and again no figures of hinges given by him. Zinsmeister and Macellari (1988) believed that the lateral tooth near the lunule in the right valve of E. meridiana, described by Woods, most likely corresponded to an anterior cardinal tooth present in D. drygalskiana. Material of Eriphyla meridiana available to me with exposed hinges reveals the presence of a singular cardinal tooth, compared to D. drygalskiana which has two cardinal teeth, hence one of the main diagnostic features separating Eriphyla s. s. and E. (Dozyia). The synonymy of E. meridiana with D. drygalskiana cannot be supported here, based on available evidence. Although Dozyia and Eriphyla have been separated as distinct genera, the minor differences in hinge details, shell outline and shell thickness of more likely of subgeneric significance than generic level differences, based on overall close similarity. Palamarczuk et al. (1984, p. 401) reported the presence of an undescribed species of Eriphyla in the Sobral Formation (Paleocene) of Seymour Island, but this identification is as to my knowledge unconfirmed. Because Eriphyla is known elsewhere from only Cretaceous rocks, the presence of this group in the Paleocene may be unlikely, considering again the ubiquity of circular to subcircular outlines in certain bivalve groups. Eriphyla n. sp.? from the Piripauan Stage was reported by Moore et al. (1988, p. 59, Tab. 1) in the Maungataniwha Sandstone west of Lake Waikaremoana, Urewera National Park, North Island, but no material of this possible new species is available to me for comparison with E. meridiana.

Eriphyla meridiana is differentiated from the Californian Cretaceous type species, E. umbonata Gabb, 1864 (p. 180, Pl. 24,

Fig. 162 and 162 a), in having a much larger shell, a more circular outline, a more robust hinge plate and stronger hinge teeth. The remarkable similarity between E. meridiana and E. umbonata probably indicates a lineal relationship.

Genus DOZYIA Bosquet in Dewalque, 1868

Dozyia Bosquet in Dewalque, 1868, p. 368.

Type species.-(by monotypy) Lucina lenticularis Goldfuss, 1840.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here. Kauffman (1973, p. 368) included Dozyia in the "Euramerican region", as the genus at that time was known to be shared between the North European and North American continents.

?DOZYIA LENTICULARIS (Goldfuss, 1840)

Plate 19 Figures 11-12, 14-15

Astarte (Eriphyla) lenticularis (Goldfuss), Woods, 1917, p. 29, Pl. 15, Figs. 9-10; Wilckens, 1920a, p. 262.

"Eriphyla lenticularis" Goldfuss, Marwick and Fleming in Wellman, 1959, p. 138.

Dimensions.-OU 40954 length 55.5 mm, height 50.5 mm; OU 40955 length 26.5 mm, height 20.5 mm.

Types.-Hypotypes TM 2543 (IGNS; Woods, 1917, Pl. 15, Fig. 10); TM 2544 (IGNS; Woods, 1917, Pl. 15, Fig. 9).

Figured specimens herein.-TM 2543 (IGNS), TM 2544 (IGNS), OU 40954, OU 409555.

Localities.-?Selwyn River, Malvern Hills, Canterbury, South Island L35/f6008; Middle Waipara, Canterbury, M34/f7263.

Stratigraphic range.-?Selwyn Rapids Beds, Conway Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from Canterbury.

Discussion.-Woods (1917) referred this species to the widespread latest Cretaceous astartid *Astarte* (*Eriphyla*) *lenticularis* Goldfuss, 1840 (p. 228, Pl. 146, Fig. 16; see also Woods, 1906, pp. 301-302, Pl. 35, Fig. 20 for Late Cretaceous South African example and Chavan *in* Moore, 1969, pp. N568-569, Fig. E68-6 for a Campanian example from the Netherlands) which was later designated by monotypy as the type species of *Eriphyla* (*Dozyia*). Unfortunately, as far as I am aware no new material of this New Zealand species has come to light. As Zinsmeister and Macellari (1988, p. 276) remarked, the South African specimen of *E*. (*D*.) *lenticularis* figured by Woods (1906) appears identical to specimens figured by Woods (1917) from Selwyn Rapids, Canterbury, New Zealand, but no details on the hinge were given by Woods (1906). As a consequence, Woods' (1917) original identification can only be considered tentative until hinge details of this species are known. Furthermore, it seems possible that both *Eriphyla* s. s. and *E*. (*Dozyia*) are represented in the New Zealand fossil record, but this remains to be proved.

Family CRASSATELLIDAE Férussac, 1822

Subfamily CRASSATELLINAE Férussac, 1822

Genus *ANTHONYA* Gabb, 1864

Anthonya Gabb, 1864, pp. 181-182.

Type species.-(by monotypy) *Anthonya cultriformis* Gabb, 1864.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-After Gabb's (1864) work, *Anthonya* received little attention until the short discussion by Vokes (1941) and Anderson

(1958, pp. 129-130), who reviewed the genus in his monograph, "Upper Cretaceous of the Pacific Coast". At the time of Anderson's writing *Anthonya* was still thought to be known only by its type species, *A. cultriformis* Gabb, 1864 (p. 182, Pl. 30, Fig. 236 and 236 a; see review and figure by Chavan *in* Moore, 1969, p. N574, Fig. E73-2), from the Late Cretaceous of California and no mention was made of *A. elongata* Woods, 1917 from the Late Cretaceous of New Zealand. Anderson (1958) stated that the nearest relative of *Anthonyia* (sic.) (error, **pro** *Anthonya*) is *Scambula* Conrad from contemporaneous deposits of central Texas, Tennessee and New Jersey, but these two taxa were referred by Chavan (ibid.) to different subfamilies in the Crassatellidae. That *Anthonya* and *Scambula* are "basically akin" (Anderson, ibid., p. 130) was not supported by Chavan's work. According to Vokes (1941, pp. 9-10) in support of Gabb (1876, p. 311) and Stewart (1930, pp. 147-149), the significant characters separating *Scambula* from *Anthonya* is that the posterior end is not produced in *Scambula*. Furthermore, the type species of *Scambula*., *S. perplana* Conrad, 1869, has finely crenulated inner margins which have not been noted in *Anthonya* species.

Anthonya has a fairly wide distribution and has been recorded from North America, Western Europe, Africa, Asia, Australia and Japan (Chavan, ibid., p. N574). As did Anderson (1958), Chavan excluded the presence of the group in the Cretaceous of New Zealand. Stinnesbeck (1986, pp. 178-179, Pl. 4, Figs. 4-6) described a new species of *Ensis*, *E. lirqueni* (Cultellidae), from the Maastrichtian of Central Chile, but this species is confidently referred herein to *Anthonya*, based on comparisons of hinge morphology, sculpture and outline with the type species and *A. elongata*. *Anthonya* is not a particularly speciose group. Warren and Speden (1978, p. 50) and Crampton and Moore (1988, p. 346) inferred *Anthonya* to be a mobile, shallow burrowing, short siphonate, suspension-feeding bivalve.

ANTHONYA ELONGATA Woods, 1917

Plate 20 Figures 1-5, 7

Anthonya elongata Woods, 1917, p. 29, Pl. 15, Figs. 11-13 and Pl. 16, Figs. 1-3; Vokes, 1941, p. 9; Fleming *in* Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-5; Crampton and Moore, 1988, p. 346.

Dimensions.-Ge 5955 (AIM) length 32.0 mm incomplete.

Type and previously figured specimens.-Lectotype (designated herein) TM 2536 (NZGS; Woods, 1917, Pl. 15, Fig. 13; Warren and Speden, 1978, Fig. 25-5); TM 2537 (NZGS; Woods, 1917, Pl. 16, Fig. 1); TM 2538 (NZGS; Woods, 1917, Pl. 15, Fig. 11); TM 2539 (NZGS; Woods, 1917, Pl. 15, Fig. 12); TM 2540 (NZGS; Woods, 1917, Pl. 16, Fig. 2); TM 2541 (NZGS; Woods, 1917, Pl. 16, Fig. 3).

Figured specimens herein.-TM 2536-2539 (IGNS); Ge 5955 (AIM).

Localities.-North face of Haumuri Bluff, southern Marlborough, South Island, O32/f9529; west wing of Haumuri Bluff, O32/f8025 (type); east wing of Haumuri Bluff, O32/f9027; Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6909; Waitangi River, Bay of Islands, Northland, P05/f9491; Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Maungataniwha Sandstone (Upper

Cretaceous); unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland to southern Marlborough.

Discussion.-*Anthonya elongata* is a relatively rare species, known for certain at only five widely separated localities in New Zealand. Curiously, no specimens of this species have been recorded south of southern Marlborough. *Anthonya elongata* seems closely related to a Maastrichtian congener from the Quiriquina Formation of Central Chile, *Ensis lirqueni* Stinnesbeck, 1986 (pp. 178-179, Pl. 4, Figs. 4-6; originally referred to *Pinna minuta* Philippi, 1887, p. 205, Pl. 58, Fig. 7b only) which is formally reassigned to *Anthonya* herein. *Ensis lirqueni* is not an *Ensis*, but a member of a Cretaceous fairly widespread crassatellid group *Anthonya*, with its somewhat compressed, narrow, elongate, transversely inequilateral shell and two, well-developed cardinal teeth, all diagnostic features of *Anthonya*. Accurate comparison of *A. elongata* and *A. lirqueni* proves somewhat difficult due to the general fragmentary nature of both species, but there is little doubt based on general outline, commarginal sculpture, hinge features and developed umbonal ridge that these two species are very closely allied. Future work may find that *A. elongata* and *A. lirqueni* are conspecific.

Anthonya elongata differs from the Californian Cretaceous type, *A. cultriformis* Gabb, 1864, in having a less arcuate posterodorsal margin, a broader ventral margin and a more narrowly rounded anterior margin, compared to the Californian species. A close relationship between these taxa is probable.

Superfamily CARDIACEA Lamarck, 1809

Family CARDIIDAE Lamarck, 1809

Subfamily CARDIINAE Lamarck, 1809

Discussion.-Cardiine bivalves from the New Zealand and New Caledonian Late Cretaceous were studied fairly recently by Freneix and Grant-Mackie (1978). For a historical review of work done on Cretaceous cardiid bivalves of New Zealand see Freneix and Grant-Mackie's work (p. 506). Other than relatively little new data, type numbers of previously described taxa, refiguring of known cardiid taxa, only a summary is presented here.

Six species of cardiid bivalves are known from the New Zealand Late Cretaceous; these are *Cardium* (*Bucardium*?) sp. (Piripauan Stage, upper Campanian) (Plate 20 Figures 11, 14), *Austrocardium* *acherontis* Freneix and Grant-Mackie, 1978 (Piripauan to Haumurian Stages, upper Campanian to Maastrichtian) (pp. 507-509, Fig. 1-6; Plate 20 Figures 6, 8-10; Plate 21, Figures 1-2, 5), *Granocardium* (*Ethmocardium*) *woodsi* (Marwick, 1944) (Haumurian Stage, Maastrichtian) (p. 259, Pl. 36, Fig. 21; *Cardium* sp. 2 of Woods, 1917, p. 33, Pl. 18, Figs. 4-5; Plate 21, Figures 7, 9-13, this work), ?*Granocardium* (*Ethmocardium*) sp. indet. of Freneix and Grant-Mackie, 1978 (p. 514; not figured here), *Schedocardia*? *waiparana* Freneix and Grant-Mackie, 1978 (Piripauan to Haumurian Stages, upper Campanian to Maastrichtian) (p. 514, Figs. 25-26; Plate 21 Figures 3-4, this work) (Note: Schneider (1992, p. 149) suggested placement of this species in *Austrocardium* as it shares apomorphies of this genus.), and *Lahillia* *aotearoa* n. sp. (Plate 22 Figures 1-10, this work). A possible species of *Austrocardium* was reported by Moore *et al.* (1988, p. 59, Tab. 1) in the Upper Cretaceous Maungataniwha Sandstone of Lake Waikaremoana, Urewera National Park, North Island. ?*Protocardia* sp. (Protocardiinae) was recorded from Upper Cretaceous rocks of Cheviot, South Island by Maxwell *in* Feldmann (1984, p. 383), but was not figured. A large, poorly preserved specimen (L 3874 from AU 2553) from Te Opu, Kaipara, Northland (Q08/f9639) is referred herein to Cardiidae? gen. et sp. indet.

Types.-*Granocardium* (*Ethmocardium*) *woodsi* (Marwick, 1944) (holotype TM 2573 (IGNS; Woods, 1917, Pl. 18, Fig. 5; Marwick, 1944, Pl. 36, Fig. 21); paratype TM 2574 (IGNS; Woods, 1917, Pl. 18, Fig. 4)); *Austrocardium acherontis* Freneix and Grant-Mackie (holotype TM 5563 (IGNS; Freneix and Grant-Mackie, 1978, Fig. 1); paratypes TM 5564 and TM 5565 (IGNS; Freneix and Grant-Mackie, 1978, Figs. 2-4)); *Schedocardia*? *waiparana* Freneix and Grant-Mackie, 1978 (holotype TM 5570 (IGNS; Freneix and Grant-Mackie, 1978, Figs. 25, 26); paratype TM 5569).

Subfamily LAHILLIINAE Finlay and Marwick, 1937

Genus *LAHILLIA* Cossmann, 1899

Lahillia Cossmann, 1899, p. 134.

Type species.-(by subsequent designation, Finlay and Marwick, 1937) *Amathusia angulata* Philippi, 1887.

Synonym.-*Lahilleona* Finlay and Marwick, 1937 (Zinsmeister, 1984, pp. 1514-1515).

Biogeographic element.-Paleoaustral (cf. Fleming, 1963a, 1963b; Zinsmeister, 1982, p. 93, p. 96; 1984, p. 1500).

Discussion.-The highly characteristic paleoaustral Campanian to Miocene cardiid bivalve *Lahillia* has received a great deal of attention over the years and numerous authors have commented on various aspects of the group's taxonomy, paleoecology, biostratigraphy and paleobiogeography (von Ihering, 1907, 1914, 1924; Wilckens, 1908, 1910, 1920a, 1920c, 1924; Marshall and Murdoch, 1923; Feruglio, 1936; Finlay and Marwick, 1937; Marwick *in* Ongley, 1939; Singleton, 1943; Hornibrook and Harrington, 1957; Freneix, 1958, 1960, 1980, 1981; Hornibrook, 1962; Fleming, 1963a, 1963b, 1979; Maxwell *in* Beu and Maxwell, 1968; Keen *in* Moore, 1969; Zinsmeister, 1979, 1984, 1986; Stevens, 1980; Medina *et al*., 1981; del Valle *et al*., 1982, 1983; Zinsmeister and Feldmann, 1984; Palamarczuk *et al*., 1984; Macellari, 1985; Stinnesbeck, 1986; Macellari *et al*., 1987; Crame, 1987; Stilwell and Zinsmeister, 1987a, 1992; Zinsmeister and Macellari, 1988; Macellari, 1988; Stilwell, 1988; Olivero *et al*., 1990; Beu and Maxwell, 1990; Griffin, 1991; and Schneider, 1992 (non-exhaustive list). A review of *Lahillia* and all known species of the group is appropriate here.

Hupé (1854, p. 302, Conquiliologia section, Pl. 6, Fig. 11) was the first to describe a species of *Lahillia*, but at that time the species was referred questionably to *Crassatella*, *C*. *veneriformis* from the Late Cretaceous of the island of Quiriquina, South America. The genus-group name *Lahillia* came about much later (refer to Wilckens, 1924, p. 540 and Finlay and Marwick, 1937, pp. 30-31 for thorough reviews), nearly fifty years after Hupé's original description, through a series of misidentifications and preoccupied names. Philippi (1887) referred species of this group to Mactra and Wilckens (1904) assigned C. veneriformis to Amathusia Philippi and three years later described a similar Late Cretaceous species A. luisa (Wilckens, 1905). Cossmann (1899) erected the name Iheringia as Amathusia was preoccupied by Amathusia Fabricius, 1807. Iheringia was also found to be preoccupied by Iheringia Keyserling, 1891 so that finally Lahillia was proposed by Cossmann the same year (1899, p. 134), named after late 19th century geologist Fernando Lahille. A further subdivision of Lahillia into Lahillia s. s. and L. (Lahilleona) was proposed by Finlay and Marwick (1937, p. 31) who believed that their newly erected L. (Lahilleona) differed from typical Lahillia in having a "well-defined, rounded pallial sinus" distinct from South American Lahillia s. s. species which have no pallial sinus. Critical features separating Lahillia from other cardiid bivalves include an orbicular, oblong, subtrigonal to suboval outline, smooth shell without radial ormanent, smooth internal margins, external ligament on large nymph, two cardinal teeth, one posterior lateral tooth in each valve and no anterior laterals, and nearly entire to shallow pallial sinus (cf. Keen in Moore, 1969, p. N590). Zinsmeister (1984, p. 1515) in a landmark paper on early Tertiary Antarctic bivalves showed that Finlay and Marwick's subgenus L. (Lahilleona) was not warranted and that Cretaceous as well as Tertiary species of Lahillia reveal a shallow pallial sinus. However, Zinsmeister (p. 1515) was mistaken in stating that Finlay and Marwick believed that "Cretaceous species of Lahillia did not have a pallial sinus".

Finlay and Marwick (1937) did in fact recognize, as did Wilckens earlier in 1920, that the Late Cretaceous New Zealand shell that Woods (1917, p. 30, Pl. 16, Figs. 8a-b) called *Mactra*? sp. was a *Lahillia* not a *Mactra*. Further, "The well-defined pallial sinus, which probably influenced Woods in his classification, was not remarked upon by Wilckens, although *Lahillia* has always been described as having no sinus" (p. 31). Finlay and Marwick believed that the developed pallial sinus of Cretaceous and Paleocene species, *L. neozelanica* Marshall and Murdoch, 1923, from New Zealand indicated that "the New Zealand stock had been separated for some considerable time" (p. 31). The real issue here, not discussed by Zinsmeister (1984), is the interspecific or supraspecific significance of assumed integripalliate vs. shallow pallial sinus of various species of *Lahillia*. The type species of *Lahillia*, *L. angulata* Philippi, 1887 (Pl. 23, Fig. 1, Pl. 25, Fig. 1 and below unnumbered, articulated specimen?; Wilckens, 1904, Pl. 20, Fig. 4; Keen *in* Moore, 1969, p. N590, Fig. E88-6a, 6b) is thought to be integripalliate, but in the original figure by Philippi (Pl. 25, Fig. 1 of the internal of a right valve and of the same specimen portrayed by Keen in Fig. E88-5b), the pallial line is partly obscurred anteriorly and posteriorly by matrix and the drawing itself is not clear so that an accurate description of this feature seems difficult. In error, Keen attributed Fig. E88-5a of *L. angulata* to Philippi (1887), whereas this figure is from Wilckens (1904), and Fig. E88-5b to Wilckens (1904), whereas this figure (slightly modified) is actually from Philippi (1887). Beu and Maxwell (1990. p. 80) concurred with Zinsmeister's (1984) decision of synonymising L. (Lahilleona) with L. (Lahillia), but gave no explanation for their support of Zinsmeister's decision, and also in error attributed Lahillia to Cossmann, 1889 whereas the correct date is Cossmann, 1899. Although for the wrong reasons, Zinsmeister's (1984) synonymy of L. (Lahilleona) with L. (L). s. s. seems justified when overall features of the numerous Lahillia species are taken into account, but further in-depth reassessment of all known species seems necessary to delineate accurate phylogenetic relationships. Even after Zinsmeister's synonymy of Lahilleona with Lahillia, Olivero et al. (1990) continued to separate these taxa per identification of their two species in the Late Cretaceous record of Chubut, South America.

Cladistic analysis of the Cardiidae suggests that Lahilliidae should be reduced to subfamilial status as proposed originally by Finlay and Marwick (1937); Lahilliinae encompasses three genera Integricardium, an ancestral form to Onestia, which is further ancestral to Lahillia (Day, 1978; Schneider, 1992, p. 148).

In South America the following Lahillia species have been described; L. veneriformis (Hupé, 1854) (Pl. 6, Fig. 11, Maastrichtian, refigured recently by Stinnesbeck, 1986, pp. 175-176, see also synonymies from 1854 to 1930), L. luisa (Wilckens, 1905) (Pl. 8, Figs. 1-3, Late Campanian to Maastrichtian), L. ferrieri Philippi, 1887 (Pl. 29, Fig. 3; Late Campanian to Maastrichtian), L. luisa Wilckens var. gigantea Feruglio, 1936 (Pl. 14, Figs. 12-13, Late Campanian to Maastrichtian, most likely a gerontic form of L. luisa), L.? tetrica Feruglio, 1936

(Pl. 14, Fig. 15, Late Campanian to Maastrichtian), *L. angulata* (Philippi, 1887) (Pl. 23, Fig. 1, Pl. 25, Fig. 1, Oligocene to Miocene), *L. orbicularis* (Philippi, 1887) (Pl. 24, Fig. 1, early Tertiary) and *L. angulata patagonica* von Ihering, 1907 (pp. 294-295, not figured, early Tertiary). Olivero *et al*. (1990, p. 130, Tab. 1, Pl. 1, Figs. 1-3) separated two species of *Lahillia* in the Late Cretaceous record of Chubut, southern South America (Lefipan Formation), and assigned these species to *Lahillia* s. s. sp. and *L*. (*Lahilleona*) sp., but no descriptions were made or possible affinities mentioned of these two species. Riccardi (1988, p. 49, Tab. 7) listed only *L. ferrieri*, *L. luisa*, and *L. veneriformis* as present in Upper Campanian to Maastrichtian rocks of southern South America. A poorly preserved specimen similar to, but slightly different from *L. angulata*, was reported and figured by Griffin (1991, pp. 134-135) from the Eocene of Argentina indicating the possible presence of yet another species of *Lahillia* in the southern South American record. Species described from Antarctica include *L. larseni* (Sharman and Newton, 1897) (Pl. 1, Maastrichtian to earliest Paleocene, redescribed and refigured recently by Zinsmeister and Macellari, 1988, pp. 276-279, Fig. 15.1-5), *L. huberi* Zinsmeister and Macellari, 1988 (Fig. 15.6-8, Paleocene), *L*. sp. of Stilwell and Zinsmeister, 1987c (p. 9, Late Cretaceous, probably Campanian), and *L. wilckensi* Zinsmeister, 1984 (Figs. 7A-E, Middle to Late? Eocene; see also Stilwell and Zinsmeister, 1992, pp. 70-71, Pl. 6, Figs. a-e). Two species are known from New Zealand Cretaceous and Tertiary rocks, the Late Campanian to Maastrichtian new species *L. aotearoa* n. sp. (Plate 22 Figures 1-10, this work) and Danian

L. *neozelanica* Marshall and Murdoch, 1923 (Pl. 16, Fig. 3; recently redescribed and refigured by Beu and Maxwell, 1990, p. 80, Pl. 1j, k). *Lahillia* n. sp.? was recorded by Campbell *et al*. (1993, Tab. 4.3, Late Cretaceous) from Chatham Islands. *Lahillia marwicki* Freneix, 1958 (Pl. 2, Figs. 10-11, Campanian, refigured more recently by Freneix, 1980, Pl. 5, Figs. 4-5) from New Caledonia is the only recorded species, as is *L*. *australica* Singleton, 1943 (Pl. 12, Figs. 3-5, mid Paleocene) from southeastern Australia. The absence of *Lahillia* in Upper Cretaceous rocks of Australia and Tertiary of New Caledonia is most likely a reflection of the poor fossil record in these areas.

A shallow, infaunal, mobile, suspension feeding habit most likely characterised *Lahillia* which positioned its posterior margin parallel to the sediment-water interface (cf. Freneix, 1981, p. 27, Fig. 3; Macellari, 1988, p. 43). In the minute drawing of the life position of *Lahillia*, Freneix (1981, p. 27, Fig. 3) incorrectly portrayed the anterior margin, as opposed to the posterior margin, as parallel to the sediment-water interface.

LAHILLIA *AOTEAROA* n. sp.

Plate 22 Figures 1-10

Mactra (?) sp., Woods, 1917, p. 30, Pl. 16, Figs. 8a-b.

Lahillia sp., Wilckens, 1920a, pp. 264-265.

Lahillia cf. *luisa* Wilckens, Wilckens, 1924, pp. 539-541, Pl. 54, Figs 1-3 and 4?.

Lahillia (*Lahilleona*) aff. *neozelanica* Marshall and Murdoch, 1923, Finlay and Marwick, 1937, p. 33; Marwick and Fleming in Wellman, 1959, p. 139; Warren and Speden, 1978, p. 50, Tab. 5; Stinnesbeck, 1986, p. 176, March and Murdoch (sic.), error.

Lahilleona aff. neozelanica (Marshall and Murdoch), Stevens in Suggate et al., 1978, p. 352, Tab. 6.2.

Lahillia (Lahilleona) cf. neozelanica Finlay and Marwick (error), Speden and Keyes, 1981, p. 56, Pl. 23, Fig. 4.

Lahillia aff. neozelanica Marshall and Murdoch, Beu and Maxwell, 1990, p. 80; Stilwell in Aitchison et al., 1993, Fig. 3g, i.

Diagnosis.-Medium to large-sized, moderately thin, subovate shell; beaks subcentral, orthogyrous; shell mostly smooth, except for widely spaced, commarginal growth lamellae, more prominent from a point midway on the disc to ventral margin; hinge plate moderately narrow compared to L. neozelanica with blunt, peg-like, elevated, subtrigonal cardinal teeth; pallial sinus well-developed for typical Lahillia.

Desription.-Shell medium- to large-sized, moderately thin dorsally to ventrally, subequilateral, subovate; beaks moderately narrow, elevated, subcentral, orthogyrous; umbones moderately broad; anterodorsal moderately long, gently convex, merging with narrowly rounded anterior margin; posterodorsal margin mostly straight to very gently convex, merging with more broadly rounded posterior margin, compared to anterior margin; ventral margin broadly convex; lunule moderately long; no escutcheon; shell mostly smooth except for widely spaced, commarginal growth lamellae, generally stronger from a point midway on disc towards ventral margin, becoming more bunched ventrally on some specimens; hinge plate moderately narrow with shallow arch anteriorly and deep arch posteriorly on ventral portion of hinge; right valve with projecting, peg-like, subtrigonal cardinal tooth, fused to nymph, situated directly below beak, nearly touching beak, with adjacent relatively broad, trigonal socket for cardinal tooth from left valve and narrow posterior lateral tooth with adjacent deep, elongated, narrow socket for lateral tooth of left valve; anterior divergent cardinal tooth of right valve poorly developed; anterior cardinal tooth of left valve, oblique, subtrigonal, elevated, relatively short, thickened, forming an inverted V with a moderately developed posterior cardinal; nymph moderately developed; posterior adductor scar sublenticular; pallial sinus shallow, somewhat pointed, but relatively well-developed for genus; inner margin smooth.

Dimensions.-Holotype TM 7500 (IGNS), right valve hinge length 33.0 mm; paratype TM 7501 (IGNS), left valve hinge length 38.5 mm; paratype OU 40530, length 80.0 mm, height 67.5 mm incomplete; paratype OU 40531, length 68.0 mm, height 62.0 mm, width of paired valves 30.0 mm; paratype OU 40959 length 78.5 mm, height 62.0 mm nearly complete.

Types and previously figured specimens.-Holotype TM 7500 (IGNS), paratypes TM 7501 (IGNS), OU 40530, OU 40531, OU 40959, TM 2568 (IGNS; *Mactra*? sp. of Woods, 1917, Pl. 16, Fig. 8; Speden and Keyes, 1981, Pl. 23, Fig. 4), TM 2569 (NZGS; *L*. cf. *luisa* of Wilckens, 1924, Pl. 54, Fig. 1), TM 2570 (NZGS; *L*. cf. *luisa* of Wilckens, 1924, Pl. 54, Fig. 3), TM 2571 (NZGS; *L*. cf. *luisa* of Wilckens, 1924, Pl. 54, Fig. 2), TM 2572 (NZGS; *L*. cf. *luisa* of Wilckens, 1924, Pl. 54, Fig. 4).

Figured specimens herein.-TM 7500-7501 (IGNS), TM 2569-2572 (IGNS), OU 40530, OU 40531, OU 40959; Ge 6430 (AIM) from Kaipara, Northland, may represent this species.

Material.-12 specimens, including two with well-preserved hinges.

Localities.-?Little Pukeiwitahi, western face, Otago, J43/f93; Matakea Point, northeastern side of Shag Point Harbour, Otago, J43/f6544A; Shag Point, J43/f6472; North Branch of Waianakarua River, Otago, J42/f82, J42/f178, J42/f218; Nedler's Point, near head of Wiatapu Bay, Whangaroa Harbour, Northland, P04/f9494; Totara Point, Whangaroa Harbour, P04/f9497; Waitangi River, Northland, P05/f9499; ?Kaiwhata River, North Island, T27/f6730; east bank of Te Hoe River, western Hawke's Bay, North Island, V19/f184, V19/f185; ?west bank of Te Hoe River, V19/f195; Te Hoe River, V19/f129; east-flowing tributary of Mangahouanga Stream, western Hawke's Bay, V19/f181A; Mangahouanga Stream, western Hawke's Bay, V19/f6909; Selwyn Rapids, Canterbury, South Island, L35/f6510; ?lower Conway rail cutting, southern Marlborough, South Island, O32/f8793; Haumuri Bluff, southern Marlborough, O32/f9504; north face of Haumuri Bluff, O32/f9529 (type); small tributary to Mikonui Stream, southern Marlborough, O32/f8788; on coast just south of Mikonui Stream, southern Marlborough, O32/f8774A; east wing of Haumuri Bluff, southern Marlborough, O32/f9026.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); ?Herbert Formation, Katiki Formation, Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Maungataniwha Sandstone (Upper Cretaceous). Also unnamed Haumurian? units in Northland.

Geographic distribution.-Northland to Otago, South Island.

Discussion.-The affinity of the New Zealand Late Cretaceous species of *Lahillia* has been uncertain until now. Wilckens (1920a, pp. 264-265) was the first to recognize the presence of *Lahillia* in the New Zealand Cretaceous and also that *Mactra* sp. of Woods (1917, p. 30, Pl. 16, Figs. 8a-8b) was not a *Mactra*, but another early member of the Austral, widespread *Lahillia* group. Marshall and Murdoch (1923) in a review of *Lahillia* in New Zealand presented no new data for the Cretaceous species, and only summarised Wilckens' (1920) findings. In a later paper Wilckens (1924, pp. 539-541, Pl. 54, Figs. 1-4) described and formally assigned the Late Cretaceous New Zealand species to *L*. cf. *L*. *luisa* (Wilckens, 1905) (incorrectly referred as *L*. *luisae* by Marshall and Murdoch (1923, p. 130)), due to the inferred similarity between this Late Cretaceous South American form and the New Zealand species. Wilckens only tentatively referred his material from Shag Point, Haumuri Bluff and Malvern Hills to *L*. cf. *L*. *luisa* as the specimens were not sufficiently complete and also because of believed slight differences in cardinal teeth morphology. (In addition, the New Zealand Cretaceous species has more orthogyrous umbones and more developed ventral arches on the hinge compared to *L*. *luisa* (see large specimens with exposed hinges of this latter species in Feruglio, 1936, Pl. 14, Figs. 12b-13)). In an extensive review of *Lahillia*, Finlay and Marwick (1937, pp. 30-33) believed that the Late Cretaceous New Zealand form should be classified as *L*. aff. *neozelanica* (which has persisted in the literature to the present) until better material is found. Prepared hinges of both left and right valves from Haumuri Bluff (O32/f9529, collected in 1967) were completed 30 years or more after Finlay and Marwick's work and represent the only nearly complete hinges to date known of this species. Surprisingly, no further comment on the Late Cretaceous New Zealand species has been made until this work. Most fossil specimens of the Late Cretaceous species, here newly described as *L. aotearoa* n. sp., are either articulated, poorly preserved or exhibit only external views.

An exciting possibility, but now known to be false, Beu and Maxwell (1990, p. 80) stated that if this species "should prove to be conspecific with the Paleocene species, *L. neozelanica* would be the only bivalve to have survived from Late Cretaceous into the early Cenozoic in New Zealand". Only one species of *Lahillia*, *L. larseni* (Sharman and Newton, 1897), is known for certain to have survived the Cretaceous/Tertiary boundary marine revolution. *Lahillia larseni*, from Seymour and possibly Humps islands, Antarctic Peninsula, ranged from late Maastrichtian to earliest Paleocene and its abundance actually increases up-section above the K/T boundary on Seymour Island without displaying any morphological change across the boundary (Zinsmeister and Macellari, 1988, p. 279). Evidently, the material including exposed hinges of *L. aotearoa* n. sp. housed at the Institute of Geological and Nuclear Sciences Limited in Lower Hutt escaped the attention of Beu and Maxwell. *Lahillia aotearoa* n. sp. differs from its inferred, closely related Paleocene descendent, *L. neozelanica* Marshall and Murdoch, 1923 (p. 130, Pl. 16, Fig. 3 only, not Figs. 1 or 2; Finlay and Marwick, 1937, pp. 32-33, Pl. 4, Figs. 8-10; Beu and Maxwell, 1990, p. 80, Pl. 1 j, k) in having less elevated orthogyrous umbones, a slightly narrower, less robust hinge plate, a less ventrally produced, shortened, peg-like, subtriangular cardinal tooth in the right valve with adjacent relatively broad, trigonal socket for opposing cardinal tooth of left valve, a more peg-like cardinal tooth in the left valve, a less developed nymph and sculpture of widely spaced, and commarginal lamellae which is bunched more ventrally on some specimens, compared to L. neozelanica. Lahillia huberi Zinsmeister and Macellari, 1988 (p. 279, Fig. 15.6-8) from the Paleocene Sobral Formation of Seymour Island, Antarctic Peninsula approximates L. aotearoa n. sp. in general outline and having orthogyrous beaks, but L. aotearoa n. sp. has more inflated, elevated umbones with a broader posterior lateral socket and apparently shorter posterior lateral tooth compared to L. aotearoa n. sp.

Freneix (1958, p. 179) described a species from the Campanian of New Caledonia, Lahillia (Lahilleona) marwicki (refigured by Freneix, 1980, pp. 43-44, Pl. 5, Figs. 4-5), but this species can be separated from L. aotearoa n. sp. by the former having a seemingly more ovate outline, less inflated umbones, a shallower pallial sinus, a more bluntly rounded cardinal tooth and moderately developed posterior cardinal (4b) in the left valve.

Although beyond the scope of this study, enough data are seemingly available to delineate phylogenetic relationships of the various Austral Lahillia species, but this has yet to be accomplished. The Late Cretaceous to Paleogene geographic distribution of Lahillia in the Austral Realm indicates moderate dispersal capabilities throughout this time interval after which the group became apparently restricted to southern South America where it became extinct during the Miocene.

Etymology.-Species named from the Maori "aotearoa" (= New Zealand).

Superfamily MACTRACEA Lamarck, 1809

Family MACTRIDAE Lamarck, 1809

Subfamily MACTRINAE Lamarck, 1809

Genus CYMBOPHORA Gabb, 1869

Cymbophora Gabb, 1869, p. 181.

Type species.-(by original designation) Mactra ashburnerii Gabb, 1864.

Synonym.-Veleda Conrad, 1870 (Keen in Moore, 1969, pp. N598-N599).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-Cymbophora is characterised by a trigonal outline, narrow and shallow resilifer that is bordered by accessory lamella, and strong lateral teeth that are situated close to the beaks (Keen in Moore, 1969, p. N598). A bivalve specimen, left valve (TM 7502, IGNS), was collected by A. McKay in 1890 from Upper Cretaceous rocks at Totara Point, Whangaroa Harbour, Northland. Study of this specimen, labelled Lahillia n. sp. by a member of Insitute of Geological and Nuclear Sciences, indicates to me that it is assignable to the Mactridae, not Lahillinae, and may be further tentatively placed in Cymbophora, a group known previously from the Upper Cretaceous of eastern and western North

America, Europe and South America. The left valve hinge of the type species of Cymbophora, C. ashburnerii (Gabb, 1864) (p. 153, Pl. 22, Fig. 127; figured by Keen *in* Moore, ibid, Fig. E93-8, hinge only), approximates the New Zealand species fairly well, except that the type species has a shorter hinge plate, apparently slightly deeper resilifer and longer lateral teeth. The cardinal tooth is broken and other parts of the hinge are incomplete, but there seems little doubt that the New Zealand specimen represents a new group. This new species is herein named *Cymbophora mckayi* n. sp. and is described below.

CYMBOPHORA MCKAYI n. sp.

Plate 23 Figures 1-2

Diagnosis.-Shell more ovate with longer hinge plate, shallower resilifer, and longer lateral teeth compared to *C. ashburnerii*; shell mostly smooth, except for raised, narrow, closely spaced, commarginal threads.

Description.-Shell large, moderately thick, robust, slightly to moderately inflated, subtrigonal to subovate; umbo central, moderately projecting, only slightly inflated; beak slightly prosogyrous; anterodorsal margin moderately long, steep, straight to gently convex, merging towards well-rounded anterior margin; posterodorsal margin moderately long, sloping at same angle as anterodorsal margin, more convex than anterodorsal margin, merging towards rounded posterior margin; ventral margin very broad, gently convex; lunule narrow, short; escutcheon long, moderately broad, impressed, extending in front of umbo to intersection of posterodorsal and posterior margins; shell mostly smooth, except for slightly raised, closely spaced, narrow, commarginal threads; hingle plate long, moderately broad, robust with single, large, cardinal tooth (broken, but remnants of being bifid), and incomplete, cardinal lamella(?); resilifer very shallow; posterior lateral socket long, deep, posterior lateral tooth apparently long, incomplete on specimen; only vestiges of anterior lateral tooth present.

Dimensions.-Holotype TM 7502 (IGNS) length 86.0 mm, height 58.0 mm.

Type.-Holotype TM 7502 (IGNS).

Figured specimen.-TM 7502 (IGNS).

Type locality.-Totara Point, Whangaroa Harbour, Northland, P04/f9497.

Stratigraphic range.-?Mangakahia Complex rocks of Northland, formation unspecified (Piripauan Stage, upper Campanian, Upper Cretaceous). The Piripauan age given here is based on a study of the small faunule from this locality (P04/f9497) by Crampton (1988b, p. 8), who identified Inoceramus cf. pacificus in the faunule.

Geographic distribution.-Whangaroa, Northland.

Discussion.-The outline of Cymbophora araucana (d'Orbigny, 1842) (reviewed and refigured by Stinnesbeck, 1986, pp. 176-177, Pl. 4, Figs. 10-12, external views only; this species was referred to Mulinoides araucana by Riccardi, 1988, p. 49, Tab. 7) from the Maastrichtian of central Chile is more trigonal and the commarginal sculpture and umbonal ridge stronger, compared to C. mckayi n. sp. A close relationship between these two species does not seem probable. Cymbophora buttensis Anderson, 1958 (p.

145, Pl. 61, Fig. 3) from the Campanian of the Chico Formation, Pacific Coast, North America approaches C. mckayi n. sp. in outline and sculpture, but the latter New Zealand species is more ovate with a more produced, narrowly rounded anterior margin. Wilckens (1905, pp. 62-63, footnote, Pl. 8, Fig. 12) figured a bivalve that he tentatively referred to Mactra sp. from the Late Cretaceous of southern Patagonia; this bivalve, poorly preserved, agrees fairly well in outline with C. mckayi n. sp., but the absence of a description of this specimen by Wilckens prevents any meaningful comparison between the two species.

Etymology.-Species named in honour of early New Zealand geologist Alexander McKay, who collected the holotype.

Subfamily PTEROPSELLINAE Keen, 1894

Genus RAETA Gray, 1853

Raeta Gray, 1853, p. 43.

Type species.-(by monotypy) Mactra campechensis Gray, 1825 (= L. plicatella Lamarck, 1818.

Synonym.-Lovellia Mayer, 1867 (Keen in Moore, 1969, p. N606).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

RAETA? n. sp.

Plate 23 Figures 3, 5, 7

Dimensions.-Ge 7641 (AIM) length 41.0 mm, height 29.5 mm; L 3876 (AU) length 22.0 mm, height 20.0 mm.

Figured specimens.-Ge 7641 (AIM), L 3876 (AU).

Material.-Two specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626, Q08/f9909.

Stratigraphic range.-Unspecified horizon in Unit 4 of Evans

(1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-Two poorly preserved specimens, Ge 7641 (AIM) and L 3876 (AU) from Bull Point, Kaipara, compare well with the mactrid genus Raeta Gray, 1853, type species R. campechensis (Gray, 1825) (Keen in Moore, 1969, p. N606, Fig. E98-3a-c), in outline and in having coarse sculpture of commarginal plications, but as internal details of the New Zealand specimens are wanting, no in-depth comparisons can be made. Raeta? n. sp. is also superficially similar to species of Thracia Leach in Blainville, 1824, but this species is doubtfully closely related as the coarse commarginal plications of R.? n. sp. point more to Raeta.

Subfamily ZENATIINAE Dall, 1895

Genus Zenatia Gray, 1853

Zenatia Gray, 1853, p. 43.

Type species.-(by monotypy) Lutraria zelandica Gray, 1837.

Biogeographic element.-Endemic (Beu and Maxwell, 1990, p. 288).

Discussion.-Woods (1917, p. 31) described a species Cultellus cretaceus (Pl. 16, Fig. 9) that was collected from the west wing of Haumuri Bluff, southern Marlborough, South Island (O32/f8025) by Alexander McKay in 1873. No review of C. cretaceus had been accomplished until Beu (1966, pp. 79-81, Pl. 1, Figs. 1-3, text-fig. 2c; see also Beu, 1968, comment p. 127) in a paper entitled, "The molluscan genera Lutraria, Resania and Zenatia in New Zealand", revised C. cretaceus and reassigned this species to Zenatia. Furthermore, Beu discovered that the matrix ("extremely hard concretionary fine sandstone") from which Z. cretaceus was supposedly collected was quite different from the "Calcareous Conglomerate of Amuri Bluff" (p. 79, referable now to Okarahia Sandstone), thus indicating the possibility that *Z. cretaceus* was younger than Late Cretaceous. A sample of this matrix (possibly not from the *Z. cretacea* specimen?) was studied for pollen by G. Wilson who inferred a Miocene age at the youngest (Beu, 1966, p. 79), so that *Z. cretaceus* is therefore a Tertiary species and not Cretaceous. However, Warren and Speden (1978, p. 50, Tab. 5) still curiously included *Z. cretacea* as present in the Okarahia Sandstone as did more recently Speden *in* Wiffen (1980, p. 527) and Crampton and Moore (1988, p. 346) in the Upper Cretaceous Maungataniwha Sandstone of western Hawke's Bay, North Island, although this identification was not confirmed by them (p. 345). The status of *Z. cretacea* was reviewed once again more recently by Beu and Maxwell (1990, p. 288) who decided that the poorly preserved holotype "has a narrower and still more nearly horizontal lunule than the oldest Cenozoic form; this name should be restricted to the Late Cretaceous species, and the early Cenozoic species identified by Beu (1966) as *Z. cretacea* should be renamed". No conclusive evidence was given by Beu and Maxwell (1990) of the supposed Miocene age (inferred from pollen) of the fine, sandstone sample from which *Z. cretaceus* was derived, as concluded by Beu (1966); Beu and Maxwell seemingly followed Warren and Speden (1978) in their belief that the holotype of *Z. cretacea* was derived from the base of the Okarahia Sandstone at Haumuri Bluff. The presence of *Z. cretacea* in the Okarahia Sandstone and Maungataniwha Sandstone can only still be deemed questionable at this time.

ZENATIA CRETACEA (Woods, 1917)

Plate 23 Figure 10

Cultellus cretaceus Woods, 1917, p. 31, Pl. 16, Fig. 9.

Zenatia cretacea (Woods, 1917), Beu, 1966, pp. 79-81, Pl. 1, Figs. 1-3, text-fig. 2c; Beu, 1968, p. 127; Warren and Speden, 1978, p. 50, Tab. 5; Speden in Wiffen, 1980, p. 527; Crampton and Moore, 1988, p. 346; Beu and Maxwell, 1990, p. 288.

Type.-Holotype TM 2542 (IGNS; Woods, 1917, Pl. 16, Fig. 9).

Figured specimen.-TM 2542.

Localities.-North face of Haumuri Bluff, southern Marlborough, South Island, O32/f8025; Mangahouanga Stream float *3, western Hawke's Bay, North Island, of Crampton and Moore (1990, p. 346).

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Western Hawke's Bay, North Island to southern Marlborough.

Discussion.-If Zenatia cretacea is truly a late Campanian species, then it is the oldest member of this endemic group by many millions of years, as the next occurrence of the genus is in the Late Oligocene. Zenatia cretacea, one of only a few members of endemic bivalve genera in the New Zealand Cretaceous, is inferred to have been an infaunal, long siphonate, suspension feeder and a deep, slow burrower (Warren and Speden, 1978, p. 50, Tab. 5; cf. Crampton and Moore, 1990, p. 346).

Superfamily TELLINACEA de Blainville, 1814

?Family TELLINIDAE de Blainville, 1814

Genus AENONA Conrad, 1870

Aenona Conrad, 1870, p. 74.

Type species.-(by subsequent designation, Stoliczka, 1871) Tellina eufaulensis Conrad, 1860.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here. Kauffman (1973, p. 369) considered Aenona as a typical endemic Gulf and Atlantic Coastal Plain bivalve.

Discussion.-The generic location of Tellina sp. cf. largillierti (d'Orbigny) of Woods, 1917 (p. 30, Pl. 16, Fig. 6) needs further appraisal. This Late Cretaceous New Zealand species is not a Tellina as it has an extremely shallow pallial sinus unlike the Recent type species of Tellina, T. radiata Linné, 1758 (figured by Sowerby, 1852, Fig. 105; Afshar, 1969, p. 24, Pl. 1, Figs. 1-5; Keen in Moore, 1969, Fig. E104-11; Abbott, 1974, Pl. 23, Fig. 5636; Lindner, 1976, Pl. 63, Fig. 8), informally known as the "Sunray Tellin" (Saul, 1974, p. 98), which has a "palleal impression with a large sinus" (Sowerby, 1852, p. 132). Homeomorphy in the Tellinidae makes features such as shell outline, for example, difficult to use alone as a basis for genus-level assignment. Agreement of subelliptical outline, broad pallial line, adductor muscle scar outline and shape, and subequilateral, compressed, smooth shell of "Tellina sp. cf. largillierti" is most consistent with a seemingly previously restricted Late Cretaceous North American group Aenona. The type species of Aeonona, A. eufaulensis (Conrad, 1860) (see Wade, 1926, p. 92, Pl. 30, Figs. 4-5, and description by J. Gardner; Afshar, 1969, p. 59, Pl. 24, Figs. 19-20; refigured by Keen in

Moore, 1969, p. N621, Fig. E108-11) is strikingly similar to the New Zealand Late Cretaceous species, except that A. eufaulensis is more broadly subelliptical with more central umbones. Although beyond the scope of this paper, the family-level assignment of Aenona is uncertain and this genus may not be a member of Tellinidae. The New Zealand species formally referred to as "T. sp. cf. largillierti" is herein reassigned provisionally to Aenona n. sp.?

Tellinacean bivalves of uncertain affinities were recorded by Crampton and Moore (1990, p. 346) from the Maungataniwha Sandstone of western Hawke's Bay, North Island. A possible tellinid was also reported by Campbell et al. (1993, Tab. 4.3) in the Kahuitara Tuff of Pitt Island, Chatham Islands.

AENONA n. sp.?

Plate 23 Figures 4, 6, 8-9, 11-12

Tellina sp. cf. Largillierti (d'Orbigny), Woods, 1917, p. 30, Pl. 16, Fig. 6; Wilckens, 1920a, p. 262; Marwick and Fleming in Wellman, 1959, p. 138.

Description.-Shell moderately large, thin, compressed, subequilateral, subelliptical; beaks small, subcentral; anterodorsal and posterodorsal margins nearly straight, gently sloping; anterior and posterior margins moderately narrowly rounded; ventral margin broadly convex; shell mostly smooth, except for closely spaced, subobsolete, commarginal striae; hinge unknown (most shells articulated); anterior and posterior adductor scars large, sub-crescent shaped, impressed; pallial line nearly entire with an extemely shallow sinus.

Dimensions.-OU 40960 (from OU 10985) length 50.0 mm nearly complete, height 30.0 mm; OU 40961 (from OU 10985) length 31.0 mm incomplete, height 32.0 mm; TM 7503 (IGNS) length 38.5 mm, height 24.0 mm, width of paired valves 11.0 mm; TM 7505 (IGNS) length 38.5 mm, height 27.0 mm, width of paired valves 11.0 mm; TM 7504 (IGNS) length of valve (internal) 54.5 mm, height 31.0 mm nearly complete.

Previously figured specimens.-TM 2578 (IGNS; Woods, 1917, Pl. 16, Fig. 6), TM 2577 (IGNS; Woods, 1917, Pl. 16, Fig. 7).

Figured specimens herein.-OU 40960, OU 40961, TM 2577-2578 (IGNS), TM 7503-7504 (IGNS).

Material.-Six specimens, all but one articulated.

Localities.-Known for certain only from Selwyn River, Malvern Hills, Canterbury, South Island, L35/f6008 and Selwyn Rapids, L35/f6510; possibly ?Awakei Creek, tributary of Waitangi River, Northland, P05/f9502; ?Little Pukeiwitahi Woolshed Creek, Otago, J43/f6471; ?Mount Pukeiwitahi, Otago, J43/f6494; ?Bull Point, Kaipara, Northland, Q08/f9668.

Stratigraphic range.-Only Selwyn Rapids Beds for certain (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland? to Otago.

Discussion.-Positive identification of specimens of *Aeonona* n. sp.? is made possible only with those examples from the Malvern Hills, Canterbury area. Woods (1917, p. 30) believed that the his New Zealand species had a possible affinity with *Tellina largillierti* (d'Orbigny, 1842) from the Late Cretaceous of central Chile, but his material at hand prevented further accurate assessment. *Aenona* n. sp.?, a rare species in the

Maastrichtian bivalve fauna, is morphologically very similar to the type species, *A. eufaulensis* (Conrad, 1860) discussed earlier and another possible congener, *Tellina largillierti* (d'Orbigny), may be related although preservation of the latter species is here not considered good enough for detailed comparison (see Stinnesbeck, 1986, pp. 179-180, Pl. 5, Fig. 4 for a figured example of *T. largillierti*). Little variability can be detected in specimens of *Aenona* n. sp.? *Tellina* sp. of Woods (1917, p. 30, Pl. 16, Fig. 7) is most likely conspecific with *Aeonona* n. sp.? The absence of material of *Aenona* n. sp.? with the hinge preserved leads me to defer naming this probable new species at this time.

Family DONACIDAE Fleming, 1828

Discussion.-Maxwell *in* Feldmann (1984, p. 383) recorded ?*Notodonax* sp. (steinkern only) in Upper Cretaceous marine sediments near Cheviot, South Island. *Donax*? sp. was also recorded in Upper Cretaceous sediments of in Okarahia Stream and Claverley Coast, southern Marlborough (Warren and Speden, 1978, p. 33, Tab. 3). As far as I am aware these are the only possible records of this group in the New Zealand Cretaceous. The presence of *Notodonax* in New Zealand rocks would not be unexpected as this group is known from Campanian to Maastrichtian rocks of southern South America (Feruglio, 1936; Riccardi, 1988).

Family PSAMMOBIIDAE Fleming, 1828

Subfamily PSAMMOBIINAE Fleming, 1828

Genus *GARI* Schumacher, 1817

Gari Schumacher, 1817, p. 131.

Type species.-(by original designation) *Gari vulgaris* (= *Solen* *amethystus* Wood, 1815).

Synonyms.-*Psammotaea* Lamarck, 1818; *Capsella* Deshayes, 1855; *Milligraretta* Iredale, 1936 (Keen *in* Moore, 1969, pp. N630-N631).

Biogeographic element.-Cosmopolitan (Keen *in* Moore, 1969, p. N631). Piccoli *et al*. (1986, Tab. 1) included *Gari* as present in the Tethyan belt as early as Late Eocene in the early Cenozoic.

GARI (s. l.) *BARRONSHILLENSIS* n. sp.

Plate 24 Figures 1-5

Gari n. sp. B, Marwick and Fleming *in* Wellman, 1959, p. 138.

Diagnosis.-Very narrowly elongate-ovate to subelliptical early *Gari* s. l.; beaks small, subcentral; anterodorsal and posterodorsal margins gently sloping, long; ventral margin very broad, gently convex; sculpture of moderately closely spaced, commarginal ribs.

Description.-Shell medium-sized, thin?, subequilateral, compressed, very narrowly elongate-ovate to subelliptical; beaks small, subcentral; umbonal ridge wanting on available material; anterodorsal and posterodorsal margins long, gently sloping, nearly straight to gently curved; anterodorsal margin merging towards narrowly rounded anterior margin; posterior margin slightly broader; ventral margin very broad, gently convex; shell mostly smooth except for commarginal, moderately closely spaced, slightly raised ribs; hinge plate narrow with two well-developed, subtrigonal cardinal teeth, situated directly below the beak and poorly developed lateral? tooth; only remnant of pallial line preserved on paratype; inner margin smooth.

Dimensions.-Holotype OU 40962 (from OU 5442) length 35.0. height

13.0 mm; paratype, OU 40963 length 32.5 mm, height 13.0 mm; paratype OU 40964 length 33.5 mm, height 13.0 mm.

Types.-Holotype OU 40962, paratypes OU 40963, OU 40964.

Type locality.-East slopes of Barrons Hill, Otago, South Island, I44/f8510.

Figured specimens.-OU 40962, OU 40963, OU 40964.

Material.-Six specimens.

Stratigraphic range.-Barrons Hill Lens of Brighton Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from the Barrons Hill area, Otago.

Discussion.-*Gari* s. l. *barronshillensis* n. sp. represents one of the earliest known occurrences of the Psammobiinae in the fossil record. The type species of *Gari*, the Miocene to Recent *G*. *amethystus* (Wood, 1815) (refigured by Keen *in* Moore (1969, p. N631, Fig. E115-7), is externally reminiscent of *G*. s. l. *barronshillensis* n. sp., but the latter New Zealand species is much more narrowly elongate-ovate with a poorly developed umbonal ridge and has more closely spaced, commarginal riblets. The ligament, which is relatively large and external, is not preserved in the generally poor New Zealand material. Assignment of *G*. s. l. *barronshillensis* n. sp. to a subgenus is not possible at this time, but most probably represents a new group. *Gari* s. l. *barronshillensis* n. sp. is again much more narrowly elongate compared to a slightly younger "Wangaloan" (Early Paleocene) new species, *Gari tokomairiroi* (described in New Zealand Paleocene bivalve section of this work), from the Tokomairiro River mouth near Wangaloa and *Gari cacuminata* Finlay and Marwick, 1937 (p.

102, Pl. 14, Fig. 17) from Castle Hill Shaft which was inferred by Beu and Maxwell (1990, p. 399) to be of uncertain age within the Dannevirke Series. Gari s. l. barronshillensis n. sp. is inferred here to have been a shallow-water, siphonate, deposit-feeding bivalve that inhabited moderate depths in the substrate in relatively coarse sediment.

Etymology.-Species named from the type locality, Barrons Hill, Otago, South Island.

Family TANCREDIIDAE Meek, 1864

Genus TANCREDIA Lycett, 1850

Tancredia Lycett, 1850, p. 407.

Type species.-(by subsequent designation, Morris and Lycett, 1855) Tancredia donaciformis Lycett, 1850.

Synonym.-Hettangia Terquem in Buvignier, 1852.

Biogeographic element.-Cosmopolitan (Cox in Moore, 1969, p. N640).

Discussion.-Tancredia has a relatively long stratigraphic range in New Zealand rocks from the Early Jurassic to Late Cretaceous. Crampton and Moore (1990, p. 346, Fig. 8-H) were the first to recognize the presence and figure a specimen of Tancredia (s. l.) from the Upper Cretaceous Maungataniwha Sandstone of western Hawke's Bay, North Island, but no systematic work of this species was presented. Crampton and Moore in the same paper stated that the specimen of Tancredia (s. l.) figured (Fig. 8H) is a left valve, but in actuality the figured specimen is a right valve. This same specimen figured by Crampton and Moore along with two other examples is in this work given the new name Tancredia sura

n. sp. Although Cox in Moore (1969, p. N640) gave a stratigraphic range of Early Jurassic to Late Jurassic for Tancredia s. s., the range of this group was extended later by Speden (1970, pp. 112-115) and Rhoads et al. (1972, p. 1103, Tab. 2) to include the Maastrichtian of South Dakota. Tancredia survived into the Danian (Lower Paleocene) in the high northern latitude region of Northern Alaska (Marincovich, 1993, p. 22). The strong similarity of Tancredia sura n. sp. to the type species, T. donaciformis Lycett, 1850, suggests that the assignment of this new species to Tancredia s. l., as done by Crampton and Moore (1990), is not warranted. Tancredia was inferred to be a shallow infaunal, short siphonate, mobile suspension feeder (Rhoads et al., 1972, p. 1103, Tab. 2, see autecological reconstruction of Tancredia in Fig. 4A).

TANCREDIA SURA n. sp.

Plate 24 Figures 6-8

Tancredia (s. l.) sp., Crampton and Moore, 1990, p. 346, Fig. 8H.

Diagnosis.-Large, thick, subtrigonal Tancredia with robust hinge; external ligament very short, thick, subconical; anterior margin subangular; shell ornamented with thick, flattened, low ribs.

Description.-Shell large, thick, moderately inflated, subequilateral, subtrigonal; umbones slightly inflated, subcentral; beaks small; posterior umbonal ridge poorly to moderately developed; anterodorsal margin long, moderately sloping, concave, merging towards subangular to very narrowly rounded anterior margin; posterodorsal margin moderately long, steeply sloping, gently convex, merging towards rounded to very slightly angular posterior margin; posterior margin only vaguely truncated; ventral margin broadly convex; lunule long, very narrow, bordered by narrow ridge; shell mostly smooth, except for low, broad, flat commarginal ribs; hinge robust, thick, with strong cardinal teeth, lateral teeth not preserved in available material; ligament external, opisthodetic, very short, thick, subconical.

Dimensions.-Holotype TM 7506 (IGNS) (from GS 14269) length 50.0 mm, height 30.5 mm; paratype TM 7507 (IGNS) (from GS 2157) length of hinge 57.5 mm nearly complete; paratype TM 6873 length 69.5 mm.

Types.-Holotype TM 7506 (IGNS), paratypes TM 7507 (IGNS), TM 6873 (IGNS).

Previously figured specimen.-TM 6873 (IGNS; Crampton and Moore, 1990, p. 333, Fig. 8H).

Figured specimens herein.-TM 7506, TM 7507, TM 6873 (all IGNS).

Figured specimens.-TM (IGNS), TM (IGNS), TM 6873 (IGNS).

Material.-Three specimens.

Localities.-Te Hoe River, western Hawke's Bay, North Island, V19/f185 (type); Mangahouanga Stream, tributary of Te Hoe River, western Hawke's Bay, North Island, V19/f6909; Selwyn Rapids Beds, Canterbury, South Island, L35/f6510.

Stratigraphic range.-Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous), Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Western Hawke'Bay, North Island to Canterbury, South Island.

Discussion.-*Tancredia sura* n. sp. represents the only known species of this group in the New Zealand Cretaceous. The type species of *Tancredia*, *T. donaciformis* Lycett, 1850 (refigured by Cox *in* Moore, 1969, p. N640, Fig. E123-4), from the Middle Jurassic of France can be distinguished from *T. sura* n. sp. by its less angular anterior margin, stronger umbonal ridge and more developed, obliquely truncated posterior margin, compared to *T. sura* n. sp. which has a subangular anterior margin, poorly to moderately developed umbonal ridge and poorly developed posterior truncation. An Early Jurassic (Upper Temaikan Stage) New Zealand species, *T. allani* Marwick, 1953 (p. 111, Pl. 14, Fig. 4; Stevens *in* Suggate *et al*., 1978, p. 219, Fig. 4.60-11), and perhaps ancestor to *T. sura* n. sp., differs from the latter new Cretaceous species in having a less angular anterior margin, less projecting umbones, broader ventral margin and more convex posterodorsal margin. The hinge of *T. allani* is unknown (Marwick, 1953, p. 111). *Tancredia americana* (Meek and Hayden, 1856) (see Speden, 1970, pp. 112-115, Pl. 27, Figs. 1-16; Pl. 28, Figs. 1-8, 14) from the Maastrichtian of South Dakota compares well with *T. sura* n. sp., but has a broader and more rounded shell with a less produced posterior end compared to the New Zealand species. One specimen of *T. sura* n. sp. (TM 6873) from Mangahouanga Stream, western Hawke's Bay (V19/f6909), approaches in anterior outline only a related Middle Jurassic to Early Cretaceous tancrediid group, *Corbicellopsis*, but the apparent absence of prominent nymphs would seem to preclude its placement within *Corbicellopsis*.

Superfamily VENERACEA Rafinesque, 1815

Family VENERIDAE Rafinesque, 1815

Subfamily PITARINAE Stewart, 1930

Genus APHRODINA Conrad, 1869

Aphrodina Conrad, 1869, p. 246.

Type species.-(by original designation) Meretrix tippana Conrad, 1858.

Synonym.-Callistina Jukes-Browne, 1908 (Keen in Moore, 1969, p. N676).

Subgenus TIKIA Marwick, 1927

Tikia Marwick, 1927, p. 595.

Type species.-(by original designation) Callista thomsoni Woods, 1917.

Biogeographic element.-Paleoaustral, as interpreted here.

Discussion.-Keen in Moore (1969, pp. N676-N677) regarded Aphrodina (Tikia) as a endemic Cretaceous venerid of New Zealand and was apparently unaware of Freneix's (1958) work on the Campanian species of A. (Tikia) from New Caledonia. Aphrodina (Tikia) seemingly also escaped the attention of Kauffman (1973) in his widely cited review of Cretaceous Bivalvia. Aphrodina (Tikia) may also be present in the Maastrichtian of central Chile. A mid Campanian species of Aphrodina (Tikia) was reported by del Valle and Medina (1980, pp. 56-57, Pl. 3, Figs. 5-6) from marine strata of Cape Lamb, Vega Island, Antarctic Peninsula and was found to be morphologically similar to A. (T.) wilckensi of New Zealand. A species of A. (Tikia) of uncertain affinity was noted as present in the Upper Cretaceous Kahuitara Tuff of the Chatham Islands (Campbell et al., 1993, Tab. 4.3). It appears that A. (Tikia) became extinct sometime during the Paleocene.

The subgeneric affinities of *Aphrodina* sp. of Medina *et al*. (1990, p. 142, Pl. 1, Fig. 6) from the Early Paleocene of Barranca de los Perros, Rio Chubut, Chubut, has yet to be shown.

Aphrodina (*Tikia*) can be separated from *Aphrodina* s. s. by the former having strong commarginal sculpture and a very long anterior lateral tooth (All) with a "high knobbed posterior end" (Marwick, 1927, p. 595; Keen *in* Moore, 1969, pp. N676-N677). *Aphrodina* (*Tikia*) is considered to have been a infaunal suspension feeder of high mobility and possessed long siphons (Warren and Speden, 1978, p. 50, Tab. 5; Freneix, 1981, p. 27, Fig. 3, note drawing; Crampton and Moore, 1990, p. 346).

Localities with *Aphrodina* (*Tikia*) of uncertain species-level affinity are listed below (see Appendix A for further details and grid references): Matakea Point, northeastern side of Shag Point boat harbour, Otago, South Island, J43/f6544A; ?left bank of Acheron River, South Island, K35/f7509; east wing of Haumuri Bluff, southern Marlborough, South Island, ?O32/f9029, O32/f8025; lower Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6511; Hook Stream, western Hawke's Bay, V19/f6649; ?headwaters of Waikokopu Stream, North Island, W18/f8; ?Looney Creek, western Hawke's Bay, V18/f8510; ?Birch Hollow, left branch, Canterbury, South Island, M34/f1; ?South Branch of Waipara River, Canterbury, M34/f7658; and Gittos Point, Kaipara Harbour, Northland, Q09/f9503.

APHRODINA (*TIKIA*) *THOMSONI* (Woods, 1917)

Plate 24 Figures 9-10; Plate 25 Figures 1, 3-6, 8, 10-11

?*Cytherea* sp., Wilckens, 1904, p. 247, Pl. 19, Fig. 15.

Callista (*Callistina*) *thomsoni* Woods, 1917, p. 32, Pl. 17, Figs.

4, 5a-b, 6.

Callista sp., Woods, 1917, p. 32, Pl. 17, Fig. 7.

Callista thomsoni Woods, Wilckens, 1920a, p. 265.

Callistina (Tikia) thomsoni (Woods), Marwick, 1927, p. 595, Figs. 55-56; Marwick and Fleming in Wellman, 1959, p. 139.

Aphrodina (Tikia) thomsoni (Woods), Keen in Moore, 1969, pp. N676-N677.

Dimensions.-TM 7508 (IGNS) length 55.0 mm, height 43.5 mm, width of paired valves 28.0 mm; OU 40965 length 32.0 mm incomplete.

Type and previously figured specimens.-Lectotype TM 2560 (IGNS; Woods, 1917, Pl. 17, Fig. 4); TM 2561 (IGNS; Woods, 1917, Pl. 17, Fig. 6); TM 2562 (IGNS; Woods, 1917, Pl. 17, Fig. 5); TM 2553 (IGNS; Woods, 1917, Pl. 17, Fig. 7).

Figured specimens herein.-TM 7508 (IGNS); TM 2560 (IGNS; from Marwick, 1927, Fig. 55); TM 2561 (IGNS; from Marwick, 1927, Fig. 56); TM 2562 (IGNS), TM 2553 (IGNS), OU 40965.

Material.-Six specimens, one with ligament preserved and other fragments.

Localities.-Selwyn Rapids Beds, Malvern Hills, Canterbury, South Island, L35/f6510; Selwyn River, Malvern Hills, Canterbury, L35/f6008; ?off Creamery Road, Brighton, Otago, South Island, I45/f8517; Barron's Hill, Otago, c. I44/f8510; Turnbull's Road, southwest of Coalgate, Canterbury, L35/f062.

Stratigraphic range.-Selwyn Rapids Beds, ?Creamery Road Member of the Brighton Formation, Chaplin Sandstone, ?Quiriquina Formation of central Chile (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Malvern Hills, Canterbury, South Island and possibly Brighton, Otago, South Island and central Chile.

Discussion.-The only review of *Aphrodina* (*Tikia*) *thomsoni* since Woods' (1917) original work was by Marwick (1927, p. 595, Figs. 55-56) who cleaned off the matrix on hinges of two of Woods' specimens so that details of these hinges could be figured. These drawings by Marwick are reproduced here in Plate 25 Figures 5, 11. Marwick (1927, p. 595) remarked that the specimen on Plate 17, Figure 7 of Woods (1917) (TM 2553; IGNS), considered by Woods to be different from *A*. (*T*.) *thomsoni*, actually represents this species and that sculptural details are consistent with *A*. (*T*.) *thomsoni* and that differences in height of the umbones are merely a reflection of the decorticated nature of Woods' figured specimen, Plate 17, Figure 6. Marwick (1927, ibid) further stated that "the difference of outline is not so apparent in the specimens themselves as in the figures". No mention of preserved ligaments of *A*. (*T*.) *thomsoni* was made by either Woods (1917) or Marwick (1927). An articulated specimen of *A*. (*T*.) *thomsoni* from Selwyn Rapids (TM 7508, IGNS, GS 2157) reveals a moderately well-preserved, opisthodetic ligament that extends from a point just in front of the beaks posteriorly to a point midway along posterodorsal margin.

Wilckens (1920a, p. 265) considered *A*. (*T*.) *thomsoni* to have "eine außerordentlich große Ähnlichkeit" (an extraordinary great similarity) to *Cytherea* sp. of Wilckens (1904, p. 247, Pl. 19, Fig. 15) from the Late Cretaceous of Quiriquina. Stinnesbeck (1986, p. 181) treated *Cytherea* sp. of Wilckens (1904) as questionably conspecific with *Aphrodina quiriquinae* (Philippi,

1887) (p. 120, Pl. 58, Fig. 3). The similarities of Cytherea sp. of Wilckens (1904) and A. (T.) thomsoni are indeed striking; perhaps further work will reveal a conspecific relationship. The distribution of A. (T.) thomsoni is relatively restricted in New Zealand and is only known for certain from the Malvern Hills area, Canterbury and possibly Brighton, Otago. It is interesting to note, however, that Fleming in Robinson (1958, p. 18) reported the presence of A. (T.) aff. thomsoni in the Upper Cretaceous Chaplin Sandstone (unpublished name) of the Brighton-Taieri Mouth area, East Otago, the southernmost extent of macrofossiliferous, marine Cretaceous strata in New Zealand.

APHRODINA (TIKIA) WILCKENSI (Woods, 1917)

Plate 25 Figures 2, 7, 9, 12-18; Plate 26 Figures 1, 4-5

Callista (Callistina) wilckensi Woods, 1917, p. 31, Pl. 15, Fig. 8, Pl. 16, Figs. 10a-b, 11, Pl. 17, Figs. 1a-b, 2a-d, 3.

Callista wilckensi Woods, Wilckens, 1920a, p. 262.

Callistina (Tikia) wilckensi (Woods), Marwick, 1927, p. 596, Fig. 57.

Tikia wilckensi (Woods), Marwick, 1938, p. 61, Pl. 10, Fig. 7.

Callistina (Tikia) wilckensi Woods, Fleming in Wellman, 1959, p. 141 (error, should be (Woods)); Warren and Speden, 1978, Fig. 26-15, 26-16 (on p. 50, Tab. 5, listed as Callista (Tikia) wilckensi).

Callistina wilckensi Woods, Speden in Wiffen, 1980, p. 527.

Aphrodina (Tikia) wilckensi (Woods), Freneix, 1980. p. 48; Crampton and Moore, 1990, p. 346; Stilwell in Aitchison et al., 1993, p. 50, Fig. 3j.

?Aphrodina (Tikia) cf. wilckensi (Woods), Moore et al., 1988, p. 59, Tab. 1.

Dimensions.-OU 40536 length 18.5 mm incomplete, height 19.0 mm; TM 7509 (IGNS) (GS 9384) length 37.5 mm, height 33.5 mm.

Type and previously figured specimens.-Lectotype TM 2554 (IGNS; Woods, 1917, Pl. 16, Fig. 10; Marwick, 1927, Fig. 57; Warren and Speden, 1978, Fig. 26-16); TM 2555 (IGNS; Woods, 1917, Pl. 17, Fig. 1); TM 2556 (IGNS; Woods, 1917, Pl. 16, Fig. 11); TM 2557 (IGNS; Woods, 1917, Pl. 17, Fig. 2); TM 2558 (IGNS; Woods, 1917, Pl. 17, Fig. 3); TM 2559 (IGNS; Woods, 1917, Pl. 15, Fig. 8); TM 5384 (IGNS; Warren and Speden, 1978, Fig. 26-15).

Figured specimens herein.-OU 40536; TM 2554-2559 (IGNS); TM 7509 (IGNS) (from GS 9384).

Material.-16 specimens, mainly poorly preserved.

Localities.-West bank, Te Hoe River, western Hawke's Bay, North Island, V19/f186; Mangahouanga Stream, western Hawke's Bay, V19/f181A, V19/f6909; ?Wakokopu Creek, tributary of Waihoroihika Stream, North Island, W18/f26; upper tributary of "Disappearing Creek" of Waihoroihika Stream, W18/f10; Ruatahuna Stream, tributary of Whakatane River, North Island, W18/f14A; north flowing tributary into headwaters of Ruatahuna Stream, North Island, W18/f7601; Waiau River, North Island, V18/f8500; Selwyn Rapids Beds, Malvern Hills, Canterbury, South Island, L35/f6510; Selwyn River, Canterbury, L35/f6008; South Peak, Moeraki, South Island, J42/f8477; North branch of the Waianakarua River, Otago, J42/f82, ?J42/f218; South Branch of the Waianakarua River, J42/f127; Pukehiwitahi, Otago, South Island, J43/f6481, ?J43/f6494; Oaro River Bed, southern Marlborough, South Island, O32/f8791; Okarahui Stream, southern Marlborough, O32/f8790; lower Conway rail cutting, southern Marlborough, O32/f8793; Haumuri Bluff, southern Marlborough, O32/f9504, O32/f9028; west wing of Haumuri Bluff, O32/f8025 (type); tributary of Mikonui Stream, southern Marlborough, O32/f8788; just south of Mikonui Stream, O32/f8774A; east wing of Haumuri Bluff, O32/f9027.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Tarapuhi Grit, Selwyn Rapids Beds, Herbert? Formation, Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-From western Hawke's Bay, North Island to Shag Point, South Island.

Discussion.-*Aphrodina* (*Tikia*) *wilckensi* is separated from *A*. (*T*.) *thomsoni* by the former having sculpture that becomes obsolete ventrally (Marwick, 1927, p. 596). *Aphrodina* (*Tikia*) *wilckensi* is also generally smaller with less prosogyrous beaks. Further work by Marwick (1938, p. 61), correcting his earlier description of *A*. (*T*.) *wilckensi*, revealed the presence of a long, narrow posterior tooth in the left valve. *Aphrodina* (*Tikia*) n. sp.? aff. *wilckensi* of Crampton and Moore (1990, p. 340, Fig. 8f) of the the Upper Cretaceous Maungataniwha Sandstone of the western Hawke's Bay area is most likely conspecific with *A*. (*T*.) *wilckensi* as little difference can be detected from their figure. The poorly preserved specimen figured by Crampton and Moore (1990, p. 340, Fig. 81) as *Costacallista*? sp. may also represent this species. *Aphrodina* *quiriquinae* (Philippi, 1887) (redescribed and refigured by Stinnesbeck, 1986, pp. 181-183, Pl. 3, Figs. 8-9), a possible consubgener from the Maastrichtian Quiriquina Formation of central Chile, is reminiscent of *A*. (*T*.) *wilckensi* in outline, but in terms of commarginal sculpture, the former South American species has consistently strong ribs from dorsal to ventral margins compared to *A*. (*T*.) *wilckensi* in which the commarginal sculpture is not nearly as strong. The geographic and stratigraphic distribution of Piripauan to Haumurian species *A*. (*T*.) *wilckensi* in New Zealand is considerably more extensive than *A*. (*T*.) *thomsoni*, which is only known from Haumurian (Maastrichtian) rocks in the Malvern Hills area. Specimens of *A*. (*T*.) *wilckensi* are typical poorly preserved, but numerous, in the Katiki Formation of Otago where they are found to be mostly in an articulated, decorticated and/or leached state of preservation. A well-preserved specimen with hinge details preserved in the collections housed at the Institute of Geological and Nuclear Sciences (TM 7509), previously identified as *Eriphyla meridiana* (Woods), is here referred to *A*. (*T*.) *wilckensi* and is figured in Plate 26, Figures 1, 4.

Genus *COSTACALLISTA* Palmer, 1927

Costacallista Palmer, 1927, pp. 73, 84.

Type species.-(by original designation) *Venus erycina* Linné, 1758.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-Before this report on New Zealand Late Cretaceous bivalves only one species of *Costacallista*, *C*. *hectori* (Finlay and Marwick, 1937) from the mid Eocene, had been described from the New Zealand Cenozoic. A specimen from Maastrichtian sediments of Bull Point, Kaipara, Northland, inferred to be an early member of *Costacallista*, was discovered recently in collections housed at Auckland University. The presence of *Costacallista* in the New Zealand Cretaceous marks the earliest known occurrence of this group; elsewhere it is known from the Paleocene to Recent of North America, Asia, New Zealand and Europe (Keen *in* Moore, 1969, p. N677). It is likely that this previous Paleocene age range for *Costacallista* was derived from the early Tertiary occurrence of *C*. *hectori* which is, at the oldest, late Early Eocene (Mangaorapan Stage), not Paleocene. *Costacallista* is not known after the mid Eocene (Bortonian Stage) in New Zealand (Beu and Maxwell, 1990, p. 92). Sculpture of strong, flat commarginal ribs, grooved cardinal tooth 2a and excavated hingeplate are main diagnostic features of *Costacallista* (Keen *in* Moore, 1969, p. N677; cf. Abbott, 1974, p. 531) which is inferred to be an infaunal, moderate to deep burrowing, mobile, suspension-feeding venerid bivalve (Crampton and Moore, 1990, p. 346). The poorly preserved specimen of *Costacallista*? sp. of Crampton and Moore (1990, Fig. 81; *Callista* (*Costacallista*? sp. of Moore *et al*., 1988, p. 59, Tab. 1) from the Upper Cretaceous Maungataniwha Sandstone of western Hawke's Bay, North Island, is probably not a *Costacallista* and more definitely not conspecific with the species described here.

Fleming (1962, p. 70) considered *Costacallista* to be an element, along with *Polinices*, *Sigaretotrema* (= *Eunaticina*) and *Priscoficus*, that was derived from the north, but the inferred presence of the group in the New Zealand Cretaceous suggests alternatively that an austral origin may be more probable.

COSTACALLISTA? n. sp.

Plate 26 Figures 2, 8

Description.-Shell small for genus, moderately thin, moderately inflated, ovate; beaks prominent, located approximately a third of length of shell from anterior margin; anterodorsal margin moderately short, straight, gently dipping, merging towards moderately narrowly rounded anterior margin; posterodorsal margin long, broadly convex, slightly steeper than anterodorsal margin, merging towards well-rounded posterior margin; no escutcheon; lunule wanting, poorly developed; sculpture moderately strong, of commarginal, closely spaced riblets that become weaker and more spaced towards ventral margin, more pronounced on umbones; subsidiary, commarginal threads stronger ventrally.

Dimension.-L 3875 (from AU 2571) length 13.5, height 9.5 mm.

Figured specimen.-L 3875 (AU); TM 6874 (IGNS) may represent this species.

Material.-One, well-preserved specimen.

Locality.-Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-Costacallista? n. sp. is very similar to a New Zealand Eocene species, C. hectori (Finlay and Marwick, 1937) (p. 101, Pl. 14, Figs. 11, 12, 16; Marwick, 1938, p. 78, Pl. 10, Figs. 13, 15; Fleming, 1966, p. 187, Figs. 494-497; Beu and

Maxwell, 1990, p. 92, Pl. 3, Figs. k, l), which may indicate a lineal relationship. Costacallista n. sp., comparable in size to smaller specimens of C. hectori, can be distinguished from the latter species by having slightly more projecting umbones and stronger commarginal sculpture dorsally becoming weaker ventrally whereas rib strength remains fairly constant for C. hectori. The Recent Indo-Pacific type species of Costacallista, C. erycina (Linné, 1758) (figured by Dance, 1990, p. 266, interestingly referred by him as Callista erycina), has more prosogyrous beaks and flatter ribs compared to C. n. sp. I defer naming this probable new species at this time, as only one articulated specimen with hinge details obscurred is available to me.

Subfamily TAPETINAE H. and A. Adams, 1857

Genus CYCLORISMINA Marwick, 1927

Cyclorismina Marwick, 1927, pp. 622, 624.

Type species.-(by original designation) Cyclorismina woodsi Marwick, 1927.

Biogeographic element.-Paleoaustral as inferred here.

Discussion.-A Dosinia-like bivalve, Cyclorismina can be differentiated the former group by lacking anterior lateral teeth, having divergent anterior cardinal teeth, and deep, linguiform pallial sinus (Marwick, 1927, p. 624; cf. Keen *in* Moore, 1969, p. N683). The absence of lateral teeth in Cyclorismina precludes its placement in Dosiniinae.

Kauffman (1973, p. 374) included Cyclorismina as an endemic taxon in his New Zealand subprovince, but since his writing this group has been reported to be present also in the Campanian of

New Caledonia (Freneix, 1980, pp. 115-116) and possibly the Eocene of the Antarctic Peninsula (Zinsmeister, 1984, p. 1522). Cyclorismina may further extend into the Maastrichtian of Antarctica. These geographic range extensions for Cyclorismina suggests that it is a paleoaustral element, not an endemic New Zealand element as previously supposed. Cyclorismina is inferred to have been a suspension-feeding, long siphonate, deep burrowing, mobile bivalve (Warren and Speden, 1978, p. 50, Tab. 5; Freneix, 1981, p. 27, Fig. 3, note autecological reconstruction).

CYCLORISMINA WOODSI Marwick, 1927

Plate 26 Figures 3, 6-7, 9-17

Dosinia sp. of Woods, 1917, p. 32, Pl. 18, Fig. 1.

Cyclorismina woodsi Marwick, 1927, pp. 622, 624-625, Figs. 185-187; Marwick and Feming in Wellman, 1959, p. 139; Keen in Moore, 1969, p. N683, Figs. E148-9(a-c); ?Warren and Speden, 1978, p. 50, Tab. 5; Freneix, 1980, p. 115.

Dimensions.-Holotype TM 2563 (IGNS) length 55.5 mm, height 47.0 mm incomplete; paratype TM 2564 (IGNS) height 42.5 mm incomplete; paratype TM 2565 (IGNS) length 48.0 mm incomplete, height 47.5 mm; paratype TM 2566 (IGNS) length 40.5 mm incomplete, height 26.0 mm incomplete; paratype TM 2567 (IGNS) length 62.0 mm, height 64.0 mm, width of paired valves 41.0 mm; OU 40966 from OU 10987 length 53.0 mm, height 50.0 mm.

Types.-Holotype TM 2563 (IGNS; Marwick, 1927, p. 625, not figured); paratype TM 2564 (IGNS; Marwick, 1927, Fig. 186); paratype TM 2565 (IGNS; Woods, 1917, Pl. 18, Fig. 1); paratype TM 2566 (IGNS; Marwick, 1927, Fig. 185); TM 2567 (IGNS; Woods, 1917, Pl. 18, Fig. 2).

Figured specimens herein.-OU 40966, TM 2563-TM 2567 (IGNS).

Material.-Five specimens.

Localities.-Selwyn River below rapids, Malvern Hills, Canterbury, South Island, L35/f6008 (type); ?north-northwestern junction of Taieri Beach and Taieri Mouth Roads, East Otago, I45/f8517; ?Little Pukehiwitahi Woolshed Creek, lower Shag Valley, Otago, J43/f6471; ?Mount Pukeiwitahi, lower Shag Valley, Otago, J43/f6494; Shag Point, Otago, J43/f6472.

Stratigraphic distribution.-Selwyn Rapids Beds, Katiki Formation, ?Herbert Formation, Chaplin Sandstone of Robinson (1958, p. 16) (informal name) (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Malvern Hills, Canterbury to Taieri Mouth area, East Otago.

Discussion.-Marwick (1927, p. 624) prepared several hinges of specimens of Cyclorismina woodsi and realised after this preparation that these examples belonged to a new genus because of the absence of an anterior lateral tooth. Cyclorismina woodsi was originally referred to as Dosinia sp. of Woods (1917) who had only four, imperfect specimens to use for his study of this group. Cyclorismina momeana Freneix, 1980 (pp. 115-116, Pl. 6, Figs. 1-3) from the Campanian of New Caledonia has a greater height to length ratio and thus is more dorso-ventrally elongated, compared to C. woodsi which has a nearly 1:1 height to length ratio and a more ovate shell. A possible congener, Cyclorisma chaneyi Zinsmeister and Macellari, 1988 (p. 280, Fig.

14.5-9), from the late Maastrichtian to earliest Danian of Antarctica is smaller with a broader ventral margin compared to *C. woodsi* which is much larger with a strongly convex margin. An additional inferred congener, "*C.*" *marwicki* Zinsmeister, 1984 (p. 1522, Fig. 10A-C; also figured by Stilwell and Zinsmeister, 1992, p. 82, Pl. 8, Figs. 1-n), from Units 2-5 of the lower Tertiary La Meseta Formation (inferred to be Mid to Late Eocene) of Seymour Island, Antarctic Peninsula has a similar outline and hinge development compared to *C. woodsi*, but "*C.*" *marwicki* has a more weakly developed lunule (Zinsmeister, 1984). *Cyclorismina* cf. *C. woodsi* was noted as present by Fleming *in* Robinson (1958, p. 18) in the Upper Cretaceous Chaplin Sandstone (unpublished name), also from the Brighton-Taieri Mouth area, East Otago.

Order MYOIDA Stoliczka, 1870

Suborder MYINA Stoliczka, 1870

Superfamily MYACEA Lamarck, 1809

Family MYIDAE Lamarck, 1809

Discussion.-The only report of a New Zealand Cretaceous species of myid bivalve was made by Warren and Speden (1978, p. 50, Tab. 5) who noted *Mya* sp. in the Piripauan (upper Campanian) Okarahia Sandstone of the north face of Haumuri Bluff, southern Marlborough, South Island (O32/f9529). No material of this group is available to me to substantiate Warren and Speden's identification.

Family CORBULIDAE Lamarck, 1818

Genus *SUROBULA* Zinsmeister and Macellari, 1988

Surobula Zinsmeister and Macellari, 1988, p. 280.

Type species.-(by original designation) *Sphaerium*? *nucleus* Wilckens, 1910.

Biogeographic element.-Paleoaustral as inferred here.

Discussion.-*Surobula* was erected by Zinsmeister and Macellari (1988, p. 280) for a somewhat atypical, Maastrichtian, Antarctic corbulid group that has a nearly subtrigonal outline, a left valve that is only slightly smaller than the right, a smooth surface with a few commarginal undulations, no pallial sinus and no rostral developement. On Seymour Island, Antarctic Peninsula *Surobula*, a herein inferred suspension-feeder, is frequently encountered in small, monotypic pockets of numerous specimens and is also inferred to have been a nestling species inhabiting depressions on the sea floor surface (Zinsmeister and Macellari, 1988, p. 280).

A specimen of Maastrichtian age from Bull Point, Kaipara, Northland (Ge 7913, AIM) fits rather comfortably in *Surobula* and is the first record of this genus outside the Antarctic continent. Additional specimens may in the future indicate a conspecific relationship with the type species of *Surobula*, *S. nucleus* (Wilckens, 1910) (pp. 69-70, Pl. 3, Fig. 19), but because only one, articulated specimen is available to me a tentative assignment is made here.

SUROBULA cf. *S*. *NUCLEUS* (Wilckens, 1910)

Plate 27 Figures 1-2

cf. *Sphaerium*? *nucleus* Wilckens, 1910, pp. 69-70 (pp. 69-68, error, Zinsmeister and Macellari, 1988, p. 280).

cf. *Surobula* *nucleus* (Wilckens, 1910), Zinsmeister and Macellari, 1988, p. 280, Fig. 14.10-12.

Description.-Shell small, subtrigonal, moderately thin, well-inflated; umbones subcentral, inflated; umbonal ridge poorly developed; anterodorsal margin moderately short, moderately sloping, slightly concave, merging with somewhat narrowly rounded anterior margin; posterodorsal margin slightly longer than anterodorsal margin, moderately sloping as in anterodorsal margin, gently convex, merging with very bluntly, slightly obliquely truncated posterior margin; posterior and ventral margins meet at slight angulation; ventral margin very broadly rounded; shell surface mostly smooth, except for broad, commarginal undulations, more prominent ventrally, and closely spaced, commarginal threads.

Dimensions.-Ge 7913 (AIM) length 8.5 mm, height 6.5 mm, width of paired valves 6.0 mm.

Figured specimen.-Ge 7913 (AIM).

Material.-One well-preserved, articulated specimen.

Locality.-Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland and perhaps Seymour Island, Antarctic Peninsula.

Discussion.-Specimen Ge 7913 (AIM) agrees fairly well with figured specimens of *Surobula nucleus* (Wilckens, 1910), except that the Kaipara specimen has apparently more subdued commarginal undulations dorsally, a poorly developed umbonal ridge, a slightly broader ventral margin, and a vague obliquely truncated posterior margin. This disparity in morphological features between the New Zealand specimen and Antarctic specimens may reflect intraspecific variation within *S*. *nucleus* or may form the basis for separating the two groups. No mention of an umbonal ridge in *S*. *nucleus* was made by Zinsmeister and Macellari (1988). More material is needed to refine the relationship between *S*. *nucleus* and the Northland species, provisionally assigned to *S*. cf. *S*. *nucleus*. Numerous, poorly preserved corbulid specimens were noted and collected by the author recently in the Maastrichtian Katiki Formation of Shag Point, Otago, South Island (J43/f159, J43/f159A) and may represent this species. These specimens at Shag Point were also noted as being present in pockets of monotypic concentrations, similar to nestling habits of Recent *Corbula* and Cretaceous *Surobula* of Antarctica. A decorticated specimen (from AU 2574) of uncertain affinity, possibly a corbulid bivalve, was collected also from the same locality as *S*. cf. *S*. *nucleus* specimen Ge 7913 (AIM), but the former specimen has a poorly to moderately developed rostrum, compared to Ge 7913 which lacks a rostrum altogether. Specimen Ge 7714 (AIM; see Plate 27 Figures 3-4 herein) from Batley, Kaipara, probably a corbulid, is most likely not congeneric with *S*. cf. *S*. *nucleus* as it has a strong umbonal ridge. Crampton and Moore (1990, p. 346) reported the presence of Corbulidae in the Upper Cretaceous Maungataniwha Sandstone, but no further genus-level subdivision was given.

Superfamily HIATELLACEA Gray, 1824

Family HIATELLIDAE Gray, 1824

Genus *CYRTODARIA* Reuss, 1801

Cyrtodaria Reuss, 1801, p. 351.

Type species.-(by subsequent designation, Vokes and Cox, 1961) *Mya siliqua* Spengler, 1793.

Synonyms.-*Cyrtodera* de Blainville, 1825; *Glycimeris* Lamarck, 1801 (non Lamarck, 1799) (Keen *in* Moore, 1969, p. N700).

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-The placement of a number of small, smooth, oblong, subtrapezoidal to subovate, compressed, fossil bivalves from inferred Maastrichtian rocks of Northland is at best problematic, but careful study suggests to me that these specimens are early representatives of the hiatellid genus *Cyrtodaria* Reuss, 1801, which is characterised by its variably elongate compressed subtrapezoidal to subquadrate outline, insignificant anteriorly placed umbones, developed nymph, edentulous hinge or with two central teeth, variable commarginal ornamentation, and small and irregular pallial sinus. Several galeommatacean groups also have representative species with a similar outline compared to the New Zealand species, such as *Erycina*, *Lepton*, *Paraborniola*, and others, but an assignment to *Cyrtodaria* seems much more likely in light of its apparent affinity with the coeval species *C*.? *minuta* Speden, 1970 (pp. 139-140, Pl. 35, Figs. 4-11), from the Maastrichtian of the Fox Hill Formation, South Dakota, North America. Without hinge details, the exact placement of these articulated specimens from Northland is difficult. No other New Zealand, Late Cretaceous bivalve group approaches *Cyrtodaria* n. sp. in outline. If truly *Cyrtodaria*, these specimens represent the oldest or one of the oldest records of the genus, which previously was known from the Paleocene to Recent of Europe and the Arctic (Keen _in_ Moore, 1969, p. N700), apart from the tentative record in the Maastrichtian of South Dakota.

CYRTODARIA n. sp.

Plate 27 Figures 5-6, 8

Description.-Shell small, thin, compressed, oblong, subquadrate, subtrapezoidal to subovate; umbones somewhat inflated, bordered anteriorly and posteriorly by poorly developed ridges; beaks small, moderately prosogyrous, located approximately a third of the length of shell from anterior margin; anterodorsal margin moderately short, steep, gently convex, merging with narrowly rounded anterior margin; posterodorsal margin long, broadly convex, merging with blunt, broadly convex, obliquely truncated posterior margin; ventral margin very broad, nearly straight, except for a very slight medial concavity; shell mostly smooth, polished at umbones, except for raised, closely spaced commarginal threads, and well-spaced commarginal undulations; internal features unkwown.

Dimensions.-Ge 8090 (AIM) length 10.0 mm, height 6.0 mm; L 3873 (from AU 2553) length 11.5 mm, height 7.0 mm.

Figured specimens.-Ge 8090 (AIM), L 3873 (AU).

Material.-Six specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626, Q08/f143; Te Opu, Kaipara Harbour, Q08/f9639.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-The external morphology of Cyrtodaria n. sp. from Kaipara is strikingly similar to C.? minuta Speden, 1970, mentioned above, and differs from the South Dakota species in having more pronounced umbones, a less expanded posterior end and a stronger posterior umbonal ridge. The cold-water type species, C. siliqua (Spengler, 1793) (Keen in Moore, 1969, p. N700, Fig. 10a-b; Abbott, 1974, p. 541, Fig. 6023) from the Recent of the North Atlantic, is more elongate-ovate with insignificant umbones and a rounded posterior end, compared to C. n. sp. which is subtrapezoidal with more developed umbones and a slightly obliquely truncated posterior end. The outline of C n. sp. is also superficially similar to the Recent North Carolina, North American species Erycina emmonsi, Dall, 1899 (figured in Abbott, 1974, p. 468, Fig. 5403), and E. periscopiana Dall, 1899 (ibid, Fig. 5404). The umbones of Cyrtodaria n. sp. have an overall shape reminiscent of the Recent New Zealand montacutid bivalve Scintillona benthicola Dell, 1956 (pp. 31-32, Fig. 40; also figured by redescribed and refigured by Powell, 1979, p. 393, Fig. 100-6), but the C n. sp. has a larger, narrower shell with a broader ventral margin. Details of the hinge and pallial line of C. n. sp. when they become available should further tighten the assignment of the Kaipara species to this genus.

Genus Panopea Ménard de la Groye, 1807

Panopea Ménard de la Groye, 1807, p. 187.

Type species.-(by subsequent designation, Children, 1823) Panopea aldrovandi Ménard de la Groye, 1807 (= Mya glycimeris Born, 1778) (I. C. Z. N. Opinion 1414, 1986) (Darragh and Kendrick, 1991, p.

88).

Synonyms.-Glycimeris Lamarck, 1799 (**non** da Costa, 1778); Panope Ménard, 1807; Panodea Oken, 1817; Panopaea Lamarck, 1818; Myopsis Agassiz, 1840; Heteromya Mayer, 1884 (Keen in Moore, 1969, p. N701.

Biogeographic element.-Indo-Pacific/Tethyan (cf. Kauffman, 1973, p. 372).

Discussion.-Panopea was widespread around the rim of the southern circum-Pacific during the Late Cretaceous. This group has been reported in Campanian rocks of New Caledonia (Freneix, 1960, 1980, 1981); upper Campanian to Maastrichtian strata of New Zealand (Woods, 1917; Wilckens, 1920a; Marwick and Fleming in Wellman, 1959; Warren and Speden, 1978; Crampton and Moore, 1990; Stilwell in Aitchison et al., 1993); Upper Cretaceous Kahuitara Tuff of Chatham Islands (Campbell et al., 1993); Campanian to Maastrichtian rocks of the Antarctic Peninsula, including Seymour and Snow Hill islands (Wilckens, 1910; Medina et al., 1981; Zinsmeister and Macellari, 1988), Vega and James Ross islands (del Valle et al., 1982), Humps Island (Stilwell and Zinsmeister, 1987c), Cockburn Island (Stilwell and Zinsmeister, 1987a); and southern South America, including Patagonia (Wilckens, 1904, 1905; von Ihering, 1914; Stinnesbeck, 1986; Riccardi, 1988).

Panopea specimens have been collected from nearly 40 Late Cretaceous localities in New Zealand and Chatham Islands. Localities with inferred Panopea of uncertain species-level affinities are listed below: ?east wing of Haumuri Bluff, southern Marlborough, South Island, O32/f9032; ?ridge above Jedburgh Station, Cheviot, South Island, O33/f9044; ?east bank of

Te Hoe River, western Hawke's Bay, North Island, V19/f184; west bank of Te Hoe River, V19/f186; ?Te Hoe River, V19/f129; and ?Bull Point, Kaipara, Northland, Q08/f9626.

PANOPEA CLAUSA Wilckens, 1910

Plate 27 Figures 7, 9-14

Panopaea? (*Pleuromya*?) *clausa* Wilckens, 1910, pp. 68-69, Pl. 3, Fig. 10a-b (Woods, 1917, p. 33, *Panopea* (sic.), error; Zinsmeister and Macellari, 1988, p. 280, *Panopea* (sic.), error).

Panopea clausa Wilckens, Woods, 1917, p. 33, Pl. 18, Figs. 6a-c, 7; Marwick and Fleming *in* Wellman, 1959, p. 139; Fleming *in* Wellman, 1959, p. 141; Freneix, 1960, pp. 43-44, Pl. 3, Fig. 6 (Zinsmeister and Macellari, 1988, p. 343 (sic.), error); Pérez and Reyes, 1978, pp. 16, 28, Tab. 2b; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 26-13; del Valle *et al*., 1982, p. 278, Tab. 30.3; Stilwell and Zinsmeister, 1987a, p. 9; Zinsmeister and Macellari, 1988, p. 280, Fig. 16.1-3; Stilwell *in* Aitchison *et al*., 1993, p. 52.

Panopaea clausa Wilckens, Wilckens, 1920a, p. 262; Medina *et al*., 1981, p. 170.

Panope (*Panope*) *clausa* (Wilckens), Freneix, 1980, p. 117.

Supplementary description.-See Zinsmeister and Macellari (1988, pp. 280-282).

Dimensions.-OU 40967 (from OU 11128) length 57.5 mm, height 42.5 mm, width of paired valves 31.5 mm; OU 40968 (from OU 11128) length 47.0 mm, height 31.0 mm, width of paired valves 18.5 mm; Ge 7892 (AIM) length 59.0 mm, height 32.0 mm, width of paired valves 23.0 mm.

Type and previously figured specimens.-Lectotype, Mo 1608 (designated by Zinsmeister and Macellari, 1988, p. 282); TM 2581 (IGNS; Woods, 1917, Pl. 18, Fig. 6); TM 2582 (IGNS; Woods, 1917, Pl. 18, Fig. 7; Warren and Speden, 1978, Fig. 26-13).

Figured specimens herein.-TM 2581-2582 (IGNS), Ge 7892 (AIM), OU 40967-40968.

Material.-Nine specimens.

Localities.-East wing of Haumuri Bluff, southern Marlborough, South Island, O32/f9025, O32/f9026, O32/f9027; near bend of "Matsumotu" Stream, southern Marlborough, O32/f8787; Haumuri Bluff, O32/f9035, O32/f9504, O32/f9028; north face of Haumuri Bluff, O32/f9530, O32/f9529; west wing of Haumuri Bluff, O32/f8025; North Branch of the Waianakarua River, Otago, South Island, J42/f218; Shag Point, Otago, J43/f6544; tributary of Mikonui Stream, southern Marlborough, O32/f8788; ?branch of Waikokopu Stream, western Hawke's Bay, North Island, W18/f27; ?Batley, Kaipara Harbour, Northland, Q08/f9023; Bull Point, Kaipara, Q08/f9626.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); ?Conway Formation, Katiki Formation, unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous); ?Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Northland to Otago, South Island, New Zealand; New Caledonia; Vega, James Ross, Seymour, and Humps islands, Antarctic Peninsula; ?Chubut, Argentina, southern South America; ?northwestern Australia.

Distribution.-Panopea clausa Wilckens is one of the most widespread, Austral bivalve species with known records from New Caledonia, New Zealand, several islands within the James Ross Island group of Antarctica, possibly Argentina and perhaps northwestern Australia. The type locality of P. clausa is Swedish South Polar Expedition Locaion 8, Seymour Island, Antarctic Peninsula. Recently, Zinsmeister and Macellari (1988, pp. 280-282, Pl. 16.1-3) redescribed P. clausa and provided evidence for a possible genus-level separation for this species. Further synonymies, not given by Zinsmeister and Macellari (1988), are presented above. Zinsmeister and Macellari noted that Seymour Island specimens of P. clausa have a well-developed, central, blade-like cardinal tooth in the left valve which is very much different from typical Panopea. Unfortunately, no specimens with hinges were figured by them. Indeed, most Panopea specimens occur as paired valves as this group has a deep-burrowing habit. No New Zealand specimens of P. clausa are known to me with the hinge exposed. A specimen from Bull Point, Kaipara, Northland (Ge 7892, AIM), referred here to P. clausa, has an elongated posterior end, compared to most specimens of the species, but this is most likely intraspecific variation. Specimen Ge 7892 is reminiscent of a Maastrichtian species, P. stenopleura Darragh and Kendrick, 1991 (pp. 88-91, Fig. 25A-F), from the Miria Formation of northwestern Australia, but appears slightly more elongated posteriorly and more compressed posteriorly. Darragh and Kendrick commented in the diagnosis and and remarks section of their paper that P. stenopleura can be separated from P. clausa by the former having a consistent greater length relative to height ratio and a compressed posterior end. However, Darragh and Kendrick did mention that Haumuri Bluff specimens available to them revealed variation with respect to length to height ratio. Some specimens of P. clausa appear to have less compressed posterior ends than others depending on degree of post-mortem closure of both valves (e. g. ventral margins of both valves touching or not touching with sediment infilling). As an example, the specimen in Fig. 16-2 of Zinsmeister and Macellari (1988) (depicting an articulated specimen of P. clausa with sediment infilling, dorsal view) would be virtually indistinguishable from Fig. 25-D of Darragh and Kendrick (1991) (depicting an articulated specimen of P. stenopleura with both valves touching) if the specimen in Fig. 16-2 had both valves touching. One should bear this mind when using features such as posterior compression as a critical feature separating species, especially in groups such as Panopea that are generally preserved with articulated valves. This observation was not commented on by Darragh and Kendrick. The variability of length to height ratio and posterior compression of P. clausa, bearing in mind the observation above, in my opinion, weakens Darragh and Kendrick's case for separating P. stenopleura from P. clausa. Although these two groups may, indeed, be distinct, more critical information is needed to differentiate these two species which appear to be conspecific, based on my criteria. As a result of this work, the New Zealand distribution of P. clausa has been extended to include Northland and Otago, South Island.

PANOPEA MALVERNENSIS Woods, 1917

Plate 27 Figures 15-17; Plate 28 Figures 1-3, 5

Panopea malvernensis Woods, 1917, p. 33, Pl. 18, Figs. 8a-b, 9, Pl. 19, Figs. 1a-b, 2; Marwick and Fleming in Wellman, 1959, p. 139; Freneix, 1960, p. 43, Pl. 3, Figs. 4-5; Crampton and Moore, 1990, p. 346; Campbell et al., 1993, Tab. 4.3.

Panope (Panope) malvernensis (Woods, 1917), Freneix, 1980, pp. 116-117; Freneix, 1981, p. 27, Fig. 3.

Supplementary description.-Shell large, moderately thin, subrectangular to subovate, elongated, inflated; umbones only slightly projecting, broad, subcentral, more anterior, orthogyrous; anterior gape slight; posterior gape moderate; anterodorsal margin moderately long, mostly straight, merging towards moderately broad, rounded anterior margin; posterodorsal margin long, gently sloping, merging with more narrowly rounded posterior margin; dorsal and ventral margins declivous; ventral margin very broad, nearly straight, except for slight medial concavity, located subcentrally on posterior portion of ventral margin; sculpture of irregularly spaced, broad, low, undulating ribs, that parallel slight concavity along ventral margin; hinge plate moderately broad with a single, moderately small, slightly oblique, cardinal tooth; chrondrophore strongly buttressed, prominent, elongated, slightly curved, tapering posteriorly; anterior adductor scar large, subtrigonally ovate; posterior adductor scar smaller than anterior adductor, subcircular; pallial line entire, pallial sinus deep, extending to a point below umbo; inner margins smooth.

Dimensions.-OU 40969 length 102.0 mm, height 52.0 mm, width of paired valves 36.0 mm; OU 40970 length 66.0 mm incomplete, height 50.0 mm, width of paired valves 35.0 mm; TM 7510 (IGNS) length 76.5 mm, height 46.5 mm, width of paired valves 34.0 mm; TM 7511 (IGNS) length of hinge 31.5 mm.

Type and previously figured specimens.-Lectotype TM 2585 (herein designated) (IGNS; Woods, 1917, Pl. 18, Fig. 9); TM 2584 (IGNS; Woods, 1917, Pl. 18, Fig. 8); TM 2586 (IGNS; Woods, 1917, Pl. 19, Fig. 2); TM 2587 (IGNS; Woods, 1917, Pl. 19, Fig. 1).

Figured specimens.- OU 40969, OU 40970, TM 7510 (IGNS), TM 2536, TM 2584-2585 (IGNS), TM 2587 (IGNS).

Material.-Six specimens.

Localities.-Selwyn Rapids Beds, Malvern Hills, Canterbury, South Island, L35/f6017, L35/f6510; oyster beds south of Selwyn River, L35/f6007; Selwyn River below rapids, L35/f6008; shellbed cropiing out on ridge near water tanks, Malvern Hills, L35/f6511; Okarahui Stream, southern Marlborough, South Island, O32/f8790; ?Little Pukeiwitahi Woolshed Creek, lower Shag Valley, Otago, South Island, J43/f6471; Mount Pukeiwitahi, J43/f6494; Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6909; eastern side of Pitt Island, Chatham Islands, CH/f11; southwestern side of neck of Taruwhenua Peninsula, Pitt Island, CH/f257A; Rockyside, Whenuatara (= Taruwhenua) Peninsula, west of Flowerpot Bay, Pitt Island, CH/f345; northern Pitt Island, CH/f466; western side of base of Taruwhenua Peninsula, Pitt Island, CH/f587.

Stratigraphic range.-?Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds, Herbert Formation? (Haumurian Stage, Maastrichtian, uppermost

Cretaceous); Maungataniwha Sandstone, Kahuitara Tuff (Upper Cretaceous).

Geographic distribution.-Western Hawke's Bay, North Island to eastern Otago, South Island; New Caledonia; Chatham Islands.

Discussion.-*Panopea malvernensis* is widespread along the eastern sector of the Weddellian Province from New Caledonia (Campanian), New Zealand (late Campanian? to Maastrichtian) to Chatham Islands (late Campanian to Maastrichtian). Von Haast (1871, p. 10) noted the presence of *Panopea* in Cretaceous rocks of Malvern Hills, Canterbury. There appears to be little doubt that this then undescribed species of *Panopea*, noted by von Haast, would refer to *P*. *malvernensis* Woods, 1917. *Panopea malvernensis* seems most closely related to a Late Campanian to Maastrichtian *Panopea* species, *P*. *thomasi* von Ihering, 1914 (pp. 63-64, Pl. 2, Fig. 8a-b; Feruglio, 1936, p. 200, Pl. 21, Figs. 10 (especially), 11), described in his catalogue of Cretaceous and Tertiary Mollusca from Argentina. *Panopea thomasi*, from Rio Chico, Chubut, Argentina, is strikingly similar, especially in outline, to *P*. *malvernensis*, except that the New Zealand species has a smoother smoother shell unlike the apparent pronounced commarginal undulations of *P*. *thomasi*. The hinge of *P*. *malvernensis*, unknown to Woods (1917), is moderately robust with a moderately small, slightly oblique cardinal tooth and well-developed, robust, buttressed chondrophore that tapers posteriorly.

Suborder PHOLADINA H. and A. Adams, 1858

Superfamily PHOLADACEA Lamarck, 1809

Family PHOLADIDAE Lamarck, 1809

Discussion.-Before this report only one species of pholadid bivalve had been described from Upper Cretaceous sediments of New Zealand, the rare and exquisitely preserved *Pholadidea* (*Hatasia*) *wiffenae* Crampton, 1990, (Martesiinae) collected from in a single locality in northwestern Hawke's Bay. An additional new species has come to light from Maastrichtian rocks of the Birch Hollow area, Waipara. This species is here referred to *Clavipholas birchhollowensis* n. sp. and represents the only known Late Cretaceous record of this genus outside North America.

Subfamily PHOLADINAE Lamarck, 1809

Genus *CLAVIPHOLAS* Conrad, 1868

Clavipholas Conrad, 1868, p. 728.

Type species.-(by monotypy) *Pholas cithara* Morton, 1834 (see Griffin, 1991, pp. 139-140, for discussion), as opposed to *Pholas pectorosa* Conrad, 1852? (by original designation) (refer to Turner *in* Moore, 1969, p. N708; according to Kelly, 1988, p. 366, Conrad, 1853).

Biogeographic element.-Indo-Pacific/Tethyan as inferred here. Kauffman (1973, p. 368) referred *Clavipholas* to his North American subprovince-province.

Discussion.-*Clavipholas* is described from the New Zealand Cretaceous fossil record for the first time. Previously reported from the Campanian to latest Maastrichtian of North America (cf. Turner *in* Moore, 1969, p. N708; cf. Kelly, 1988, p. 366) and a possible sole Tertiary occurrence in the Eocene of Argentina (Griffin, 1991), the presence of *Clavipholas* in the Maastrichtian of New Zealand greatly extends the geographic range of the group into the Gondwana Realm.

<u>CLAVIPHOLAS</u> <u>BIRCHHOLLOWENSIS</u> n. sp.

Plate 28 Figure 4

<u>Diagnosis</u>.-Subrectangular to subclavate, moderately large <u>Clavipholas</u> with moderately reduced, elongated, posterior end and moderately developed postumbonal groove; ventral margin broadly convex; commarginal sculpture of closely spaced ribs, stronger on anterior portion of shell as with radial sculpture; differs from <u>C</u>. <u>pholadoides</u> (Wilckens, 1905) in having a less elongated posterior end, less developed postumbonal groove and more numerous commarginal and radial ribs with more abundant nodes.

<u>Description</u>.-Shell moderately large, inequilateral, subrectangular to subclavate, moderately inflated; umbo declivous, broad, inflated, subcentral, very slightly prosogyrous; postumbonal groove moderately developed, fairly wide, located just posterior to midpoint of shell along ventral margin; anterodorsal margin moderately to steeply sloping, moderately long, convex, merging towards well-rounded anterior margin; posterodorsal margin long, mostly straight, moderately sloping, merging with narrowly rounded to bluntly subangular, reduced, posterior margin; ventral margin very broad, slightly convex; commarginal ornamentation of close, equally spaced, strong, raised, complete, subrounded ribs that become sharp on the anterior slope of shell, especially near ventral margin; radial sculpture of small nodes, diverging from umbones and strong, spaced, divergent ribs, more pronounced along anterior margin; nodes more closely spaced along postumbonal groove; hinge, accessory plate, apophysis unknown.

Dimensions.-Holotype TM 7512 (IGNS) length 33.0 mm, height 17.0 mm.

Type.-Holotype TM 7512 (IGNS).

Type locality.-Upstream side of large meander in Birch Stream (Hollow), Waipara, South Island, M34/f7896.

Figured specimen.-TM 7512 (IGNS).

Material.-One specimen, moderately well-preserved.

Stratigraphic range.-Waipara Greensand? (Haumurian Stage, Maastrichtian, uppermost Cretaceous), associated with Haumurian microfauna.

Geographic distribution.-Waipara, South Island.

Discussion.-*Clavipholas birchhollowensis* n. sp., the only known member of this group in New Zealand, seems most closely related to *Pholadomya pholadoides* Wilckens, 1905 (p. 50, Pl. 10, Fig. 4; redescribed and age reassessed by Griffin, 1991, pp. 138-140, Fig. 9.1-9.6, as *Clavipholas*? *pholadoides* from the Eocene of Argentina, not Late Cretaceous as previously supposed). The type of *Clavipholas*? *pholadoides*, supposedly unique from Upper Cretaceous sediments of Cerro Cazador, Santa Cruz, is presumed to be lost and a search for more specimens at the same stratigraphic horizon of the type specimen ended without new material being collected of this species; other references to this species are from near Rìo Turbio and Atlantic coast of southern Santa Cruz in Tertiary sediments indicating that Wilckens' locality description was incorrect (Griffin, 1991, p. 139). Griffin treated the South American species as tentatively referable to *Clavipholas*, *C*.? *pholadoides*, but there seems little doubt that his assignment was correct because this species fits very comfortably in the presupposed solely Late Cretaceous pholadid *Clavipholas*. The main differences separating *C. birchhollowensis* n. sp. from *C. pholadoides* are less elongated posterior end, weaker postumbonal groove and more numerous commarginal and radial ribs (and hence, more numerous nodes) in the former New Zealand species compared to *C. pholadoides*. *Clavipholas birchhollowensis* n. sp. was probably a borer in semiconsolidated sediments similar to a life habit inferred by Griffin (1991, p. 140) for *C. pholadoides*.

Subfamily MARTESIINAE Grant and Gale, 1931

Genus *PHOLADIDEA* Turton, 1819

Pholadidea Turton, 1819, p. 147.

Type species.-(by original designation) *Pholadidea loscombiana* Turton, 1819.

Subgenus *HATASIA* Gray, 1851

Hatasia Gray, 1851, p. 385.

Type species.-(by subsequent designation, Stoliczka, 1871) *Pholas melanura* Sowerby, 1834.

Synonyms.-*Hatoisia* Schaufuss, 1869; *Hastasia* Paetel, 1875 (Turner *in* Moore, 1969, p. N716).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-*Pholadidea* (*Hatasia*) *wiffenae* Crampton, 1990, represents the oldest known member of the genus and subgenus in the fossil record and material of this species is amongst the most exquisitely preserved from the New Zealand Cretaceous marine record. All specimens of *P.* (*H.*) *wiffenae* are derived from a single float concretion in Mangahouanga Stream, northwestern Hawke's Bay, North Island (Upper Cretaceous Maungataniwha

Sandstone). A wood-boring bivalve, *P*. (*H*.) *wiffenae* may possibly represent an intermediate form between *Opertochasma*, a Cretaceous pholadid group, and *Pholadidea* and *Martesia*, early Tertiary genera (Crampton, 1990, p. 985).

PHOLADIDEA (*HATASIA*) *WIFFENAE* Crampton, 1990

Plate 28 Figures 6-9; Plate 29 Figures 1-7; Plate 30 Figures 1-4

Pholadidea (*Hatasia*) *wiffenae* Crampton, 1990, pp. 985-990, Pls. 1-3, Text-figs. 3-4.

Description.-See Crampton (1990, pp. 985-990) for detailed description.

Types.-Holotype TM 6942 (IGNS; Crampton, 1988, Pl. 1, Figs. 1-4, Pl. 3, Fig. 6); paratypes TM 6938-6941, TM 6943-6953.

Type locality.-Mangahouanga Stream, northwestern Hawke's Bay, North Island, V19/f6909a (float concretion).

Figured specimens.-TM 6942, TM 6951, TM 6941.

Stratigraphic range.-Maungataniwha Sandstone (Upper Cretaceous), horizon unknown, either upper Campanian or Maastrichtian.

Geographic distribution.-Northwestern Hawke's Bay, North Island.

Discussion.-Crampton (1990, p. 990) noted a gross similarity in morphology and life habit to the Maastrichtian Chilean species, *Martesia leali* Stinnesbeck, 1986 (pp. 185-186, Pl. 5, Fig. 9), but incomplete knowledge of accessory plates prevented detailed comparison of many subcoeval Austral species with *Pholadidea* (*Hatasia*) *wiffenae*.

Family TEREDINIDAE Rafinesque, 1815

Subfamily TEREDININAE Rafinesque, 1815

Discussion.-Teredinid bivalves have been reported from the north face of Haumuri Bluff, southern Marlborough, South Island in the Maastrichtian Claverley Sandstone by Warren and Speden (1978, p. 50, Tab. 5, "clavagellid bivalve (= Teredo sp.)") and from the Te Hoe River area, western Hawke's Bay, North Island in the Upper Cretaceous Maungataniwha Sandstone (Crampton and Moore, 1990, p. 346).

Subclass ANOMALODESMATA Dall, 1889

Order PHOLADOMYOIDA Newell, 1965

Superfamily EDMONDIACEA King, 1850

Family PHOLADOMYIDAE Gray, 1847

Discussion.-Maxwell in Feldmann (1984, p. 383) recorded a possible member of this family, ?Pholadomya sp. (could be Clavipholas, P. A. Maxwell, pers. commun., 1993), in inferred Campanian to Maastrichtian sediments cropping out along the Jed River, Cheviot, South Island (O33/f8171), associated with bivalves ?Protocardia and ?Tancredia, gastropod ?Biplica, corals, ammonites, chordates, and the decapod Haumuriaegla glaessneri Feldmann. Maxwell stated that most of these fossils are preserved as phosphatised steinkerns and are difficult to identify.

Superfamily PANDORACEA Rafinesque, 1815

Family THRACIIDAE Stoliczka, 1870

Genus THRACIA Leach in Blainville, 1824

Thracia Leach in Blainville, 1824, p. 347 (Keen in Moore (1969, p. N850) attributed this genus to Sowerby, 1823, but as indicated by Vaught (1989, p. 139) Thracia Leach in Sowerby, 1823 is **nom. nud.**).

Type species.-(by subsequent designation, Anton, 1839) "Thracia pubescens Lamarck" (= Mya pubescens Pulteney, 1799).

Synonyms.-Numerous, possibly Eximiothracia Iredale, 1924 (Keen in Moore, 1969, p. N850; Vaught, 1989, p. 140).

Biogeographic element.-Cosmopolitan, as interpreted here.

Discussion.-Thracia was a fairly common element in the Late Cretaceous bivalve fauna of the Gondwana Realm with records from New Zealand (Woods, 1917; this work); Vega Island (del Valle, 1980), Humps Island (Stilwell and Zinsmeister, 1987c), Seymour Island (Zinsmeister and Macellari, 1988), Antarctic Peninsula; and southern Patagonia (Wilckens, 1905). In accordance with Keen in Moore (1969, p. N850) and Vaught (1989, p. 140), Eximiothracia may be treated as a synonym of Thracia, as Recent species formerly assigned to Eximiothracia (refer to Macpherson and Gabriel, 1962, for Australian examples) appear to fall within the the variability of Thrasia s. s. However, outline and sculptural differences of the type of Eximiothracia, E. speciosa (Angus, 1869) (refer to drawing, albeit poor, by Macpherson and Gabriel, 1962, p. 397, Fig. 465), compared to Thracia s. s. may indicate alternatively that Eximiothracia should be considered distinctive at least at the subgenus-level (P. A. Maxwell, personal commun., 1992).

THRACIA HAASTI Woods, 1917

Plate 30 Figures 5, 8-10, 13-14

Thracia haasti Woods, 1917, p. 34, Pl. 19, Figs. 3a-c, Figs. 4a-b; Wilckens, 1920a, p. 263; del Valle and Medina, 1980, p. 55; Zinsmeister and Macellari, 1988, p. 282.

Eximiothracia haasti (Woods, 1917), Finlay, 1926b, p. 474.

Eximiothracia (?) haasti (Woods), Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 26-14.

Dimensions.-Ge 7677 (AIM) length 4.5 mm, height 3.0 mm.

Type and previously figured specimen.-Holotype TM 2580 (IGNS; Woods, 1917, Pl. 19, Fig. 3; Warren and Speden, 1978, Fig. 26-14); TM 2579 (IGNS; Woods, 1917, Pl. 19, Fig. 4).

Figured specimens herein.-TM 2579-TM 2580 (IGNS); Ge 7677 (AIM).

Localities.-West wing of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 (type); ?east wing of Haumuri Bluff, O32/f9032; ?shellbed cropping out on ridge near water tanks, Malvern Hills, Canterbury, South Island, L35/f6511; ?Middle Waipara, Canterbury, M34/f7263; ?Te Hoe River, western Hawke's Bay, North Island, V19/f129; ?Gittos Point, Kaipara Harbour, Northland, Q09/f9502; Te Opu, Kaipara, Northland, Q08/f9639.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); ?Conway Formation, ?Selwyn Rapids Beds, ?Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous); ?Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Possibly Northland to Canterbury, South Island.

Discussion.-Finlay (1926b, p. 474) believed that Thracia haasti Woods, 1917, and Thracia sp. of Woods, 1917, should be reassigned to Eximiothracia, but presented no morphological evidence for this reallocation. In outline and sculpture Thracia haasti appears to be strikingly similar to typical Thracia; in my opinion the reassignment of T. haasti to Eximiothracia by Finlay

(1926b) appears unwarranted. An older Cretaceous species referred by Woods (1917, p. 11, Pl. 5, Fig. 1) as *Thracia* sp. differs from *T. haasti* in having broader ventral margin, a more bluntly truncated posterior end and weaker umbonal ridge. A specimen from inferred Maastrichtian rocks of Te Opu, Kaipara, Northland (Ge 7677; AIM) appears to be a juvenile of *T. haasti*. Two further specimens from Bull Point, Kaipara (Ge 7641, AIM and L 3876 from AU 2574) may be congeners, but the commarginal sculpture, mostly decorticated, is much coarser compared to *Thracia* s. s. (Another more probable assignment is the mactrid *Raeta* Gray, 1853). Specimen L 3876 has the truncated posterior end and umbonal ridge as in typical *Thracia*, but the sculpture appears atypical of the group. Although there is little doubt that these specimens represent a new group, more material is needed for an accurate assessment. Zinsmeister and Macellari (1988, p. 282) compared *T. haasti* with their newly erected species *T. askinae* (p. 282, Fig. 16.4) from the Campanian? to Maastrichtian of Vega Island and Seymour Island, Antarctic Peninsula, and *T. lenticularis* (Wilckens, 1905) (pp. 50-51, Pl. 8, Fig. 9) from southern Patagonia, citing differences in shell outline and valve compression. The distribution of *Thracia askinae* most likely extends to Humps Island, where Stilwell and Zinsmeister (1987c, p. 9) reported the presence of *Thracia* in Campanian calcareous siltstone concretions, associated with numerous ammonites, nautiloids, belemnites, other molluscs and invertebrate groups. *Thracia haasti* is inferred to have been an infaunal, siphonate, suspension feeder of high mobility (Warren and Speden, 1978, p. 50, Tab. 5; Crampton and Moore, 1990, p.

346).

Superfamily POROMYACEA Dall, 1886

Family CUSPIDARIIDAE Dall, 1886

Genus CUSPIDARIA Nardo, 1840

Cuspidaria Nardo, 1840, p. 202.

Type species.-(by monotypy) Cuspidaria typus (= Tellina cuspidata Olivi, 1792).

Synonym.-Neaera Griffith, 1834, non Robineau-Desvoidy, 1830 (Abbott, 1974, p. 564).

Biogeographic element.-Cosmopolitan, as inferred here; included in the Euramerican region by Kauffman, 1973 (p. 368).

Discussion.-Cuspidaria Nardo is reported from the New Zealand Cretaceous for the first time. External features of Cuspidaria include feeble sculpture (but sculpture in Cuspidaria species can be quite variable) and a small, inequivalve shell that is globose in front and strongly rostrate posteriorly (Keen in Moore, 1969, p. N854; Abbott, 1974, p. 564). Typically, Cuspidaria species are greatly inflated anteriorly and the posterior rostrum which is compressed is demarcated in a narrow interval by an abruptly declivous or otherwise very rapidly descending flank. Cuspidaria surocretacica n. sp. from the New Zealand Cretaceous is no exception and is typical of the group.

Cuspidaria is reported from Upper Cretaceous rocks to Recent of Europe, North America (Keen in Moore, 1969, p. N854) and now from New Zealand. The group is also present in the Late Paleocene of southeastern Australia (T. Darragh, personal commun., 1991). Cuspidaria is known to have migrated as early as

Early Eocene to the Tethyan Belt (Paris Basin) (Piccoli et al. 1986, Tab. 1). Maxwell (1988b, p. 25) reported the presence of Cuspidariidae in the "Wangaloan" (Early Paleocene) of New Zealand, but this has not been confirmed by the author's present work and is probably based mistakenly on the much younger C. sp. from Castle Hill Shaft. The oldest Cenozoic Cuspidaria taxa from New Zealand are undescribed species from Castle Hill Shaft (see Finlay and Marwick, 1937, p. 104, Pl. 14, Fig. 13) and the Kauru Formation which are undated, but believed to be Porangan? (mid Eocene) or older. The undescribed Cuspidaria sp. from the Kauru Formation is interpreted to have lived in a relatively shallow marine environment in contrast to most late Mesozoic to Cenozoic records of Cuspidariidae which are mostly bathyl. Cuspidaria surocretacica n. sp. is interpreted to have lived in a middle to outer shelf environment.

CUSPIDARIA SUROCRETACICA n. sp.

Plate 30 Figures 6-7

Diagnosis.-Subtrigonally ovate shell, greatly inflated anteriorly with pronounced rostrum; rostrum clearly demarcated by rapidly descending posterior flank; umbones located subcentrally, strongly opisthogyrate; anterodorsal margin steep, strongly convex; ventral margin strongly convex; sculpture moderately coarse of spaced, moderately wide, commarginal ribs; differs from Cuspidaria undulata (Sowerby) in being much smaller with more poorly developed commarginal sculpture and more rounded umbones.

Description.-Shell small, thin, greatly inflated medially, compressed posteriorly, subtrigonally subovate, strongly rostrate; height to width of paired valves ratio 1:1; rostrum demarcated clearly by rapidly descending posterior flank; umbones small, subcentral, rounded, strongly opisthogyrate; anterodorsal margin steep, short, slightly convex, merging to well-rounded anterior margin; posterodorsal margin moderately long, straight, very gently descending, merging to rostrate, narrowly rounded?, partially incomplete posterior margin; ventral margin well-rounded, strongly convex; lunule narrow, not well-defined; escutcheon moderately broad, well-defined; commarginal sculpture of approximately 15, spaced, widened, ribs that fade to microsculpture near umbones and faint, secondary riblets; anterior hingeplate moderately short.

Dimensions.-Holotype Ge 7621 (AIM), length 3.0 mm nearly complete, height 2.5 mm, width of paired valves 2.5.

Type.-Holotype Ge 7621 (AIM).

Type locality.-Bull Point, Kaipara, Northland, Q08/f9626.

Material.-One well-preserved, articulated, nearly complete specimen.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation not specified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Known only from Kaipara, Northland.

Discussion.-*Cuspidaria surocretacica* n. sp. is distinct from other Cenozoic New Zealand *Cuspidaria* species such as *Cuspidaria* sp. of Finlay and Marwick, 1937 (p. 104, Pl. 14, Fig. 13) from the mid? Eocene of Castle Hill Shaft, South Island, in having a small, greatly inflated shell medially that descends rapidly towards a compressed, posterior third portion of the shell. Sculpture in *C. surocretacica* n. sp. is moderately well developed of spaced, commarginal ribs. The rostrum of *C. surocretacica* n. sp. is clearly demarcated and well developed, but the extreme posterior portion is incomplete on the holotype. A superficially similar New Zealand Late Miocene species assigned to the nuculanid genus *Saccella*, *S. onairoensis* (Marwick, 1926) (refigured by Fleming, 1966, pp. 104-105, Pl. 3, Figs. 43, 44), approximates *S. surocretacica* n. sp. in general outline and degree of inflation, but the new Cretaceous species has a more compressed posterior third of the shell and lacks the bevelled sculpture prominent in the Late Miocene species. A close relationship of *C. surocretacica* n. sp. with the Cretaceous English species *C. undulata* (Sowerby, 1827) (refigured by Woods, 1909, p. 260, Pl. 44, Fig. 4) from the Gault of Folkestone seems probable, but the former new New Zealand species is much smaller with more rounded umbones and more poorly developed commarginal ribs that are more spaced, weaker, and only slightly raised compared to *C. undulata* which has strong, commarginal ribs and is much larger. *Cuspidaria ventricosa* (Meek and Hayden, 1856) (see Speden, 1970, pp. 155-156, Pl. 40, Figs. 1-9) from the Maastrichtian Fox Hills Formation of South Dakota, North America, is comparable in degree of valve inflation, but has a more convex ventral margin and more closely spaced growth pauses, compared to *C. surocretacica* n. sp. which has a moderately broad ventral margin and well-spaced growth pauses. As with most bivalve taxa from the Cretaceous of Northland, very few hinges are available for study presumably due to the quiet conditions on the interpreted middle to outer shelf. Cuspidaria surocretacica n. sp. is no exception in being articulated, and although this new species is known from only one nearly complete specimen, it is clearly assignable to the Cuspidariidae.

Etymology.-Species named from the Spanish "sur" (= south) and for its presence in Cretaceous rocks of New Zealand.

Class GASTROPODA Cuvier, 1797

Subclass PROSOBRANCHIA Milne-Edwards, 1848

Order ARCHAEOGASTROPODA Thiele, 1925

Suborder PLEUROTOMARIINA Cox and Knight, 1960

Superfamily PLEUROTOMARIACEA Swainson, 1840

Family PLEUROTOMARIIDAE Swainson, 1840

Discussion.-Pleurotomariid species show an interesting diversity trend during the Cretaceous. Peak diversity for the Pleurotomariidae occurred during the Cenomanian (earliest Late Cretaceous) with approximately 30 species known. Before the Cenomanian the group steadily increased from Berriasian to Hautervian time and decreased until Aptian time before its acme in the Cenomanian; during the mid Cenomanian the diversity dropped suddenly to a low in the Coniacian and is paralleled by decreased geographic range during this time (Sohl, 1987, p. 1105). In the plot of diversity of Pleurotomariidae versus time interpreted above, Sohl (1987, p. 1106, Fig. 11) showed a gradual decrease in the number of taxa from mid Campanian to the end of the Maastrichtian. The presence, however, of a pleurotomariid species in the Maastrichtian? of Patagonia (Feruglio, 1936) not mentioned in Sohl's review of the distribution of this group during the latest Cretaceous, undescribed Maastrichtian pleurotomariid taxa in the Chatham Islands (Campbell et al., 1993), and undescribed species from the Maastrichtian Miria Formation of northwestern Australia (T. A. Darragh, personal commun.) indicates that the diversity of the Pleurotomariidae through the Campanian to Maastrichtian remained rather constant without a decrease. The apparent anomalous trend of overall decreasing diversity of Pleurotomariidae during the Cretaceous compared to Temperate Realm gastropod diversity, which was relatively high during the Campanian to Maastrichtian, may not be as anomalous as previously thought.

Genus PEROTROCHUS P. Fischer, 1885

Perotrochus Fischer, 1885, p 850.

Type species.-(by original designation) Pleurotomaria quoyana Fischer and Bernardi, 1856.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-Around the rim of the southern circum-Pacific during the Late Cretaceous, Perotrochus was seemingly restricted to New Zealand, Antarctic Peninsula, possibly Chatham Islands and Patagonia, southern South America. Elsewhere, Perotrochus is known from the Oligocene to Recent of Europe, Japan, South Africa (Cox, 1960, p. I220) and New Caledonia (Bouchet and Métivier, 1982, p. 309). In New Zealand Perotrochus ranged from Late Campanian to Miocene and is represented by only four named species: P. maoriensis Wilckens, 1922 (Late Campanian), P. allani Marwick, 1928 (Late? Paleocene), P. masoni Maxwell, 1978 (Late Oligocene), and P. marwicki Fleming, 1970 (late Early Miocene). Only one Recent species P. tangaroana Bouchet and Métivier, 1982, occurs near New Zealand on the Betty Guyot, northern Three Kings Rise at 841 m depth.

Perotrochus is characterised by having a turbiniform to trochiform outline, an absence of an umbilicus (anomphalous), broad shell, moderately convex whorls, medial or submedial selenizone and finely cancellating spiral and collabral threads (cf. Cox, 1960, p. I220). Most Recent Perotrochus species live in outer shelf or upper bathyal zones in tropical to subtropical regions (Beu and Maxwell, 1990, p. 94), but Late Cretaceous Antarctic and New Zealand Perotrochus species are inferred to have lived in mid shelf to inner shelf habitats. Late Cretaceous Perotrochus species are inferred to have been epifaunal browsers on mostly soft substrates (Warren and Speden, 1978, p. 50; Macellari, 1988, p. 43).

PEROTROCHUS MAORIENSIS (Wilckens, 1922)

Plate 31 Figures 1-4, 6

Pleurotomaria maoriensis Wilckens, 1922, pp. 2-4, Pl. 1, Figs. 1-2.

Pleurotomaria (Perotrochus) maoriensis Wilckens, Fleming in Wellman, 1959, p. 141; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-8.

?Perotrochus cf. maoriensis (Wilckens), Scott in Gage, 1970, p. 538.

Supplementary description.-Shell medium-sized, moderately solid, trochiform to turbiniform; spire moderately short with at least five gently convex whorls; whorl inflation generally constant; ratio of height versus diameter of last whorl approximately 1:1; spire angle approximately 65°; protoconch unknown; suture slightly channelled on later whorls to almost flush on later apical and early teleoconch whorls; growth lines complex, prosocline on ramp posteriorly, strongly opisthocyrt along selenizone, and sinuous anteriorly; last whorl strongly capacious, mostly convex, vaguely biangulate; posterior slope of last whorl slightly concave; last whorl sculptured with numerous, closely spaced, finely cancellating collabral and spiral threads; spiral sculpture slightly stronger than collabral sculpture; antepenultimate and older whorls similarly sculptured as in last whorl; adapical spiral sculpture fine; spiral sculpture on base mostly constant adaxially; selenizone moderately broad, well-demarcated, located medially on last whorl, just above outer periphery; selenizone vague by antepenultimate whorl; base gently convex, mostly anomphalous; aperture shape subrhomboidal?

Dimensions.-TM 7514 (IGNS) height 64.5 mm, diameter of last whorl 69.5 mm.

Types.-Lectotype TM 2593 (IGNS; Wilckens, 1922, Pl. 1, Fig. 2); TM 2594 (IGNS; Wilckens, 1922, Pl. 1, Fig. 1); TM 5378 (IGNS; Warren and Speden, 1978, Fig. 25-8).

Figured specimens.-TM 2593-2594, TM 5378, TM 7514 (all IGNS).

Material.-Four specimens, one well-preserved.

Localities.-Trelissik Basin (= Castle Hill Basin), Canterbury, South Island, K34/f9096; Haumuri Bluff, southern Marlborough, South Island, O32/f9035, O32/f9028; west wing, Haumuri Bluff, O32/f8025 (type); east wing, Haumuri Bluff, O32/f9027.

Stratigraphic range.-Okarahia Sandstone, Saurian Beds (Piripauan Stage, upper Campanian, Upper Cretaceous).

Geographic distribution.-Southern Marlborough to Canterbury, South Island.

Discussion.-Pleurotomariid gastropods are relatively rare in the Late Cretaceous molluscan fauna of New Zealand. Perotrochus maoriensis is known for certain only from five localities from southern Marlborough (the Haumuri Bluff area) to Canterbury (the

Trelissik (= Castle Hill) Basin. The type material of P. maoriensis available to Wilckens was poorly preserved so that comparisons with other similar Cretaceous taxa were difficult at best. I cleared the matrix from the abapertural part of a moderately well-preserved specimen from Haumuri Bluff, illustated here in the systematic catalogue (TM 7514 (IGNS)). Further clearance of well-cemented matrix from the apertural portion of the shell would most likely result in decortication, the beginnings of which are present on various parts of the shell.

Wilckens (1922) compared his poorly preserved P. maoriensis with several European and Austral taxa. Perotrochus maoriensis is rather similar to P. larseniana Wilckens, 1910 (pp. 73-74, Pl. 3, Fig. 24; Macellari, 1984, Pl. 34, Figs. 1-4), from the Late Cretaceous to earliest Tertiary of the Antarctic Peninsula, but apparent differences in position of the selenizone, inflation of the last whorl, and size of the shell (possibly also sculptural differences, but this is unclear from Macellari's photos), suggests that these species are not closely related. Pleurotomaria tardensis Stanton, 1901 (pp. 29-30, Pl. 7, Figs. 1-2) from the Cretaceous of Argentina is similar to P. maoriensis in overall outline, but as noted by Wilckens (1922, p. 3) the Argentine species has coarser sculpture. A close relationship seems probable between P. maoriensis and a Paleocene species from Chatham Islands, P. allani Marwick, 1928 (pp. 474-475, Figs. 110, 114; Beu and Maxwell, 1990, p. 94, Pl. 4, Fig. i). The last whorl appears to be more inflated and sutures slightly impressed in P. allani, compared to P. maoriensis, but otherwise these two species seem very similar.

It is unfortunate that Wilckens (1922) used the species-level name "maoriensis" for this group, as the name has a geographic implication. Although there are New Zealand place names such as Maori Bay or Maori River, all of these areas are well away from the the type locality of P. maoriensis, which is Haumuri Bluff. Most likely named after the Maori people of New Zealand, "maorii" may have been a more appropriate name to alleviate the dubious, geographic implication of maoriensis.

Genus CHELOTIA Bayle in Fischer, 1885

Chelotia Bayle in Fischer, 1885, p. 850.

Type species.-(by original designation) Pleurotomaria concava Deshayes, 1832.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-The origin of Chelotia, a relatively rare pleurotomariid taxon, appears to have been in the southern hemisphere. The earliest known record of Chelotia is C. woodsi Wilckens, 1922, from upper Campanian rocks of Haumuri Bluff, where it has been collected from a single locality (O32/f9027). After the late Campanian in New Zealand, Chelotia reappeared in the Eocene of Europe where it is represented by only a few species (Wenz, 1938, p. 150). As with Perotrochus, species of Chelotia are inferred to have been epifaunal browsers on relatively soft substrates (Warren and Speden, 1978, p. 50, Tab. 5).

CHELOTIA WOODSI (Wilckens, 1922)

Plate 31 Figures 5, 7-8

Pleurotomaria woodsi Wilckens, 1922, p. 4, Pl. 1, Figs. 3-4.

Pleurotomaria (*Chelotia*) *woodsi* Wilckens, Fleming *in* Wellman, 1959, p. 140; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-9.

Type and previously figured specimen.-Lectotype TM 2592 (IGNS; Wilckens, 1922, Pl. 1, Fig. 4; Warren and Speden, 1978, Fig. 25-9); TM 2591 (IGNS; Wilckens, 1922, Pl. 1, Fig. 3).

Figured specimens herein.-TM 2592 (IGNS), TM 2591 (IGNS).

Material.-Two specimens.

Locality.-East wing of Haumuri Bluff, southern Marlborough, South Island, O32/f9027 (type).

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous).

Geographic distribution.-Known only from Haumuri Bluff, South Island.

Discussion.-Wilckens (1922, p. 4) was unsure of the affinity of *Pleurotomaria woodsi* and did not compare this species directly with other pleurotomariid taxa. Fleming *in* Wellman (1959, p. 140) was apparently the first to recognize the relationship of *P. woodsi* with the European Eocene pleurotomariid group *Chelotia* and in his checklist of Piripauan New Zealand gastropods assigned this species to *Pleurotomaria* (*Chelotia*) *woodsi*. Comparison of *C. woodsi* with the type species of *Chelotia*, *C. concava* Deshayes, 1832 (Cox, 1960, pp. I219-I220; Wenz, 1938, p. 150, Fig. 216), indicates, indeed, a close relationship.

Order PATELLOGASTROPODA Lindberg, 1986

Discussion.-Patellogastropods have received considerable attention over the years in terms of anatomy, taxonomy, phylogeny, biogeography, etc. (e. g. Wenz, 1938; Keen, 1960, Powell, 1973, 1979; Lindberg, 1988; Lindberg and Squires, 1990;

Beu and Maxwell, 1990). Virtually no attention has been given to New Zealand Late Cretaceous patellogastropods since the only described species *Patella*? *amuritica* was erected by Wilckens (1922), based on a single, poorly preserved example from Haumuri Bluff, South Island. Powell (1973, p. 82) reviewed the generic status of *P*.? *amuritica* in his monograph on patellid limpets of the world, and like Wilckens, was at a loss to assign this species to any genus because of the poor preservation of the holotype; indeed, little can be done with a damaged, incomplete shell with the entire apical area not preserved. Powell included *P*.? *amuritica* as a "doubtful species of Patellidae" (p. 82). The oldest *Patella* s. l. species in the fossil record appears to be *Patella* (*Scutellastra*) *aurorae* Fleming, 1973, which in New Zealand ranges probably from the Duntroonian to Waitakian Stages (Upper Oligocene to lowermost Miocene) (Beu and Maxwell, 1990, p. 403). Conversely, Powell (1973, p. 82) mentioned an unsubstantiated Early Miocene species from Motuihi Island, Auckland. *Patella* *kaffraria* Rennie, 1930 (refigured by Powell, 1973, Plate 79), from the Late Cretaceous of Pondoland, South Africa, is also probably not a *Patella*. It seems unlikely that *Patella* was present during the Late Cretaceous.

At least two species (perhaps three) patellogastropod taxa are present in New Zealand Upper Cretaceous rocks; these are *Cellana*? n. sp. of the Nacellidae and *Patelloida*? n. sp. of the Lottiidae. The affinity of *Patella*? *amuritica* remains uncertain.

Suborder ACMAEOIDEA Forbes, 1850

Family LOTTIIDAE Gray, 1840

Subfamily PATELLOIDINAE CHAPMAN and GABRIEL, 1923

Genus *PATELLOIDA* Quoy and Gaimard, 1834

Patelloida Quoy and Gaimard, 1834, p. 349.

Type species.-(by subsequent designation, Gray, 1847) *Patelloida rugosa* Quoy and Gaimard, 1834.

Biogeographic element.-Indo-Pacific/Tethyan (cf. Fleming, 1967, p. 116).

Discussion.-The taxonomy and paleobiogeography of *Patelloida* was reviewed recently by Lindberg (1988) and Lindberg and Squires (1990, p. 580). *Patelloida* species have been described from the Early Cretaceous to Recent of England, France, Oregon, Washington, British Columbia, and Alaska. Today *Patelloida* species occur in all oceans of the northern hemisphere to 70°N and to 50°S in the southern hemisphere, except the South Atlantic, and possibly the Late Cretaceous of New Zealand. Some previously described fossil *Patelloida* taxa were assigned to this group on external morphological grounds alone, and should be reassessed by studying the shell microstructure (Lindberg, 1988, p. 44).

Reports of fossil limpets preserved in living position are rare in the literature. Limpets, herbivorous gastropods, attach themselves to firm substrates and soon after death become detached as their soft parts deteriorate. *Patelloida*? n. sp. from the latest Cretaceous of North Island is inferred to have had a similar lifestyle. Detached shells are differentially preserved in the fossil record or become destroyed, depending on the sedimentary and environmental regime at the time. The epifaunal lifestyle of limpets, coupled with high energy settings on the shallow shelf, would likely reduce the survivorship of these shells in the fossil record. An interesting example has come to light from inferred mid-shelf deposits of the Maastrichtian (uppermost Cretaceous) of the southern hemisphere. A large limid bivalve, *Acesta shackletoni* Zinsmeister and Macellari, 1988, was discovered recently in Unit 9 of the Lopez de Bertodano Formation with a limpet (*Acmaea* n. sp.) attached to the bivalve's outer surface (Zinsmeister, 1990, pp. 477-478). The environment of deposition, based on sedimentological evidence, was inferred to have been a quiet one on the mid-shelf well below storm-wave base. Zinsmeister postulated that the limpet became trapped when the *Acesta* turned over in the sandy mud of the sea floor surface and the limpet became unable to escape because of the weight of the large *Acesta*. A further example of a fossil limpet preserved in life position was reported by Stilwell and Zinsmeister (1992, p. 90), who recorded a poorly preserved limpet from the basal facies of the La Meseta Formation (lower? to mid Eocene) that was attached to a specimen of "*Chlamys*" sp. A. Detached limpets and limpet-like gastropods are very rare in the Paleogene, if not the entire Tertiary, of New Zealand. I know of only one species, *Scutus petrafixus* Finlay, 1930, which may be present in the latest Eocene of New Zealand.

PATELLOIDA? n. sp.

Plate 31 Figures 10-11

Description.-Shell moderately large, moderately thin, base elongate-ovate, of low profile; apex located approximately a third of total length of shell from anterior margin; lateral slopes mostly straight, slightly concave; external sculpture weak (partly eroded) of moderately closely spaced radial ribs and concentric, threadlike growth lines; shell margin mostly smooth; shell microstructure unknown.

Dimensions.-TM 7515 (IGNS) length 24.0 mm, width 20.0 mm.

Figured specimen.-TM 7515 (IGNS).

Material.-One specimen.

Locality.-Te Rata Stream, Raukumara Peninsula, North Island, Y16/f203.

Stratigraphic range.-Whangai Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Raukumara Peninsula, North Island.

Discussion.-The affinities of this limpet are uncertain, but seem to lie with the Early Cretaceous to Recent *Patelloida* group, a group which shows notable morphological variation. *Patelloida*? n. sp. could be related closely to a Late Cretaceous species, *P. traskii* (Gabb, 1864) (p. 140, Pl. 21, Fig. 103; refigured by Lindberg, 1988, p. 47, Fig. 5a) from California and *P. tejonensis* (Gabb, 1869) (pp. 172-173, Pl. 28, Fig. 56; refigured and redescribed by Lindberg and Squires, 1990, pp. 580-582, Fig. 3) from the Eocene of California. *Patelloida*? n. sp. can be differentiated from *Cellana*? n. sp., also from the Late Cretaceous of New Zealand, in having a smaller shell of lower profile, a more anterior apex and more subdued sculpture. More material of this species is needed for a firmer assignment. As a minor sidenote, Beu and Maxwell (1990, p. 402) inadvertently assigned *Patelloida* to the subfamily Patelloididae (sic.) (should be Patelloidinae).

Family NACELLIDAE Thiele, 1929

Genus CELLANA H. Adams, 1869

Cellana H. Adams, p. 273.

Type species.-(by original designation) Nacella cernica Adams, 1869.

Synonym.-Helcioniscus Dall, 1871 (Keen, 1960, p. I235; Powell, 1973, p. 147).

Biogeographic element.-Indo-Pacific/Tethyan (cf. Fleming, 1967, p. 116).

Discussion.-Cellana is characterised by having a moderately solid shell, subcentral apex (more anterior), variably moderate to strong radial, rounded ribs and a glazed interior (cf. Keen, 1960, p. I235; Macpherson and Gabriel, 1962, p. 45; cf. Powell, 1973, p. 147). Cellana has a wide geographic distribution today in the Indo-Pacific and South Pacific as far south as subantarctic Campbell Island (Powell, 1973, p. 147). The oldest reports of Cellana in the fossil record of the southern hemisphere are C. feldmanni Stilwell and Zinsmeister, 1992, from the Late Eocene of Seymour Island, Antarctic Peninsula and C. n. sp. from the Runangan (Upper Eocene) of Westland, New Zealand (Beu and Maxwell, 1990, p. 115). A further possible species of Cellana is C.? carpentariana Skwarko, 1966, from the Early Cretaceous of Australia. In the northern hemisphere C. ampla Lindberg and Hickman, 1986, from the Eocene of Oregon is most likely the oldest record of the genus. Lindberg (1988, p. 45) reported that Cellana, as in Patelloida, shows its highest

Holocene diversity in the Australasian region with no known members in the New World, unlike previous widespread fossil distributions.

CELLANA? n. sp.

Plate 31 Figures 9, 12-13

Description.-Shell medium-sized, moderately solid, patelliform, base broadly subovate, of moderately high profile; apex subcentral; lateral slopes mostly straight to very gently convex, moderately steep; external sculpture of numerous, thickened, rounded, low, closely spaced radial ribs; concentric growth increments mostly inconspicuous, broad; shell margin slightly crenulate; shell microstructure unknown.

Dimensions.-TM 7516 (IGNS) length 42.0 mm, width 34.0 mm, height 15.5 mm; TM 7517 (IGNS) length 41.0 mm, width 35.0 mm, height 15.5 mm.

Figured specimens.-TM 7516 (IGNS); TM 7517 (IGNS).

Material.-Two specimens.

Locality.-North of "Old Claverley" Stream, southern Marlborough, South Island, O32/f8795.

Stratigraphic range.-Claverley Sandstone? (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Southern Marlborough, South Island.

Discussion.-The affinities of this probable new limpet species are uncertain, but the position of the apex, radial sculpture, and shell profile seem to be consistent with the Cellana group of possible Early Cretaceous and Eocene to Recent age. However, this assignment can only be considered tentative, as data on the shell microstructure are not available. Cellana? n. sp. has a more broadly ovate outline, a more strongly crenulated shell margin and more subdued radial sculpture than C.? carpentariana Skwarko, 1966 (refigured by Powell, 1973, p. 172, Pl. 152, Fig. 1) from the Early Cretaceous of Australia. The Late Eocene species Cellana feldmanni Stilwell and Zinsmeister, 1992 (p. 90, Pl. 11, Fig. a), from the uppermost Unit 7 of the La Meseta Formation, Seymour Island, Antarctic Peninsula, approaches Cellana? n. sp. in outline, but C. feldmanni has a lower shell profile. Cellana? n. sp. is also similar to the type species, C. cernica (Adams, 1869) (refigured by Keen, 1960, p. I235, Fig. 148-1), in general outline and sculpture, but C.? n. sp. is slightly broader with more poorly developed radial sculpture.

Family PATELLIDAE Rafinesque, 1815

Subfamily PATELLINAE Rafinesque, 1815

Genus PATELLA Linné, 1758

Patella Linné, 1758, p. 782.

Type species.-(by subsequent designation, Fleming, 1818) Patella vulgata Linné, 1758.

PATELLA? AMURITICA Wilckens, 1922

Plate 31 Figure 14

Patella? amuritica Wilckens, 1922, p. 5, Pl. 1, Fig. 8; Powell, 1973, p. 82.

"Patella" amuritica Wilckens, Fleming in Wellman, 1959, p. 141.

Type.-Lectotype TM 2597 (designated herein) (IGNS; Wilckens, 1922, Pl. 1, Fig. 8).

Figured specimen.-TM 2597 (IGNS).

Localities.-West wing, Haumuri Bluff, southern Marlborough, South

Island, O32/f8025 (type); ?Ngamahanga Point, north side of Hokianga Harbour, Northland, O06/f7574; ?west bend, Birch Hill Road, Raukumara Peninsula, North Island, X16/f9161.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); unnamed formation in Northland and possibly Rakauroa Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Only Haumuri Bluff, South Island for certain.

Discussion.-As mentioned above meaningful comparisons of *P.? amuritica* with other taxa (genus- or species-level) cannot be accomplished, based on the poorly preserved holotype, and it is surprising that Wilckens actually assigned a species name to this group. Perhaps **nomen dubium** status should be invoked for *P.? amuritica*, as this species has little significance and affinities are uncertain below the family level.

Suborder TROCHINA Cox and Knight, 1960

Superfamily TROCHACEA Rafinesque, 1815

Family TURBINIDAE Rafinesque, 1815

Subfamily ANGARIINAE Thiele, 1921

Genus *ANGARIA* Röding, 1798

Angaria Röding, 1798, p. 71.

Type species.-(by subsequent designation, Fischer, 1875) *Turbo delphinus* Linné, 1758.

Synonym.-*Delphinula* Lamarck, 1804, only (Hickman and McLean, 1990, p. 41).

Biogeographic element.-Indo-Pacific/Tethyan (cf. Hickman and McLean, 1990, p. 41).

Discussion.-Historically, Angaria has been assigned to the Trochidae by various workers who have been "misled" by the operculum which is fully corneous and who "have overlooked the fact that this group shares a common radular plan with both the Liotiinae and the more advanced turbinid subfamilies..." (Hickman and McLean, 1990, p. 41).

ANGARIA? sp.

Plate 32 Figures 7-8, 10

Figured specimen.-TM 2596 (IGNS; Wilckens, 1922, Pl. 1, Fig. 5).

Localities.-West wing of Haumuri Bluff, southern Marlborough, South Island, O32/f8025; Ngaroma, Conway River, southern Marlborough, O32/f8862; Selwyn River, Malvern Hills, Canterbury, South Island, L35/f6017.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Saurian Sands, Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Southern Marlborough to Canterbury?, South Island.

Discussion.-Virtually no new data are available to reconcile the problems associated with the affinity of this species, except to note the probable geographic extension of this species to include a further locality in southern Marlborough and one in Canterbury. It is possible that the this species is not an Angaria, but a member of the Neritopsidae. Wilckens, 1922 (p. 4, Pl. 1, Figs. 5a-c) assigned two poorly preserved gastropod steinkerns to Delphinula? sp. (a synonym of Angaria), but did not discuss this assignment of these specimens to this group. The cancellate sculpture of the specimen in Wilckens' Fig. 5 is similar to the specimen assigned to Neritopsis? sp. from Shag Point figured in a later paper by Wilckens (1924, p. 542, Pl. 54, Fig. 5). The aperture of the specimen in Wilckens' Fig. 5 is also consistent with Neritopsidae, but because of poor preservation relationships are uncertain. Little information can be gleaned from the material available.

Subfamily TURBININAE Rafinesque, 1815

Genus TURBO Linné, 1758

Turbo Linné, 1758, p. 761.

Type species.-(by subsequent designation, Montfort, 1810) Turbo petholatus Linné, 1758.

Synonyms.-Laeviturbo Cossmann, 1918; Amphibiloliturbo Magne, 1940; Neocollonia Kuroda and Habe, 1954 (Keen in Knight et al., 1960, p. I268).

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-Turbo first appears in the fossil record in Upper Cretaceous rocks (Hickman and McLean, 1990, p. 57), much earlier than the Oligocene earliest occurrence given by Keen in Knight et al., 1960, p. I268). Crampton and Moore (1990, pp. 340, 347) documented Turbo sp. from the Upper Cretaceous Maungitaniwha Sandstone of western Hawke's Bay, North Island (localities V19/f6511 (lower Mangahouanga Stream) and V19/f6649 (Hook Stream)), extending further the geographic range of the group in the Late Cretaceous. Crampton and Moore did not did figure or discuss Turbo sp., except to acknowledge that the presence of this browsing group in the Maungataniwha Sandstone also suggests the presence of algae. Most members of the Turbininae are also restricted to hard substrates (Hickman and McLean, 1990, p. 57). No specimens of this species were encountered in the IGNS collections.

Family SKENEIDAE Thiele, 1929

Genus BROOKULA Iredale, 1912

Brookula Iredale, 1912, p. 219.

Type species.-(by original designation) Brookula stibarochila Iredale, 1912.

Biogeographic element.-Paleoaustral, as inferred here.

Discussion.-The most important distinguishing morphological characteristics of Brookula were reviewed recently by Beu and Maxwell (1990, p. 376); these are, "Diameter 0.9-1.5 mm, turbiniform, spire depressed or elevated, narrowly or widely umbilicate; whorls rounded, inflated. Sculpture of prominent axial costae and finer interstitial spiral cords or threads. Aperture circular, peristome continuous". Aequispirella Finlay, 1924, a subgenus of Brookula, differs from Brookula s. s. in being more narrowly umbilicate with a higher, more pointed spire (Finlay, 1924, p. 531; Powell, 1979, p. 77; Beu and Maxwell, 1990, p. 376). Dell (1990, p. 102) recognised the need for a comprehensive review of Brookula s. l. as several groups appear to be present. Brookula s. s. and Brookula s. l. species have been described from the mid Tertiary to Recent of the South Pacific, including Antarctica. The oldest described species of Brookula appears to be B. (Aequispirella) bifurcata Maxwell, 1992, from the Bortonian Stage (upper Middle Eocene) of South Canterbury, South Island, New Zealand. Brookula s. s. may also be present as early as late Early Eocene in New Zealand (Mangaorapan Stage) (Beu and Maxwell, ibid), so that earlier records should not be surprising. A new Late Cretaceous species from Whangaroa, Northland, fits loosely in the *Brookula* group, but is distinguished from *B*. (*Aequispirella*) in having more subdued, axial wrinkles, instead of strong axial ribs, and a lower spire. There is little doubt that this new species is an early member of *Brookula* and is described here as a new subgenus *Paleobrookula*.

The family-level placement of *Brookula* s. s. and *Brookula* s. l. is in a state of flux. Hickman and McLean (1990, pp. 34, 141) in their monograph on the systematic revision and suprageneric classification of trochacean gastropods included *Brookula* in Skeneidae and tentatively treated Skeneidae (= Cyclostrematidae of authors) as a natural group within Trochacea. Most of the problems surrounding this family-level, and for that matter suprafamily-level uncertainty, stems from the fact that the soft-part anatomy of species within Skeneidae is unknown; whether Skeneidae is monophyletic or polyphyletic is arguable. Hickman *in* Hickman and McLean (ibid, p. 34) held firm ground in stating that on the basis of divergent radular groundplans in Skeneidae, this group can be regarded as polyphyletic. Marshall (1988, p. 953) conversely argued that "it is possible that the skeneids are a monophyletic group that has undergone an independent radiation paralleling the Trochidae and Turbinidae", and in his paper preferred this monophyletic scenario. Divergence of radular groundplans in skeneid gastropods indicates to me that polyphyly for the group seems most likely. Until the soft-part anatomy of

Skeneidae is known, however, the relationship of skeneids to other trochaceans will remain uncertain. I follow Hickman and McLean (1990), Beu and Maxwell (1990) and Maxwell (1992) in treating Brookula as a genus within Skeneidae, as opposed to Powell (1979), Vaught (1989) and Dell (1990) who included Brookula in Cyclostrematidae: Cyclostrematinae.

PALEOBROOKULA new subgenus

Diagnosis.-Shell small, relatively thin, turbiniform with strongly convex whorls; umbilicus shallow; sculpture moderately weak, of relatively widely spaced axial wrinkles, stronger subsuturally on posterior portion of ramp and at umbilicus.

Type species.-Brookula (Paleobrookula) marshalli n. sp.

Biogeographic element.-Endemic, as inferred here.

Discussion.-Paleobrookula is proposed here as a new subgenus and early member of Brookula, as this shell does not fit comfortably within any known Brookula s. l. group, extinct or extant. Presence of widely spaced, axial wrinkles and a short spire along with absence of spiral sculpture in B. (Paleobrookula) n. subgen., in my opinion, warrants separation of this group from B. (Aequispirella).

Etymology.-New subgenus named after combination of "paleoaustral" and relationship to Brookula.

BROOKULA (PALEOBROOKULA) MARSHALLI n. subgen. n. sp.

Plate 32 Figures 1-4

Diagnosis.-Same as for subgenus.

Description.-Shell relatively small, thin, polished, moderately depressed, turbiniform; spire low, paucispiral, of at least two convex whorls; spire angle approximately 84°; protoconch unknown; umbilicus shallow; suture impressed; growths lines suborthocline, more opisthocyrt on posterior ramp; last whorl capacious, well-inflated, strongly convex; last whorl much more inflated than penultimate whorl; shell mostly smooth, except for moderately weak, relatively widely spaced, axial wrinkles, numbering approximately 17 on last whorl, and very fine growth lines; axial wrinkles somewhat stronger subsuturally on posterior section of ramp and also at umbilicus; penultimate whorl similarly sculpture, but more subdued; aperture circular, holostomatous.

Dimensions.-Holotype TM 7518 (IGNS) height 3.5 mm mostly complete, diameter of last whorl 4.5 mm.

Type.-Holotype TM 7518 (IGNS).

Type locality.-Exact locality not known, but collected at north shore of Whangaroa Harbour, Northland, possibly N11/f606 (= P05/f7606), by P. Marshall before 1926.

Figured specimen.-TM 7518 (IGNS).

Material.-Holotype only.

Stratigraphic range.-Otamatea Beds (Ferrar, 1924; Hay in Fleming, 1959) (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Whangaroa, Northland.

Discussion.-Brookula (Paleobrookula) marshalli n. subgen. n. sp. is known only from the well-preserved holotype, collected by early twentieth century New Zealand geologist P. Marshall before 1926, presumably from the Otamatea Beds (?Maastrichtian) of Whangaroa, but the exact locality is not known. Marshall (1926, p. 207) in his landmark paper on Late Cretaceous ammonites of New Zealand remarked that a number of gastropod taxa were collected in association with ammonites described in his paper. Most likely, *B*. (*P*.) *marshalli* n. subgen. n. sp. represents one of the twelve or so species of gastropods associated with the ammonites noted by Marshall in the Upper Cretaceous marine sediments. Marshall (1926, p. 207) mentioned that "it is hoped to classify the species of gasteropods and lamellibranchs next year", but unfortunately this work never came to fruition.

Brookula (*Paleobrookula*) *marshalli* n. subgen. n. sp. can be differentiated from the type species of *Brookula* s. s., *B*. *stibarochila* Iredale, 1912 (refigured by Keen, 1960, p. I273, Fig. 177-3) from the Recent of Kermadec Islands, in having a shorter, more compressed shell, a narrower umbilicus, and axial wrinkles instead of ribs. In outline only *B*. (*P*.) *marshalli* n. subgen. n. sp. is similar to *B*. (*B*.) *pukeuriensis* Finlay, 1924 (pp. 529-530, Pl. 53, Fig. 3a-c; Beu and Maxwell, 1990, p. 376. Pl. 53, Figs. d, g) and *B*. (*Aequispirella*) *iredalei* Finlay, 1924 (pp. 527-528, Pl. 53, Fig. 2a-c) from the Miocene of New Zealand and also to *B*. (s. l.) *rossiana* Dell, 1990 (p. 102, Fig. 169) from the Recent of Antarctica, but the strong axial sculpture of the latter three species differs from *B*. (*P*.) *marshalli* n. subgen. n. sp. considerably. Perhaps further work will bridge the major gap in information available on Paleocene and Early Eocene skeneids in New Zealand.

Etymology.-New species named after P. Marshall, who collected the holotype in the 1920's.

Family TROCHIDAE Rafinesque, 1815

Subfamily EUCYCLINAE Koken, 1897

Genus *AMBERLEYA* Morris and Lycett, 1851

Amberleya Morris and Lycett, 1851, p. 55 (as *Amberlya* p. 54.).

Type.-(by subsequent designation) *A*. *bathonica* Cox and Arkell, 1950 (= *A*. *nodosa* Morris and Lycett, 1851).

Biogeographic element.-Indo-Pacific/Tethyan, but predominantly Tethyan in "warm, shallow-water paleoenvironments" (Hickman and McLean (1990).

Discussion.-Recent research on the genera of the Amberleyidae has resulted in the recognition that the Recent taxa *Cidarina*, *Bathybembix*, and *Calliotropis* can be considered, on the basis of "unifying radula and sculptural characters", to be a continuation of the Mesozoic lineage including *Amberleya* (Hickman, 1980, p. 16; McLean, 1981, p. 335). Both Hickman and McLean realized the close relationship of Amberleyidae to Trochidae and justifiably reduced the Amberleyidae to subfamilial rank within the Trochidae. McLean (1981) further suggested that currently recognized Craspedostomatacea and Amberleyacea be "reconsidered as possible familial or subfamilial lineages in the Trochacea". Indeed, the close relationship between Jurassic New Zealand species previously assigned to *Amberleya* and their possible relationship to *Cidarina* suggests a need for revision. *Amberleya torosa* Marwick, 1953 (See p. 113, Pl. 15, Fig. 3), has a shell outline and sculpture, although with more widely spaced nodes, more like the Recent type species of *Cidarina* (*C*. *cidaris* Carpenter) which ranges from Alaska to Baja California than to the type species of *Amberleya*, *A*. *bathonica* Cox and Arkell (figured by Cox *in* Knight et al., 1960, p. I307, Fig. 203-5) from the Middle Jurassic (Bathonian) of England. Marwick stated that *A. torosa* was provisionally placed in *Amberleya* as "many rather flat-based shells" have been included in this group. *Amberleya torosa* is definitely not an *Amberleya*, and is herein reassigned to *Cidarina* as an early member of the group. Trechmann (1923, p. 262, Pl. 13, Fig. 12) assigned a New Zealand Jurassic species from Kawhia Harbour to *Amberleya* (*A. zealandica*) (see also Marwick, 1953, p. 113, Pl. 15, Fig. 1). The genus-level status of this species is uncertain because the figured specimen is incomplete, but the morphologic features present suggest a closer affinity to *Amberleya* than to *Cidarina*. Marshall (1926, p. 207) remarked that a specimen similar to *Amberleya spinigera* Wilckens, 1910, of Antarctica was collected from Northland, New Zealand, in association with the ammonites described in his paper. Marshall's specimen (TM 7519, IGNS, here designated as holotype), from the north shore of Whangaroa Harbour, and additional specimens from Kaipara, represent a Late Cretaceous species of *Amberleya*, although it cannot be referred to *A. spinigera* and is described as a new species herein.

In a recent, long overdue, monograph on a systematic review and revision of the suprageneric classification of trochacean gastropods, Hickman and McLean (1990, pp. 74-76) placed *Amberleya* within the exclusively fossil tribe Eucyclini of Eucyclinae which is followed here. External morphological features restricted to Eucyclinae include ..."certain kinds of nodose sculpture and certain patterns of delicate granular or reticulate axial sculpture...Apertures are nearly radial to moderately oblique and range from nearly circular to elongate or quadrate, and the peristome is always interrupted...", whereas shell size, shape, thickness and some sculptural features can be quite variable (Hickman and McLean, 1990, p. 74). The relationships of eucycline genera such as Amberleya and Eucyclus, and also of Late Mesozoic species assigned to Amberleya, remain uncertain and need to be resolved. Historically, part of the problem stems from the fact that the original fossil material of Amberleya was derived from carbonate facies in which the original shell was not preserved (Hickman and McLean, 1990, p. 76). Most of the best Amberleya material known is derived from very fine-grained marine siltstone or shale facies, as revealed by exquisite specimens from the latest Cretaceous of Antarctica and New Zealand. Even with the comprehensive treatment of extinct and extant trochacean gastropods by Hickman and McLean, suprageneric relationships with the Trochacea are still uncertain in many Mesozoic fossil groups (K. Bandel, personal commun., 1992).

Wenz (1938, p. 263) gave the range of Amberleya as questionably Late Triassic to Late Jurassic of Europe, North America and New Zealand, while Cox in Knight et al. (1960, p. I306) later gave a range of Triassic to Late Jurassic of only Europe and North Africa and did not mention New Zealand. A range of Middle Triassic to Middle Jurassic was supported by Hickman and McLean (1990, p. 75), who were, curiously, either unaware of the Late Cretaceous Antarctic species A. spinigera Wilckens or although not stated explicitly, believed that Cretaceous amberleyas are more closely related to Eucyclus which ranged into the Oligocene. The New Zealand and Cretaceous species are closely related to the type species A. bathonica Cox and Arkell, 1950 (see Cox in Knight et al., 1960, p. I307, Fig. 203-5), from the Middle Jurassic but not to Eucyclus obeliscus Eudes-Deslongchamps, 1860 (See Cox in Knight et al, ibid, Fig. 203-6), from the Jurassic of France. However, in Antarctica the genus survived well into the latest Cretaceous or earliest Paleocene depending on placement of the K/T boundary (which is not resolved; Zinsmeister et al., 1989). In New Zealand the genus ranges from Early Jurassic(?) (at least Temaikan Stage) to Maastrichtian latest Cretaceous (Haumurian Stage).

Amberleya is inferred to have been a sea floor scavenger or grazer that fed on algae on a shallow sea floor (McKerrow, ed., 1978, p. 216), although there is more evidence for the former. Macellari (1988, p. 43) reported the discovery of Amberleya living inside the living chamber of large Maorites specimens in two inferred middle shelf localities of Seymour Island, Antarctic Peninsula, suggesting that the genus was a scavenger or possibly an epifaunal carnivore. Amberleya whangaroaensis n. sp. probably had a similar mode of life to A. spinigera and also lived in a middle shelf environment as indicated by the distal concretionary, siliceous shale and sandstone facies of the Otamatea Beds, Northland.

AMBERLEYA WHANGAROAENSIS n. sp.

Plate 32 Figures 5-6, 9, 11-13

Diagnosis.-multiangulate Amberleya with two posterior rows of well developed nodes at the shell periphery and a third anterior row of poorly developed nodes; penultimate whorl with two rows of nodes, posterior row of nodes more developed than the anterior.

Description.-Shell medium-sized, moderately solid, high-spired trochiform; spire moderately high, with at least four biangulate, concave whorls; whorl inflation rapid before ultipenultimate whorl; spire angle 62°; protoconch of one and a half whorls?; suture moderately impressed; growth lines opisthocyrt posteriorly on ramp, becoming more orthocline medially; last whorl capacious, multiangulate; posterior slope of last whorl long, concave, bordered on the periphery by strong angulation; last whorl sculptured with six, strong, widely spaced, spiral cords, posterior three cords heavily sculptured with 12 projecting, spaced nodes greatly decreasing in strength anteriorly to very blunt raised ridges and obliquely offset to posterior-most cord; axial sculpture poorly developed; penultimate whorl biangulate, concave, sculptured with one heavily nodose, posterior spiral cord at outer periphery and anterior, moderately nodose cord just above suture; postnuclear whorl biangulate, sculpture parallel to penultimate whorl; aperture holostomatous, subovate(?); inductura narrow.

Dimensions.-Holotype TM 7519 (IGNS) height 46.5 mm nearly complete, diameter of last whorl 32.0 mm incomplete; paratype, Ge 5996 (AIM) height 32.0 mm incomplete, diameter of last whorl 33.5 mm incomplete; paratype, Ge 7658 (AIM) height 11.5 incomplete, diameter of antepenultimate? whorl 12.0 mm; paratype G 7038 (from AU 2577) height 25.0 mm incomplete, diameter of last whorl 27.5 mm mostly complete; paratype G 7037 (from AU 2577) height 17.5 mm incomplete, diameter of last? whorl 23.5 mostly complete (juvenile specimen?); paratype Ge 6424 (AIM) height 17.5 mm incomplete, diameter of last whorl 19.5 mm.

Types.-Holotype TM 7519 (IGNS); paratypes Ge 5996 (AIM), Ge 6424 (AIM), Ge 7658 (AIM), G 7037 (AU), G 7038 (AU).

Type locality.-Exact locality not known, but collected at north shore of Whangaroa Harbour, Northland, possibly N11/f606 (= P5/f7606), 12218760 to 12208765 = P5/751650, by P. Marshall before 1926.

Figured specimens.-TM 7519 (IGNS), Ge 5996 (AIM), Ge 7658 (AIM), G 7037 (AU), G 7038 (AU).

Material.-Eight incomplete specimens, shells partly decorticated and apertures incomplete.

Localities.-North shore of Whangaroa Harbour, Northland, P5/f7606; Bull Point, Kaipara, N28/f626 = Q08/f9626; Te Opu, Kaipara, Q09/f9639; Whakapirau Creek, Kaipara, N28/f637 = Q08/f9637.

Stratigraphic range and age.-Otamatea Beds (Ferrar, 1924; Hay in Fleming, 1959) and unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic Distribution.-Kaipara and Whangaroa, Northland.

Discussion.-*Amberleya whangaroaensis* n. sp. is known from seven imperfect specimens apart from the nearly complete holotype, collected by P. Marshall before 1926 in Northland, Whangaroa Harbour. The holotype was collected in association with ammonites which were subsequently described by Marshall (1926) and Henderson (1970). The source rocks of fossil-bearing concretions from Whangaroa Harbour are known only from Ferguson Point in a "grey, jarositic, concretionary, siliceous shale", although none of the ammonites were collected in situ (Henderson, 1970). Specimens of *Amberleya whangaroaensis* n. sp. were also collected from several localities in the Kaipara Harbour area, but the species is not known south of these two areas in New Zealand. Its absence elsewhere in New Zealand is probably due to lack of suitable facies and not collection failure, as middle shelf environments are wanting in South Island.

Amberleya whangaroaensis n. sp. is considered closely related to the Late Cretaceous (middle to late Campanian) to earliest Paleocene(?) Antarctic species *Amberleya spinigera* Wilckens, 1910, and both have most likely descended from an unknown Austral Cretaceous species. *Amberleya spinigera* is one of the most beautiful of the Antarctic Peninsula fossil species. Many collected examples have preserved nacreous shell. *Amberleya spinigera* is reported as common on Seymour Island and Snow Hill islands (Wilckens, 1910, p. 74-76, Pl. 3, Figs. 25, 26; Macellari, 1985, Pl. 34, Figs. 9, 10). *Amberleya spinigera* is also reported from Cape Lamb (del Valle *et al*., 1982) and more recently from Ula Point, James Ross Island (Stilwell and Zinsmeister, 1987b). *Amberleya whangaroaensis* n. sp. can be distinguished from the Antarctic species by its three rows of nodes at the periphery on the last whorl and two rows of nodes on the penultimate whorl. *Amberleya whangaroaensis* n. sp. is also much smaller. *Amberleya spinigera* has only one row of nodes on the last whorl and posterior whorls and a sharper shoulder angulation. The New Zealand species is similar to the type species *A*. *bathonica* Cox *in* Knight et al. (1960, Fig. 203-5), but is separated from the English species in having more rows of nodes and spiral cords on the last whorl. *Amberleya bathonica* has only one row of nodes at the periphery like the Antarctic species, but lacks the anterior spiral cords prevalent in the New Zealand and Antarctic species.

Etymology.-Species named for its type locality along the north shore of Whangaroa Harbour, Northland.

Genus *CALLIOMPHALUS* Cossmann, 1888

Calliomphalus Cossmann, 1888, p. 48.

Type species.-(by subsequent designation) *Turbo squamulosus* Lamarck, 1804.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-*Calliomphalus* has received relatively little attention from workers over the years since its erection in 1888 by Cossmann (e. g. Wenz, 1938; Sohl, 1960; Kase, 1984; Hickman and McLean, 1990). Kase (1984, pp. 61-62) reported the oldest known *Calliomphalus* species from the Early Cretaceous (Aptian-Albian) of Japan, further extending the previously reported ranges of Late Cretaceous to Tertiary of Sohl (1960, p. 53), Late Cretaceous to Miocene of Wenz (1938, p. 325) and Keen *in* Knight *et al*. (1960, p. I253), and Late Cretaceous to Eocene of Hickman and McLean (1990, p. 79). The diagnosis of *Calliomphalus* given by Sohl (1960, p. 53) was: "Trochiform shell with a nacreous inner shell layer, commonly with beaded or spinose spiral sculpture; base striated; umbilicus wide and with noded margin; aperture round to subround". A closely related subgenus, *Calliomphalus* (*Planolateralus* Sohl, 1960) differs from *C*. (*C*.) s. s. by the former having "round-sided posteriorly shouldered whorls, which lack either a basal keel or axial sculpture on the base" (Sohl, 1960, p. 54).

Sohl (1960) did not compare his latest Cretaceous *Calliomphalus* s. s. species with the type, *C. squamulosus* (Lamarck, 1804), from the Eocene of the Paris Basin. This species has quite variable whorl profiles as figured by Keen *in* Knight *et al*., 1960, p. I252, Fig. 162-7 and Hickman and McLean, 1990, p. 82, Fig. 44-H). According to Keen *in* Knight *et al*. (1960, p. I252), a further distinguishing feature of *Calliomphalus* s. s., not mentioned by Sohl, is the presence of an "ear-shaped process" on the inner lip. Late Cretaceous species apparently lack this feature, and the taxonomic significance of this character is uncertain. Furthermore, Hickman and McLean (1990, p. 79) listed *Calliomphalus* and *Planolateralus* as questionably related to other genera in their informal Calliotropini. These authors gave little information regarding this uncertainty except to state that these groups are more appropriately assigned here than to the Chilodontinae, based on both the inferred convergence of ornamentation of *Planerolateralus* on *Cidarina* (also Calliotropini) (which is seemingly negative evidence) and the restricted carbonate facies of coeval Tethyan Chilodontinae. No evidence was presented by Hickman and McLean to explain the supposed convergence of sculpture between *Planerolateralus* and *Cidarina*. Incidentally, Hickman and McLean (1990, pp. 79, 86) treated *Planerolateralus* as generically distinct from *Calliomphalus*, unlike Sohl (1960) who assigned the former group as a subgenus of *Calliomphalus*. In my opinion, the subtle differences between these two taxa indicate that subgeneric distinction is more appropriate than generic separation in accordance with Sohl's original decision. The recent work on this group by Hickman and McLean (1990) resulted in a shift of *Calliomphalus* from the Angariidae or Trochidae: Angariinae (Wenz, 1938; Sohl, 1960; Keen *in* Knight *et* *al*., 1960) to Trochidae: Eucyclinae who stated that this genus is definitely trochacean and seems "to fit more comfortably into the Trochidae than to the Turbinidae" (p. 42) and further, as stated above, into the tribe Calliotropini. The groups in this clade seem to be more associated with clastic settings (unconsolidated sediments predominantly) than to carbonate platform environments and firm substrates (Hickman and McLean, 1990, p. 80).

A new species from Maastrichtian rocks of Kaipara, Northland, represents *Calliomphalous*, but the subgenus-level assignment is tentative. The umbilicus of this new species is moderately wide like *Calliomphalous* s. s., but the presence of a posterior, peripheral angulation is more similar to *C*. (*Planolateralus*). However, the peripheral angulation of *C*. (s. l.) *hickmanae* n. sp. from New Zealand is well-developed also on the penultimate whorl, unlike most species in *C*. (*Planerolateralus*). Sohl (1960, p. 55) in his diagnosis of *C*. (*Planerolateralus*) stated that one of the diagnostic features of this subgenus is the presence of a noded, umbilical margin, but the species of *C*. (*C*.) s. s. figured by Sohl have generally stronger umbilical nodes than species of *C*. (*P*.). Sculpture appears to variable in both *C*. (*C*.) s. s. and *C*. (*Planerolateralus*). A further disparity is the equally strong spiral and axial sculpture of C. s. l. hickmanae n. sp. Calliomphalous s. s. has dominating spiral sculpture; conversely C. (Planerolateralus) has strong axial sculpture. Future work may see the elimination of C. (Planerolateralus), especially in light of species like C. (P.?) angustus Sohl, 1960, and C. s. l. hickmanae n. sp. The mix of characters seen in these species suggests that, indeed, C. (Planolateralus) may not be a monophyletic group and should be abandoned.

CALLIOMPHALOUS s. l. HICKMANAE n. sp.

Plate 32 Figures 14-16; Plate 33 Figures 1-2

Diagnosis.-Shell relatively thin, trochiform with phaneromphalous, moderately wide umbilicus; spire angle about 75°; last whorl greatly inflated, mostly convex, with posterior angulation due to inflated, raised, narrow, spiral cord; spiral sculpture slightly stronger than axial sculpture of about 40 closely spaced spiral cords; umbilicus bordered by angulation; differs from C. (P.?) angustus Sohl in having an inferred lower spire, wider umbilicus, stonger umbilical angulation, and more subdued axial sculpture.

Description.-Shell small- to medium-sized, relatively thin, trochiform; umbilicus phaneromphalous, moderately wide; most of spire missing, inferred to be low, of three or four, posteriorly angulate, gently convex to somewhat straight-sided whorls; spire angle approximately 75°; protoconch unknown; growth lines opisthocyrt; suture impressed, slightly channelled; last whorl capacious, convex, well-inflated compared to penultimate whorl, posterior ramp moderately sloping, posteriorly angulate due to an inflated, narrow, sharp spiral cord, angulation located at a point midway between shell periphery and sutural margin; penultimate whorl with similar, equally strong, posterior angulation; sculpture subreticulated, of numerous, closely spaced, raised, approximately 40 spiral cords and secondary spiral threads, intersected obliquely by opisthocyrt growth lines; spiral and axial sculpture approximately at right angles on inflated posterior angulation; spiral sculpture on last and penultimate whorls slightly stronger than axial sculpture; base mostly flat; umbilicus bordered by moderately strong angulation; umbilical walls generally smooth, except for growth lines; aperture holostomatous, inferred to be subcircular.

Dimensions.-Holotype G 7039 (from AU 2553) height 8.5 mm incomplete, diameter of last whorl 9.0 mm; paratype Ge 7670.1 (AIM) height 4.5 mm incomplete, diameter of last whorl 5.5 mm.

Types.-Holotype G 7039 (AU), paratype Ge 7670.1 (AIM).

Type locality.-Te Opu, Kaipara, Northland, Q08/f9639.

Figured specimen.-G 7039 (AU).

Material.-Two specimens. Several other poor examples, including Ge 7911 (AIM), Ge 8070.1 (AIM), Ge 8070.2 (AIM), Ge 7672 (AIM) may represent this species.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-*Calliomphalus* s. l. *hickmanae* n. sp. is generically similar to *C*. (*Planerolateralus*?) *angustus* Sohl, 1960 (p. 58, Pl. 5, Figs. 20-22) from the Upper Cretaceous Ripley Formation of

Tennessee, except that the New Zealand species has a wider, phaneromphalous umbilicus, an inferred shorter spire, a stronger umbilical angulation and more subdued axial sculpture. The last whorl profile of *C*. (*C*.) sp. of Sohl, 1960 (p. 55, Pl. 5, Fig. 11) from the Upper Cretaceous Owl Creek Formation is also similar to *C*. s. l. *hickmanae* n. sp., but sculpturally these two species are distinct. The spiral and axial sculpture of the type species of *Calliomphalus*, *C*. *squamulosus* (Lamarck, 1804) (refigured by Wenz, 1938, p. 325, Fig. 741; Keen *in* Knight *et* *al*., 1960, p. I252, Fig. 162-7; Hickman and McLean, 1990, p. 82, Fig. 44-H) from the Paris Basin (Eocene of France) is much stronger than in *C*. s. l. *hickmanae* n. sp., and the type species lacks a posterior angulation which is moderately strong in the New Zealand species. *Afrollonia* *matsushimensis* Kase, 1984 (pp. 60-61, Pl. 6, Figs. 5, 8-10) from the Early Cretaceous of Japan is superficially similar to *C*. s. l. *hickmanae* n. sp. in outline and sculpture, but the former Japanese species is bicarinate with subsutural tubercles and strong umbilical ornamentation, unlike *C*. s. l. *hickmanae* n. sp. which only has a posterior angulation and generally fine sculpture without tubercles. Although the holotype of *C*. s. l. *hickmanae* n. sp., a rare species in the Northland Late Cretaceous molluscan fauna, is partially decorticated, the remnant shell is exquisitely preserved, so that detail of shell microsculpture is revealed. Like other members of the *Calliomphalus* group, *Calliomphalus* s. l. *hickmanae* is inferred to have been a deposit feeder that lived in a clastic environment of mostly unconsolidated, fine-grained sediments on the mid shelf.

Etymology.-Species named after C. S. Hickman, Museum of Paleontology, University of California, Berkeley, for her work on fossil and recent trochacean gastropods.

KAIPAROMPHALUS n. gen.

Diagnosis.-Shell small- to medium-sized, shell moderately thick, trochiform; spire low with gently convex, non-shouldered, rapidly expanding whorls; shell phaneromphalous, umbilicus moderately wide; early teleoconch whorls with subreticulate sculpture of relatively strong, thin, axial cords that diminish in strength abapically and equally strong, thin, spiral cords; sculpture generally fine; umbilical margin finely noded; base mostly flat.

Type species.-*Kaiparomphalus austrinus* n. sp.

Biogeographic element.-Endemic, as inferred here.

Discussion.-*Kaiparomphalus* is proposed as a new genus within Trochidae Eucyclinae. Despite the plethora of genus-group names in Trochidae there is seemingly no previously described group to which *Kaiparomphalus austrinus* n. sp. belongs. The closest allies of *Kaiparomphalus* n. gen. are inferred to be *Calliomphalus* s. s. Cossmann, 1888 (Early Cretaceous to mid Tertiary), and *C*. (*Planerolateralus*) Sohl, 1960 (Late Cretaceous only?), both of the Eucyclinae. As mentioned above, Hickman and McLean (1990, p. 79) listed *Calliomphalus* and *Planerolateralus* as questionably related to other Recent gastropod taxa of Calliotropini; the phylogenetic relationships of these groups to other trochid groups is uncertain. Disparity in shell sculpture, basal angulation, spire height and whorl expansion between *Kaiparomphalus* n. gen. and *Calliomphalus* s. s. and *C*. (*Planerolateralus*) are considered here the most distinguishing diagnostic features separating the above groups. In particular, Kaiparomphalus n. gen. has overall finer sculpture of closely spaced, subreticulate cords that diminish in strength abapically not found in species of Calliomphalus s. s. and C. (Planerolateralus) and lacks a basal angulation present in most species of the two groups above. Whorl expansion in Kaiparomphalus n. gen. from penultimate to last whorl is greater, compared to species in C. s. s. and C. (P.). These differences cited above between Kaiparomphalus n. gen. and Calliomphalus s. s. and C. (Planerolateralus), in my opinion, are sufficient grounds for the genus-level separation of the herein considered, endemic, short-lived Maastrichtian eucycline group Kaiparomphalus.

Etymology.-Genus named after the type locality, Kaipara, Northland, and inferred relationship to Calliomphalus.

KAIPAROMPHALUS AUSTRINUS n. gen. n. sp.

Plate 33 Figures 4-10, 13

Diagnosis.-Same as for genus.

Description.-Shell small- to medium-sized, moderately thick, trochiform; spire moderately low, paucispiral, of at least three gently convex, non-shouldered, rapidly expanding whorls; shell phaneromphalous, umbilicus moderately wide; protoconch unknown; spire angle about 80°; suture slightly impressed; growth lines opisthocyrt; whorl expansion great from penultimate to last whorl; last whorl strongly convex, capacious, sculptured with numerous, closely spaced, spiral cords and slightly weaker axial growth lines; early teleoconch whorls with subreticulate sculpture of relatively strong, closely spaced, thin, slightly raised, axial cords that diminish in strength abapically and equally strong spiral cords; sculpture overall fine; umbilical margin moderately defined, bordered by very fine nodes; umbilicus with both closely spaced spiral and axial threads; base mostly flat to very gently convex; peristome holostomatous, ovate to subcircular.

Dimensions.-Holotype G 7040 (from AU 2574), height 4.5 mm incomplete, diameter of last whorl 4.5 mm; paratype TM 7520 (IGNS) height 5.0 mm incomplete, diameter of last whorl 5.5 mm; paratype G 7041 (from AU 2574) height 3. 5 mm incomplete; paratype Ge 7670.1 (AIM) height 4.5 mm incomplete, diameter of last whorl 5.0 mm; paratype G 7042 (from AU 2574) height 6.5 mm, diameter of last whorl 7.0 mm.

Types.-Holotype G 7040 (AU); paratypes, TM 7520 (IGNS), G 7041 (AU), G 7042 (AU), Ge 7670.1 (AIM).

Figured specimens.-G 7040 (AU), TM 7520 (IGNS), G 7041 (AU), G 7042 (AU), Ge 7670.1 (AIM).

Material.-Ten specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9909 (type), Q08/f9626.

Stratigraphic range.-Unspecified horizon with Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-Kaiparomphalus austrinus n. gen. n. sp. has been recorded only from two localities in the Bull Point area, Kaipara, Northland. Few trochid taxa within Eucyclinae, whether

Cretaceous or more recent groups, approach *K*. *austrinus* n. gen. n. sp. in sculpture, suggesting that *Kaiparomphalus* was geologically short-lived and geographically restricted. *Calliomphalus* s. l. *hickmanae* n. sp., although both superficially similar and recorded from coeval rocks in the Kaipara area, Northland, is separated from *K*. *austrinus* n. gen. n. sp. in being relatively larger with a thinner shell and a developed, posterior angulation. It is possibile that *C*. s. l. *hickmanae* n. sp. is a gerontic example of *K*. *austrinus* n. gen. n. sp., but this seems very unlikely; the strong posterior angulation on the penultimate whorl of the thicker-shelled holotype of *C*. s. l. *hickmanae* n. sp. is quite distinct from whorl profiles that are free of any angulation in the ten thin-shelled specimens of *K*. *austrinus* n. gen. n. sp. *Calliomphalus* s. s. *americanus* Wade, 1926 (pp. 178-179, Pl. 60, Figs. 1-3; see numerous specimens figured by Sohl, 1960, p. 54, Pl. 5, Figs. 1-10), from the Upper Cretaceous Ripley Formation of Tennessee can be distinguished from *K*. *austrinus* n. gen. n. sp. by the former having a strongly noded umbilicus, less whorl inflation from penultimate to last whorl, much stronger spiral sculpture with variably strong tubercles, and a larger shell. *Kaiparomphalus* *austrinus* n. gen. n. sp. is inferred to have been an epifaunal browser that preferred unconsolidated sediments in an offshore setting in agreement with extant members of the Calliotropini.

Etymology.-Species named after the Latin "austrinus" (= southern) for its Austral occurrence.

Subfamily MONODONTINAE Cossmann, 1916

Genus CHRYSOSTOMA Swainson, 1840

Chrysostoma Swainson, 1840, p. 353.

Type species.-(by original designation) Turbo nicobaricus "Chemnitz, 1781" (not binomial) = Helix paradoxa Born, 1780. Hickman and McLean (1990, p. 100) attributed this latter species to Born, 1778.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-Chrysostoma is a Cretaceous to Recent monodontine group with a restricted geographic distribution similar to other genera in this group, known from the Indo-Pacific (Recent), New Zealand and provisionally East Africa (Wenz, 1938, p. 306). Chrysostoma, an epifaunal browser on rocky substrates, is restricted today to tropical and subtropical waters (Hickman and McLean, 1990, pp. 97-99).

Trechmann (1917, p. 299) erected Chrysostoma selwynensis for a unique specimen from the Selwyn Rapids deposits of Malvern Hills, Canterbury, South Island. Trechmann considered this specimen to be a "small and insignificant-looking shell" (ibid), but strongly believed this species as related to the Recent type species of Chrysostoma, C. paradoxum (Born, 1778) (see Swainson, 1840, p. 353, Fig. 112 (a-b); Wenz, 1938, p. 306, Fig. 680; Keen, 1960, p. I253, Fig. 163-8; Lindner, 1976, Pl. 6, Fig. 20; Hickman and McLean, 1990, Fig. 58G, for various examples). Chrysostoma selwynensis does, indeed, appear to be related to C. paradoxum, but the latter Recent species has a longer, steeper posterior ramp and a thicker parietal callus. Little attention has been given to C. selwynensis since Trechmann's (1917) description and was not discussed in Wilckens' (1922) monograph of New Zealand

Late Cretaceous gastropods and was more recently left out of the extensive list of Cretaceous New Zealand Mollusca in Wellman (1959). I know of no new material of *C. selwynensis*. Additional collections by University of Otago workers, including myself, in the Selwyn Rapids area have unfortunately not included specimens of *C. selwynensis*.

CHRYSOSTOMA SELWYNENSIS Trechmann, 1917

Plate 33 Figures 11-12

Chrysostoma selwynensis Trechmann, 1917, p. 299, Pl. 21, Fig. 4a-b; Wilckens, 1922, p. 32; Speight, 1928, p. 25.

Type.-Holotype G 27427 (BMNH; Trechmann, 1917, Pl. 21, Fig. 4a-b).

Figured specimen.-G 27427 (BMNH).

Type locality.-Selwyn Rapids, Canterbury, South Island, exact locality not known.

Stratigraphic distribution.-Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Distribution.-Selwyn Rapids, Canterbury, South Island.

Discussion.-As far as I am aware, *Chrysostoma selwynensis* is the oldest member of this group; no coeval species have been described from around the southern circum-Pacific for comparison and no other species are known from the New Zealand Cenozoic. Perhaps the documented decrease in water temperatures during the latest Cretaceous-early Tertiary (see Spicer and Corfield, 1992) forced *Chrysostoma*, an inferred subtropical to tropical genus, to migrate from New Zealand to lower latitudes and hence to warmer water. The presence today of *Chrysostoma* in New Caledonia may reflect this migration.

Subfamily CALLIOSTOMATINAE Thiele, 1924

Genus CALLIOSTOMA Swainson, 1840

Calliostoma Swainson, 1840, p. 351.

Type species.-(by subsequent designation, Herrmannsen, 1846) Trochus conulus Linné, 1758 (T. zizyphinum Linné, 1758 (Abbott, 1974, p. 42)).

Synonyms.-Numerous, including Conulus Nardo, 1841, Manotrochus Fischer, 1885 (Keen, 1960, p. I257; Abbott, 1974, p. 42). Hickman and McLean (1990, p. 109) realized a need for a full review of Calliostoma as New Zealand and Australian authors tend to recognize in general more genera than European and North American systematists who have traditionally used Calliostoma s. s. and subgenera of Calliostoma. This general pattern, where New Zealand and Australian systematists recognize more genera than their northern colleagues apparently exists for many molluscan groups and is not just restricted to Calliostoma.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-Calliostoma decapitatum Wilckens, 1922, from the Late Cretaceous of New Zealand seems more appropriately placed in this calliostomatine group than any other. In outline C. decapitatum is strikingly similar to C.? ojii Kase, 1980, from the Early Cretaceous of Choshi District, central Japan, and also to C.? sp. of Kase (1984) from the Early Cretaceous of the Miyako area, Japan. Kase (1980, p. 298) believed that the presence of the "thick, inclined and anteriorly lobed columellar lip agrees well with that of the genus Calliostoma", but umbilical differences between his his species, C.? ojii, and C. (s. s.) indicates to me that a genus-level separation is probably warranted. Further, Hickman and McLean (1990, p. 111) stated that the thickened and anteriorly lobed columellar lip in *C*.? *ojii* of Kase as consistent with *Calliostoma*, alone warrants separation at genus-level. *Calliostoma decapitatum* lacks the thickened and anteriorly lobed columellar lip characteristic of the Early Cretaceous Japanese species, and most likely represents an early member of the *Calliostoma* group. Hickman and McLean (1990, p. 109) emphasised that the genus did not become recognizable until the Late Cretaceous. *Calliostoma decapitatum* is inferred to have been an epifaunal browser, mostly on soft substrates (Warren and Speden, 1978, p. 50, Tab. 5). Furthermore, Recent species of calliostomatine trochids live on various substrates and prefer coelenterates, sponges and tunicates as invertebrate prey (Hickman and McLean, ibid.).

CALLIOSTOMA DECAPITATUM Wilckens, 1922

Plate 33 Figures 14-17

Calliostoma decapitatum Wilckens, 1922, pp. 4-5, Pl. 1, Figs. 6a-b, 7a-b.

"*Calliostoma*" *decapitatum* Wilckens, Fleming *in* Wellman, 1959, p. 141.

Calliostoma? *decapitatum* Wilckens, Warren and Speden, 1978, p. 50, Tab. 5.

Supplementary description.-Shell medium-sized, moderately thick, trochiform, spire conic; spire of at least five, mostly flat-sided to very gently concave whorls; protoconch unknown; spire angle approximately 56°; ratio of height to diamater of base slightly less than 1:1; suture mostly indistinct, mostly flush on teleoconch; last whorl somewhat compressed, slightly inflated at very strongly angled periphery; base mostly flat; growth lines subprosocline; sculpture mostly indistinct, of fine spiral threads, apparently slightly stronger on base; penultimate and older whorls with slightly inflated anterior, spiral cord, adjacent to suture; shell anomphalous; details of columella unknown; aperture subquadrate.

Dimensions.-TM 7521 (IGNS) height 12.0 mm, diameter of base 11.0 mm.

Types.-Lectotype TM 2588 (IGNS; Wilckens, 1922, Pl. 1, Fig. 6); TM 2595 (IGNS; Wilckens, 1922, Pl. 1, Fig. 7).

Figured specimens.-TM 2588, TM 2595?, TM 7521 (all IGNS).

Material.-Three specimens.

Localities.-Penehu Point, north side of Hokianga Harbour, Northland, O05/f9573; west wing of Haumuri Bluff, southern Marlborough, South Island, O32/f8026 (type); east wing of Haumuri Bluff, O32/f9025.

Stratigraphic range.-Okarahia Sandstone, also unnamed? unit at Hokianga (Piripauan Stage, upper Campanian, Upper Cretaceous).

Geographic distribution.-Hokianga, Northland to Haumuri Bluff, southern Marlborough.

Discussion.-Beu and Maxwell (1990, p. 116) treated *Calliostoma* (s. l.) *waiareka* (Laws, 1935) from the Late Eocene (Kaiatan Stage) as the oldest named definite member of the genus in New Zealand, but made no mention of *C. decapitatum* from the Late Cretaceous. No *Calliostoma* species have been recorded from New Zealand Paleocene rocks, but an undescribed species of the genus was noted by B. A. Marshall (personal commun.) *in* Beu and Maxwell (1990, p. 116) in Mangaorapan rocks (upper Lower Eocene) of North Canterbury.

Wilckens (1922, p. 5) compared *C. decapitatum* with *Tectus tamulicus* Stoliczka, 1868 (pp. 371-372, Pl. 24, Figs. 4-5), from the Late Cretaceous of southern India; indeed, a close relationship of the above two species seems probable. *Tectus tamulicus* is not a *Tectus*, but most likely an early member of *Calliostoma*. Stoliczka's assignment of this Cretaceous Indian species is surprising, given that *Tectus* s. s. has strong axial folds, unlike *T. tamulicus* which is mostly smooth and void of axial folds. I am unaware of any other Late Cretaceous *Calliostoma* species in marine deposits around the southern circum-Pacific which might be compared with *C. decapitatum*.

The distribution of *C. decapitatum* is extended here to include the Hokianga region, Northland. More material of this seemingly rare species is needed to more clearly define the details of the aperture, columella and protoconch.

TROCHIDAE gen. indet. n. sp.

Plate 33 Figure 3

Description.-Shell medium-sized, moderately solid, trochiform; spire low of at least three, convex whorls; spire angle approximately 48°; protoconch conical, paucispiral?; suture impressed; whorl inflation rapid from penultimate to last whorl; last whorl inflated, convex; sculpture wanting, most likely preservational; umbilicus shallow; base flat; aperture subcircular?

Dimensions.-TM 7522 (IGNS) height 12.5 mm, diameter of last whorl 10.0 mm; TM 7523 (IGNS) height 5.0 mm, diameter of last whorl 5.0 mm.

Locality.-Just north of Koromea (Red Island), southern Hawke's Bay, North Island, W22/f8499 (GS 4894).

Figured specimen.-TM 7522 (IGNS).

Material.-Five specimens, mostly worn.

Stratigraphic range.-Formation unknown, believed to be Mangaotanean (Santonian?) to Piripauan Stages (upper Campanian, Upper Cretaceous) ("Base of Mangatu? on intraformational conglomerate in Tapuwaeroa", I. W. Keyes, pers. commun., 1993).

Geographic range.-Known only from southern Hawke's Bay.

Discussion.-Five specimens of an inferred trochid species, labelled as "Gibbula" n. sp. by an unknown worker at the Institute of Geological and Nuclear Sciences, are available to me for study. The subfamily- and genus-level affinities of this presumed new species are uncertain, except to suggest that a close relationship with Gibbula s. s. Risso, 1826, is unlikely since the very smooth shell with strongly convex whorl profiles is different from Gibbula s. s. The affinity of this species may lie within the Gibbulinae; however, whether the species is related to smooth-shelled groups such as Nanula Thiele, 1924, or Buckmanina Cossmann, 1920, remains to be shown. The smooth nature of the shell in this species is most likely a reflection, in part, of preservation as even growth lines are not preserved.

Suborder NERITOPSINA Cox and Knight, 1960

Superfamily NERITACEA Rafinesque, 1815

Family NERITOPSIDAE Gray, 1847

Subfamily NATICOPSINAE S. A. Miller, 1889

Genus DAMESIA Holzapfel, 1888

Damesia Holzapfel, 1888, p. 168.

Type species.-(by subsequent designation, Wenz, 1938) Crepidula cretacea (Müller, 1851).

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-As Sohl (1960, p. 63) pointed out Damesia is poorly represented in the fossil record and poorly known taxonomically. Wenz (1938, p. 419) assigned Damesia as a subgenus of Otostoma Archiac, 1859, but Sohl (ibid) disagreed with Wenz as so far as that these groups are closely related on the grounds of "growth history and presence of the umbilicus" in Damesia which is different from Otostoma. A further distinguishing feature of these genera is the absence of teeth in the aperture of Damesia; Otostoma has teeth. Cox in Knight et al. (1960, p. I277) separated Damesia from Otostoma at genus- and subfamily-levels, as is followed here. Damesia is one of the more curious neritopsid gastropods with its greatly inflated last whorl and eccentric, flattened spire.

A specimen (TM 7526, IGNS) from Okarahia Stream in the vicinity of Haumuri Bluff, southern Marlborough, South Island (O32/f8790) conforms to the generic diagnosis of Damesia. Apertural features of the Okarahia Stream specimen are concealed by very hard, well-cemented sandstone matrix, so that only a tentative assignment is made. The specimen probably represents a juvenile of the species which appears to be new. If indeed a member of Damesia this is the first record of the restricted Late

Campanian to Maastrichtian genus in the southern hemisphere, previously represented by two species in Germany, D. cretacea Müller, 1851, and D. decheni Holzapfel, 1888, and a further rare species from latest Cretaceous of Mississippi, North America, D. keownvillensis Sohl, 1960.

DAMESIA? n. sp.

Plate 35 Figure 1

Description.-Shell small, thin, mostly smooth, narrowly globose; spire eccentric, flat, flush with top of aperture; whorl inflation rapid; protoconch smooth, one whorl?, slightly emersed; suture canaliculate; whorls of spire somewhat loosely coiled; growth lines subprosocline; sculpture partially eroded, spiral component vague, axial component of slightly wavy, narrow threads and growth lines; apertural details concealed by matrix.

Dimensions.-TM 7526 (IGNS) (from GS 9827) height 2.5 mm, diameter of last whorl 4.5 mm.

Figured specimen.-TM 7526 (IGNS).

Material.-One specimen, probably a juvenile.

Locality.-Okarahia Stream, southern Marlborough, South Island, O32/f8790.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous).

Geographic distribution.-Southern Marlborough, South Island.

Discussion.-Damesia? n. sp. is striking similar to D. cretacea (Müller, 1851) (figured by Cox in Knight et al., 1960, p. I277, Fig. 181-6), the type species of Damesia, from the latest Cretaceous of Germany in outline, eccentric spire and sculpture. Damesia? n. sp. is discriminated from D. cretacea in having an even flatter spire and mostly smooth shell with obsolete axial and spiral elements (possibly due in part to shell erosion). It cannot be discounted altogether that this species is an *Otostoma* as the apertural details are unknown and presence of teeth would preclude its placement in *Damesia*. Some latest Cretaceous south African neritopsid species such as *Nerita unzambiensis* Woods, 1908 (p. 311, Pl. 37, Figs. 14-15), and *N. kaffraria* Woods, 1908 (p. 311, Pl. 37, Fig. 16) also have flattened eccentric spires similar to *D.*? n. sp.

Subfamily NERITOPSINAE Gray, 1847

Genus *NERITOPSIS* Grateloup, 1832

Neritopsis Grateloup, 1832, p. 126.

Type species.-(by original designation) *Neritopsis moniliformis* Grateloup, 1832.

Synonym.-*Nerilopsis* (err. pro *Neritopsis*) d'Orbigny, 1842, pp. 174-177, 1843, Pl. 176, Pl. 177 bis. Neave (ed., 1940, p. 319) in the *Nomenclator Zoologicus* incorrectly attributed *Nerilopsis* to d'Orbigny, 1843, p. 174.

Biogeographic element.-Cosmopolitan (Keen *in* Knight *et al*., 1960, p. I279).

Discussion.-Wilckens (1924, p. 542, Pl. 54, Fig. 5) described a poorly preserved, incomplete gastropod specimen from the Shag Point area, North Otago, and tentatively assigned this specimen to the cosmopolitan Triassic to Recent genus *Neritopsis* which was also geographically widespread during the Cretaceous. This poor preservation leads me, as with Wilckens, to tentatively assign his species to *Neritopsis*, pending the discovery of other material from Shag Point. A partially decorticated specimen (TM 7527, IGNS)) from inferred Maastrichtian rocks from Northland is probably conspecific with the Shag Point species; preserved sculpture on the specimen indicates that this example is a *Neritopsis* and, further, may be a latest Cretaceous representative of *Hayamiella* Kase, 1984, proposed originally as a subgenus of *Neritopsis*. *Hayamiella* is characterised by its generally small size, globose shell and "coarsely cancellated surface ornamentation formed by intersecting spiral cords and transverse axial ribs" (Kase, 1984, p. 83). In the New Zealand species minute pustules are present at the intersection of the axial and spiral cords and the collabral sculpture is more orthocline, compared to *N*. (*Hayamiella*), which has more rounded, weak nodes and more prosocline, collabral sculpture, but the New Zealand species seems more appropriately placed in *N*. (*Hayamiella*) at this time pending further work.

Subgenus *HAYAMIELLA* Kase, 1984

Hayamiella Kase, 1984, p. 83.

Type species.-(by original designation) *Neritopsis* (*Hayamiella*) *japonica* Kase, 1984.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

NERITOPSIS (*HAYAMIELLA*?) sp.

Plate 35 Figures 2-3

Neritopsis? sp., Wilckens, 1924, p. 542, Pl. 54, Fig. 5; Marwick and Fleming *in* Wellman, 1959, p. 139; Crampton and Moore, 1990, p. 347.

Dimensions.-TM 7527 (IGNS) height 20.0 mm incomplete, diameter of last whorl 20.0 mm incomplete.

Previously figured specimen.-TM 2609 (IGNS; Wilckens, 1924, Pl. 54, Fig. 5).

Figured specimens this work.-TM 2609, TM 7527 (both IGNS).

Localities.-Shag Point, Otago Beach, Otago, South Island, J43/f6472; ?Matakea Point, northeast side of Shag Point boat harbour, Otago, J43/f6544; Waitangi River, Northland, P05/f9499; ?Waiau River, eastern central North Island, V18/f8500.

Material.-Two specimens.

Stratigraphic range.-Kaitiki Formation and unnamed? North Island formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland to Otago, South Island.

Discussion.-An early catalogue of New Zealand fossils listed a species of Neritopsis in "Chalk and Marl, overlying Sandstone with Reptilian bones, and streaks of Coal" (Conway Siltstone?) at Haumuri Bluff, southern Marlborough (Catalogue of the Colonial Museum, Wellington, 1870, p. 192), but the absence of N. (Hayamiella?) sp. at this locality suggests that the species of Neritopsis referred to in the Catalogue actually represents the Neritopsis-like species Protodolium speighti or Procancellaria parkiana. Wilckens (1924, p. 542) compared Neritopsis? sp. with N. crassa Stoliczka, 1868 (pp. 309-310, Pl. 23, Fig. 7), from the Late Cretaceous of southern India, but did not comment on any similarities between these two taxa; most likely, the similarity of cancellate sculpture in N. crassa prompted Wilckens' decision to assign this problematic New Zealand species to Neritopsis. The cancellate sculpture of Neritopsis? sp. is also strikingly similar to Nerilopsis (sic.) robineausiana d'Orbigny, 1842 (pp.

174-175; 1843, Pl. 176, Figs. 1-4) from the Early Cretaceous of Saint-Sauveur, France, but the former New Zealand species has more widely spaced, axial and spiral cords, compared to N. robineausiana. Neritopsis robineausiana and N. crassa have recently been assigned to N. (Hayamiella) (Kase, 1984, p. 84).

Genus PROTODOLIUM Wilckens, 1922

Protodolium Wilckens, 1922, pp. 18-20.

Type species.(by original designation) Neritopsis? speighti Trechmann, 1917.

Synonym.-Pseudodolium Wilckens, 1922 (= **nomen nudum**) (Stilwell, 1994b, p. 3).

Diagnosis.-"Shell medium- to large-sized, moderately thick and solid, subglobose; spire low, moderately obtuse of at least three flat-sided to gently convex whorls; mean spire ange ranging from about 73°-112°; protoconch obtusely conical to slightly domed of two smooth whorls; growth lines orthocline; last whorl moderately to greatly inflated, convex, sculpture variable, predominantly spiral of strong, raised, flattened, wide cords separated by deep furrows and weak to moderately collabral strong growth lines; some specimens with axial sculpture and blunt tubercles; penultimate whorl with two or three spiral cords; umbilicus very shallow; columella concave adapically; abapical portion of inner lip slightly reflected; inductura moderately thick, narrow, thinning to a variably broad to narrow glaze in parietal region; aperture holostomatous, broadly ovate to subovate." (Stilwell, 1994b, p. 3).

Biogeographic element.-Paleoaustral (Stilwell, 1994b, p. 3).

Discussion.-"Wilckens (1922, p. 18) erected the New Zealand Late

Cretaceous endemic monotypic genus *Protodolium* for *Neritopsis*? *speighti* Trechmann, 1917. Wilckens noted that *P*. *speighti* has similarities in shell outline and sculpture to species of the Recent and Tertiary genus *Dolium* Lamarck, 1801 (= *Tonna* Brünnich, 1772) and thus interpreted *Protodolium* as being an early representative of the family Doliidae (= Tonnidae). Earlier, Trechmann (1917, p. 300) stated that *Neritopsis*? *speighti* is more likely to be related to *Neritopsis* Grateloup, 1832, than to such genera as *Cinulia*, *Dolium*, *Pyrula*, and *Fossarus* because the "moderate thickness of the shell and increasing thickness of the adult lip and sharpness of the aperture point to *Neritopsis*..." Wilckens (1922, p. 19) disputed Trechmann's earlier conclusion as the relationships with *Neritopsis* by concluding that "*Neritopsis* is characterised by the broad angular emargination of its inner lip, not present in *P*. *speighti*. Wickens wrongly thought that the absence of a "channel" (= siphonal canal) in *Protodolium* is a primitive character and that in this Cretaceous genus "...the channel of *Dolium* has not yet developed" (p. 19). *Tonna* species are siphonostomatous with a fasciole and thin shell, quite unlike *Protodolium*, which is holostomatous without a fasciole and has a shell of moderate thickness. Wilckens, in my opinion, placed too much weight on inferred homeomorphic characters in the orders Neritomorpha and Neotaeniglossa among others such as shell outline, sculpture and growth lines (which are common to several groups, including *Tonna*), and too little on the absence of a siphonal canal in *Protodolium*. Ironically, Wilckens' use of "*Pseudodolium*" (p. 5, here considered a **nomen nudum**; most likely a name used in earlier drafts of Wilckens' paper that remained unchanged after the formal naming of *Protodolium*) would have been more appropriate than *Protodolium*, since the latter implies a phylogenetic relationship with *Dolium* (= *Tonna*).

Wenz (1941, p. 1076) reviewed the diagnostic features of *Protodolium* and tentatively placed the genus in Tonnidae without discussion. As a sidenote, Wenz stated that *Protodolium* is present in Maastrichtian rocks of North America and Java?, though these records are unsubstantiated. *Protodolium* escaped the attention of Kase and Maeda (1980) and Kase (1984) in their extensive discussions on *Neritopsis*-like gastropods. Apparently, *Protodolium* has received little or no taxonomic attention since Wenz (1941).

The overall morphology of *Protodolium* is here taken to indicate a relationship to the Mid Jurassic to Recent genus *Neritopsis* s. s. Features common to *Protodolium* and *Neritopsis* include a globose to subglobose outline reflecting a capacious, convex last adult whorl; a moderately thick shell; a low, obtuse spire of few whorls; abaxial orthocline to adaxial prosocline growth lines towards the inner lip; variable spiral and axial sculpture, consisting in most species of predominantly spiral cords, some taxa with collabral ribs; a shallowly umbilicate to nonumbilicate shell; a thickened, narrow, inner lip; a holostomatous aperture; and an unarmoured to slightly armoured labrum. The type species of *Protodolium*, *P*. *speighti*, differs from the type species of *Neritopsis*, *N*. *moniliformis* Grateloup, 1832 (pp. 125-131, Figs. 1-3; see Wenz, 1938, p. 412, Fig. 999), from the Miocene of Europe and the Recent Indo-Pacific species *N*.

radula (Linné, 1758) (Wenz, 1938, p. 412, Fig. 1001; Cox *in* Knight et al., 1960, pp. I278-I279, Fig. 182-7-9; Cernohorsky, 1972, pp. 52-53, Pl. 11, Fig. 11; Dance, 1989, p. 97, Fig. 6), in having a larger shell; a slightly less inflated last whorl and hence a broadly convex outer lip; a slightly higher spire; well-spaced, very strong, flattened, thick spiral cords mostly without rounded nodules or pustules; a subsuturally swollen, thickened posteriormost (adapical) spiral rib giving a somewhat angular, subsutural profile; a smooth, concave columella without a blunt tooth; a seemingly more reflected abapical portion of the inner lip; an obsolete umbilicus; and an elongate subovate to sublenticular aperture. The main features of *Neritopsis* s. s. are a small, globose shell up to 20 mm high with convex whorls; sculpture of spiral rows of small, rounded pustules or nodules, and closely spaced axial riblets; a large, orbicular aperture, striated within; concave columella; and the presence of blunt, central tooth on the columella (cf. Cernohorsky, 1972, pp. 52-53; cf. Kase, 1984, p. 81). *Protodolium* differs from *Hayamiella* Kase *in* Kase and Maeda, 1980 (type species *H. rex* Kase, 1980, pp. 301-305, Pl. 35, Figs. 5-10, text-fig. 7, Figs. 2a-b), a Late Triassic to Late Cretaceous subgenus of *Neritopsis*, by the latter having a quadrate depression in the central part of the inner lip surface and sculpture of granulate, spiral cords or reticulation, significantly different from typical *Protodolium*. *Neritoptyx* Oppenheim, 1892 (type species *Nerita goldfussii* Keferstein *in* Goldfuss, 1844 (see Cox *in* Knight et al., 1960, p. I279, Figs. 182-183)), a Late Cretaceous European subgenus of *Neritopsis*, is differentiated from Protodolium in having a prominent, parietal tubercle, absent in Protodolium. Protodolium is tentatively separated from Neritopsis s. s., N. (Hayamiella) and N. (Neritoptyx) at genus-level due to the above differences in sculpture, inner lip and aperture shape, but future work may show that a subgenus-level separation is more appropriate. Although it is usually easy to differentiate between Neritopsis s. s. and N. (Hayamiella) species, morphologically intermediate forms exist (Kase, 1984, p. 83), so further study is needed to assess phylogenetic relationships between these taxa. Any similarity between Protodolium and siphonostomatous Tonna is superficial.

The paleoautecology of Protodolium speighti (Trechmann, 1917) has received little attention in the literature. It has been interpreted as an epifaunal carnivore (Warren and Speden, 1978: 50, tab. 5; Crampton and Moore, 1990: 347), evidently because of the perceived relationship with carnivorous Tonna. Marine neritacean gastropods are predominantly herbivorous and are generally intertidal (Cernohorsky, 1972: 48), so Protodolium may have had the same habits. However, although rocky shores are the main environment for neritacean gastropods, they have been observed living on sand as far as 300 m away from the nearest rock, indicating a preadaptation to a burrowing lifestyle (Fischer, 1966: 52). Also, dead shells of Neritopsis atlantica have been recovered from the sandy bottom off the coast of Cuba at 10-15 m depth (Sarasua, 1973: 5). Most records of Protodolium have been collected from sandstone deposited at interpreted tidal to subtidal depths (most likely shallower than mid shelf), suggesting that some Cretaceous neritopsids lived at greater depths than most living neritaceans. The moderately thick, solid shell of Protodolium species suggests that the foot was probably quite muscular. The functional significance of the very slight depression along the abapical-most part of the inner lip (more obvious in P. pittensis n. sp. than in P. speighti) is uncertain, but may be the attachment site of the operculum (P. A. Maxwell, pers. comm.) or alternatively reflect the presence of a small inhalant siphon." (Stilwell, 1994b, pp. 3-5).

PROTODOLIUM SPEIGHTI (Trechmann, 1917)

Plate 34 Figures 1-19

Neritopsis (?) speighti Trechmann, 1917, pp. 300-301, Pl. 19, Figs. 12-15; Neritopsis speighti (sic.), Wilckens, 1922, p. 18, error.

Protodolium speighti (Trechmann), Wilckens, 1922, pp. 18-20, Pl. 4, Figs. 3a-b, 4a-b, 5; Wilckens, 1924, p. 541; Wenz, 1941, p. 1076, Fig. 3065; Fleming in Robinson, 1958, p. 18; Marwick and Fleming in Wellman, 1959, pp.. 139, 142; Fleming in Wilson, 1963, p. 25; Warren and Speden, 1978, p. 50, Tab. 5; Crampton and Moore, 1990, p. 347; Stilwell in Aitchison et al., 1993, p. 50, Fig. 3e; Stilwell, 1994b, pp. 1-16, Figs. 2a-h, 3a-j.

Supplementary description.-"Shell medium-sized, moderately thick, solid, subglobose; spire low, only 20% of total height of shell, moderately obtuse, compressed, paucispiral, of three, almost flat-sided to weakly convex whorls; whorl inflation rate high after apical whorls, highest between penultimate and last adult whorls; mean spire angle approximately 112°; protoconch obtusely conical to slightly domed, paucispiral, of two smooth whorls;

suture slightly impressed; growth lines orthocline, very shallow sinus abapically; last whorl capacious, well-inflated, moderately convex, whorl profile of adapical portion of last whorl to periphery somewhat flat; basal constriction mostly constant; last whorl sculpture predominantly spiral, of 12-15, very strong, raised, spaced, flattened spiral cords, separated by 1.0-1.5 mm wide, deep interspaces or furrows, crossed perpendicularly by orthocline growth lines abaxially, more curved adaxially towards inner lip; spiral cords 1.5 mm wide on average (adult shells); few shells with broad axial sculpture, more subdued than spiral sculpture; adapical spiral rib on last whorl subsuturally thickened, inflated, 3.5 mm wide; first spiral furrow appears well abapical of adapical portion of sutural ramp; penultimate whorl with only two, strong, spiral cords; umbilicus very shallow; umbilicus with narrow furrow extending to abapical part of inner lip, paralleling abaxial margin of inner lip; abapical portion of inner lip slightly reflected; abapical portion of columella broadly concave; inductura moderately thick, narrow; parietal region with variable (size and shape), moderately broad to narrow glaze; aperture broadly ovate, holostomatous; labrum smooth." (Stilwell, 1994b, p. 5).

Dimensions.-OU 40916 height 30.5 mm, diameter of last whorl 27.5 mm; OU 40917 height 29.5 mm, diameter of last whorl 30.0 mm; OU 40918 height 14.5 mm, diameter of last whorl 12.0 mm; TM 7460 (IGNS) (from GS 13) height 32.0 mm, diameter of last whorl 30.0 mm; TM 7461 (IGNS) (from GS 11359) height 18.5 mm, diameter of last whorl 18.0 mm; TM 7462 (IGNS) (from GS 589) height 10.5 mm nearly complete, diameter of last whorl 11.0 mm.

Types, figured and museum specimens.-Lectotype G 27447 (BMNH; Trechmann, 1917, Pl. 19, Fig. 12; Stilwell, 1994b, Fig. 2a) (designated herein); paralectotypes G 27448-27450 (BMNH; Trechmann, 1917, Pl. 19, Figs. 13-15 respectively; Stilwell, 1994b, Figs. e-f, b respectively); paralectotype G 27451 (BMNH; not figured); TM 2646 (IGNS; Wilckens, 1924,p. 541); TM 2647 (IGNS; Wilckens, 1924, p. 541); TM 2648 (IGNS; Wilckens, 1924, p. 541); TM 2649 (IGNS; Wilckens, 1922, Pl. 4, Fig. 5); TM 2650 (IGNS; Wilckens, 1922, Pl. 4, Fig. 4; Wenz, 1941, Fig. 3065; Stilwell, 1994b, Figs. 2g-h); TM 2651 (IGNS; Wilckens, 1922, Pl. 4, Fig. 3; Stilwell, 1994b, Fig. 2c-d); OU 40537 (OU; Stilwell in Aitchison et al., 1993, Fig. 3e); OU 40916 (OU; Stilwell, 1994b, Fig. 3a-c); OU 40917 (OU; Stilwell, 1994b, Fig. 3g); OU 40918 (OU; Stilwell, 1994b, Fig. 3e); TM 7460 (IGNS; Stilwell, 1994b, Fig. 3d); TM 7461 (IGNS; Stilwell, 1994b, Figs. 1, upper left, 3i-j).

Figured specimens herein.-G 27447, G 27448, G 27449, G 27450 (all BMNH), OU 40916, OU 40917, OU 40918, TM 7460 (IGNS), TM 7461 (IGNS), TM 7462 (IGNS); TM 2649-2651 (IGNS).

Type locality.-Selwyn Rapids, Malvern Hills, mid Canterbury, South Island, New Zealand, exact locality not given by Trechmann (1917), most likely near L35/f6017 or L35/f6008.

Material.-Fourteen specimens and other fragments.

Localities.-?eastern slope of Barron's Hill, Otago, South Island, I44/f8519; Fairfield Quarry, Otago, near I44/f173; near junction of Taieri Beach and Taieri River Mouth Roads, Otago, I45/f8517; Shag Point, Otago, J43/f6472, J43/f159; ?North Branch of

Waianakarua River, Otago, J42/f082; Selwyn River, Malvern Hills, mid Canterbury, South Island, L35/f6017, L35/f6008; Selwyn Rapids, L35/f74; Middle Waipara, Canterbury, M34/f7263; South Branch of Waipara River, Canterbury, M34/f7658; Haumuri Bluff, southern Marlborough, South Island, O32/f9542; west wing of Haumuri Bluff, O32/f8025; Okarahia Stream, southern Marlborough, O32/f8790; Waitangi River, Northland, P05/f9499; Gittos Point, Northland, Q09/f9502; Waiau River, central North Island, V18/f8500; south bank of Mangahouanga Stream, Hawke's Bay, North Island, V19/f182A; Mangahouanga Stream, V19/f6909; east bank of Te Hoe River, Hawke's Bay, V19/f184, V19/f185; west bank of Te Hoe River, V19/f186, V19/f195; main branch of Waikokopu Stream, Hawke's Bay, W18/f026.

Stratigraphic range.-Okarahia Sandstone (note stratigraphic position of P. speighti in column of Warren and Speden, 1978: 46, fig. 27) (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds (= Conway Formation?), Brighton Formation, unspecified formation of "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Chaplin Sandstone of Robinson (1958, unpublished name), Katiki Formation, Maungitaniwha Sandstone (Upper Cretaceous).

Discussion.-"Trechmann (1917, p. 301) reported the presence of Neritopsis? speighti at only one locality in New Zealand: Selwyn Rapids, in the Malvern Hills, Canterbury. Later, Wilckens (1922, p. 18) reported Protodolium speighti from four localities at "Amuri" (= Haumuri) Bluff in southern Marlborough; Selwyn Rapids in Canterbury; and middle Waipara. Fleming in Robinson (1958, p. 18) reported P. speighti as present in the southernmost extent of

Upper Cretaceous, macrofossiliferous marine rocks (Chaplin Sandstone, unpublished name) of the Taieri River Mouth area, East Otago. Marwick and Fleming in Wellman (1959, p. 139) recorded this species, in addition, from Shag Point and Barron's Hill, Otago. Warren and Speden (1978, p. 46, Fig. 27) recorded the stratigraphic range of P. speighti in the Haumuri Bluff area as the lower part of the Okarahia Sandstone to possibly the lowest part of the Conway Siltstone. Speden in Wiffen (1980, p. 527) identified Protodolium sp. (probably P. speighti) from Campanian-Maastrichtian rocks of Mangahouanga Stream, western Hawke's Bay, associated with Moanasaurus mangahouangae. More recently, Crampton and Moore (1990, p. 347) reported P. speighti from several localities in the Te Hoe River area, western Hawke's Bay, extending for certain the geographic range of the species to include North Island. Protodolium speighti is also present in the Katiki Formation of the Waianakarua River area, North Otago (Stilwell in Aitchison et al., 1993) and the Fairfield Greensand Member of the Brighton Formation at Fairfield Quarry, Otago (this work). In summary, P. speighti has been identified from approximately 20 localities in North and South islands, the metric grid references of which are listed in the Appendix.

A supposed operculum of "Velates sp. cf. Neritopsis speighti" was noted (unpublished) in the information given for locality X17/f7674 (GS 8405) (headwaters of Ron Stream, Raukumara Peninsula, eastern North Island) originally determined by J. Marwick and re-examined by I. Speden in 1970. This supposed operculum is most likely a fracture mark which has been misconstrued as an operculum or possibly the operculum has been lost (I. W. Keyes and A. G. Beu, pers. comm., 1992). As far as I know, no Protodolium specimens have been recovered with operculae present. As neritopsid taxa have thick operculae, it would indeed be possible to find a specimen of P. speighti with an operculum preserved." (Stilwell, 1994b, pp. 8-9).

Superfamily LOXONEMATACEA Koken, 1889

Family ZYGOPLEURIDAE Wenz, 1938

Genus ZYGOPLEURA Koken, 1892

Zygopleura Koken, 1892, p. 203.

Type species.-(by subsequent designation, Cossmann, 1909) Cerithium meyeri Klipstein, 1843.

Biogeographic element.-Cosmopolitan (Cox in Knight et al., 1960, p. I315).

Discussion.-The Mesozoic zygopleurid gastropod Zygopleura is characterised by having strongly convex whorls and well-defined parasigmoid riblets without spiral ornament (Cox in Knight et al., 1960, p. I315). A New Zealand Cretaceous species previously referred to Katosira, K. obliquestriata Trueman, 1924, seems more related provisionally to Zygopleura. The parasigmoid curve in the growth lines present in K. obliquestriata is very strong compared to that present in the type species, K. periniana (d'Orbigny) (see Wenz, 1938, p. 384, Fig. 919; Cox in Knight et al., 1960, p. I315, Fig. 209-1), from the Late Jurassic of France which has very weak parasigmoid riblets. Although it is acknowledged that the presence of a spiral element in K. obliquestriata most likely precludes its placement in Zygopleura, this species is more closely related to Zygopleura which has strong parasigmoid axials. It seems likely that K. obliquestriata represents a new genus, but will not be named here due to insufficient knowledge of Zygopleuridae taxonomy and stratigraphic position of the species. Cox in Knight et al. (1960, p. I315) and Sepkoski (1982, p. 28) cited the range of Zygopleuridae as Triassic to Late Jurassic. The presence of Zygopleuridae in inferred Upper Cretaceous rocks of New Zealand greatly extends the range of this family.

ZYGOPLEURA? OBLIQUESTRIATA (Trueman, 1924)

Plate 35 Figures 5-6, 8-14

Katosira obliquestriata Trueman, 1924, pp. 601-604, Figs. a-f; Ongley and Macpherson, 1928, NZGS Bull. 30, p. 32.

Supplementary description.-Shell medium-sized, thin, polished, high-spired turriform; whorl inflation rate constant; spire high of at least eight convex whorls; spire angle about 20°; protoconch partially preserved, axial ornament present; suture impressed; growth lines strongly parasigmoid, more opisthocline on extreme anterior portion of whorls near suture; posterior slope of last whorl steep, slightly concave; axial sculpture stronger than spiral sculpture; axial riblets strong on earliest whorls fading abruptly medially on fourth? whorl; early whorls with about 15 riblets; axial ornament on fifth? to last whorls reduced to strong, very closely spaced growth lines; spiral component weak of alternating weak threads and raised blunt, mostly flattened ribs broadening anteriorly and becoming more spaced; aperture holostomatous, sublenticular; inner lip thickened with narrow inductura broadening and thinning to glaze in parietal region; outer lip thin.

Dimensions.-TM 7528 (from GS 1086) height 33.0 mm, diameter of last whorl 12.5 mm; TM 7530 (from GS 2077) height 21.0 mm incomplete; TM 7529 (from GS 2077) height 30.0 mm incomplete.

Types.-Holotype TM 2603 (IGNS; Trueman, 1924, Fig. a); paratypes TM 2598-2602, TM 2604-2607 (all IGNS).

Figured specimens herein.-TM 2598-2607, TM 7528-7529 (all IGNS).

Material.-13 specimens.

Localities.-Rotokautuku Creek, Tapuwaeroa Valley, Raukumara Peninsula, North Island, Z15/f6489 (GS 1086) (changed to "Mangarua Creek" on IGNS fossil record form); Mangarua Creek, Tapuwaeroa Valley, Z15/f6500 (GS 2077) (type); ?north side of Tapuwaeroa River, Z15/f6500; Mangahmi Stream, Tapuwaeroa Valley, Z15/f7529.

Stratigraphic range.-Tapuwaeroa Formation (Haumurian Stage?, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-East Cape area, North Island.

Discussion.-Curiously, Zygopleura? obliquestriata is restricted at present to the Tapuwaeroa Valley, East Cape, Raukumara Peninsula, North Island, where it has been collected from a few localities in monotypic concentrations in siltstone. As far as I am aware, no attention has been given to this species since Trueman's description in 1924 apart from a short acknowledgment of the presence of K. obliquestriata in a boulder in Mangarua Creek, Mangaoporo, by Ongley and Macpherson (1928, p. 32). High-spired Zygopleura-like gastropods of uncertain affinity and superficial similarity to "Z." obliquestriata have also been collected in inferred Cretaceous rocks of North Island; these specimens (TM 7531 (Pl. 35 , Fig. 7), TM 7532 (Pl. 35, Fig. 15), TM 7533 (Pl. 35, Fig. 4)) are labelled as "Loxonema n. sp.", but the very strong fasciole present on the specimens suggests placement elsewhere other than Loxonematacea.

Superfamily CERITHIACEA Fleming, 1822

Discussion.-See Houbrick (1988) for extensive discussion of cerithiacean phylogeny.

Family POTAMIDIDAE H. and A. Adams, 1854

Genus BITTISCALA Finlay and Marwick, 1937

Bittiscala Finlay and Marwick, 1937, pp. 44-45.

Type species.-(by original designation) Scala (Epitonium) simplex Marshall, 1917.

Biogeographic element.-Endemic, as inferred here (possibly Indo-Pacific/Tethyan).

Discussion.-Finlay and Marwick (1937) erected Bittiscala for a latest Cretaceous to earliest Tertiary cerithiid gastropod having a shell similar to Epitonium, but with a circular to rhomboidal aperture that is "somewhat effuse and showing a rudimentary, oblique, wide, anterior notch at the base of the pillar..." (p. 44). Wenz (1940, p. 747) was unsure of the subfamilial placement of Bittiscala and assigned this genus to the Batillariinae, but was apparently certain of the group's allocation to Potamididae. Beu and Maxwell (1990, p. 406) also included Bittiscala in the Potamididae. Finlay and Marwick's assumption that Zeacumantus Finlay, 1927 [Zeacumanthus, error, Wenz, 1940, p. 748], is related to Bittiscala (perhaps ancestor-descendent) is apparently a valid one. Zeacumantus has a more developed, deeper notch in the canal, but otherwise *Bittiscala* is very similar in outline and sculpture.

Although *Bittiscla* is considered here to be endemic, Elder and Saul (1993, p. 184, Pl. 2, Fig. 9) figured a supposed Campanian species of *Bittiscala* from the Pigeon Point Formation of California, North America. Whether or not the California species is congeneric with *Bittiscala* cannot be deduced from the sole figure (in side profile) of Elder and Saul.

Potamidid gastropods today are mostly tropical to temperate in distribution and inhabit predominantly intertidal, muddy habitats (Powell, 1979, p. 131). *Bittiscala inaequicostata* (Wilckens, 1922) from the Maastrichtian of New Zealand was perhaps an epifaunal browser (Warren and Speden, 1978, p. 50, Tab. 5). Crampton and Moore (1990, p. 347) were more certain that *Bittiscala* was an epifaunal browser; furthermore, the species' presence in the Maungataniwha Sandstone of western Hawke's Bay indicates that the preferred depth of *Bittiscala* was most likely shallow, nearshore in fully marine conditions of moderate to high energy. This interpretation is consistent with the presence of *Bittiscala* in the inferred shallow marine Conway Formation of Haumuri Bluff, southern Marlborough.

BITTISCALA INAEQUICOSTATA (Wilckens, 1922)

Plate 35 Figures 17-18, 20-21

Cerithium inaequicostatum Wilckens, 1922, pp. 8-9, Pl. 2, Fig. 4.
Bittiscala inaequicostata (Wilckens), Finlay and Marwick, 1937, p. 45; Marwick and Fleming *in* Wellman, 1959, p. 139; Warren and Speden, 1978, p. 50, Tab. 5; Moore *et al*., 1988, p. 59, Tab. 1; Crampton and Moore, 1990, p. 347.

Dimensions.-TM 7534 (IGNS) height 15.5 mm, diameter of last whorl 7.0 mm); OU 40975 height 12.5 mm.

Type.-Lectotype (designated herein) TM 2614 (IGNS; Wilckens, 1922, Pl. 2, Fig. 4).

Figured specimens.-TM 2614 (IGNS); TM 7534-7535 (IGNS); OU 40975.

Material.-Three specimens. Two other poor specimens and TM 7535 (IGNS) from Te Hoe River, western Hawke's Bay, may represent this species.

Localities.-Shag Point, North Otago, South Island, c.J43/f6544; east wing of Haumuri Bluff, southern Marlborough, South Island, O32/f9031 (type); Hook Stream, western Hawke's Bay, North Island, V19/f6507; Mangahouanga stream, western Hawke's Bay, North Island, V19/f6909; upper reaches of upper tributary of Waihoroihika Stream, western Hawke's Bay, North Island, W18/f10.

Stratigraphic range.-Conway Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous), Maungataniwha Sandstone, Katiki Formation (Upper Cretaceous).

Geographic distribution.-Western Hawke's Bay, North Island to Shag Point, South Island.

Discussion.-Finlay and Marwick (1937, p. 45) stated that the main differences between Bittiscala inaequicostata (Wilckens, 1922) and the type species B. simplex (Marshall, 1917) (p. 451, Pl. 34, Figs. 1, 2; Wenz, 1940, p. 747, Fig. 2160) are that the former Cretaceous species is larger with coarser spiral sculpture. I know of no specimen of B. inaequicostata with the aperture preserved.

Bittiscala inaequicostata is a rare gastropod species in the

Late Cretaceous molluscan fauna of New Zealand and is known from only five localities spanning North and South Islands. Moore *et al*. (1988 p. 59, Tab. 1) were the first to recognise *B. inaequicostata* in the North Island, specifically the Lake Waikaremoana area, in the Upper Cretaceous Maungataniwha Sandstone. More recently Crampton and Moore (1990, p. 347) recognised this species in the western Hawke's Bay area. Before this work, *B. inaequicostata* had been reported only from a single locality at Haumuri Bluff, southern Marlborough, South Island (Wilckens, 1922; Warren and Speden, 1978, p. 50, Tab. 5). This species is further known in the South Island from Shag Point, North Otago (this work).

Family PROCERITHIIDAE Cossmann, 1905

Subfamily METACERITHIINAE Cossmann, 1906

Genus *BATHRASPIRA* Cossmann, 1906

Bathraspira Cossmann, 1906, p. 52.

Type species.-(by original designation) *Cerithium tecta* d'Orbigny, 1842.

Biogeographic element.-Indo-Pacific/Tethyan, as inferred here.

Discussion.-*Bathraspira* is a member of the ancient, long-ranging, Paleozoic to Mesozoic gastropod family Procerithiidae. Sepkoski (1982, p. 28) in a review of fossil marine families stated that the range of Procerithiidae was Devonian to latest Cretaceous (Maastrichtian). *Bathraspira* represents a relatively short-lived end-member of this lineage which was previously reported from Aptian to Albian rocks of Europe (France, Germany, Switzerland, England), Madagascar and Japan (Wenz, 1940, p. 734; Abbass, 1973, p. 123; Kase, 1984, pp. 133-134) and now is recognised for the first time in uppermost Cretaceous rocks of New Zealand, considerably extending the stratigraphic range of the group.

The type species of Bathraspira, B. tecta (d'Orbigny, 1842) (pp. 368-369, 1843, Pl. 230, Figs. 4-6; Wenz, 1940, p. 734, Fig. 2126; Abbass, 1973, pp. 123-126, Pl. 3, Figs. 1-2?, also Figs. 1-3, 1-4) from the Early Albian of France, Germany, Switzerland and Madagascar can be distinguished from all other Bathraspira species by "its characteristic pagodiform shape, which is the result of the contiguity of the concave adapical part of the whorl and the sharp, posterior carina" (Abbass, ibid., p. 124). Study of d'Orbigny's original figures of B. tecta (Pl. 230, Figs. 4-5) indicate further that this species is bicarinate on the last whorl with moderately fine spiral sculpture, fine, weakly opisthocline growth lines, a subquadrate aperture and a short, narrow, oblique, siphonal canal. A specimen inferred by Abbass to be conspecific with B. tecta from the Albian of England (Pl. 3, Fig. 2) reveals more opisthocyrt growth lines posteriorly and orthocline growth lines medially between the carinae, suggesting variability of growth lines in this species. Bathraspira zealandica n. sp. from the Late Cretaceous of New Zealand fits comfortably in this genus and is described below.

Bathraspira is inferred to have been an epifaunal, sea-floor scavenger similar to the interpreted habit of Procerithium and Recent cerithacean groups (see McKerrow, ed., 1978, pp. 212, 216, 222, 272). Bathraspira zealandica n. sp. is interpreted also to have lived probably in a shallow-water shelf environment.

BATHRASPIRA ZEALANDICA n. sp.

Plate 35 Figures 16, 19

Diagnosis.-Small- to medium-sized *Bathraspira* with high-spired, pagodiform shell; spire angle about 35°; last whorl tricarinate with medial, principal carina separated by more abapical, bunched, subdued carinae; growth lines opisthocyrt to more orthocline subsuturally; spiral sculpture weak of sparse spiral cords; aperture subpentagonal; separated from *B. tecta* by having less developed carinae on the spire and last whorl that are more abapical in position and fewer spirals.

Description.-Shell small- to medium-sized for genus, moderately thick, high spired pagodiform; spire moderately high, of at least five, strongly carinate whorls; whorl inflation relatively constant; protoconch unknown; spire angle approximately 35°; suture impressed; growth lines faint, opisthocyrt, slightly orthocline subsuturally; last whorl slightly inflated, tricarinate; posterior slope of last whorl concave, merging with medial, narrowly rounded (slight abrasion?), pronounced, principal carina, separated anteriorly by narrow concavity and two, more subdued, bunched carinae; spiral sculpture weak, of about five cords on posterior slope, and a single spiral cord, of equal strength, located just anterior of medial carina and between anteriormost carinae and medial carina; penultimate and earlier whorls similarly sculptured with strong, subsutural carina anteriorly and sparse, spiral cords on posterior slope and at least one cord abapically below carina, just above suture; axial sculpture extremely vague; aperture siphonostomatous, subpentagonal, incompletely preserved on holotype; outer lip thin.

Dimensions.-Holotype TM 7536 (IGNS) height 11.0 mm nearly complete, diameter of last whorl 6.25 mm.

Type.-Holotype TM 7536 (IGNS).

Type locality.-Waimarama, southeastern North Island, W22/f8499 (GS 4894).

Figured specimen.-TM 7536 (IGNS).

Material.-One specimen.

Stratigraphic range.-Maungataniwha Sandstone? or other formation (Upper Cretaceous, probably Mangaotanean Stage (Santonian) or Piripauan Stage (upper Campanian)).

Geographic distribution.-Southeastern North Island.

Discussion.-*Bathraspira zealandica* n. sp. from Upper Cretaceous rocks of North Island has a close morphological affinity with the type species of *Bathraspira*, *B*. *tecta* (d'Orbigny, 1842) discussed above, apart from the position and strength of carinae and slight sculptural differences. *Bathraspira zealandica* n. sp. has less swollen, less pronounced, more abapical carinae on the spire and last whorl fewer spiral cords overall compared to *B*. *tecta* which has very strong, medial carinae and numerous spiral cords. The disparity in growth lines between *B*. *zealandica* n. sp. and *B*. *tecta* may be more apparent than real, per different figured specimens of *B*. *tecta*. *Bathraspira zealandica* n. sp. is separated from the English, Late Albian species *B*. *fouadi* Abbass, 1973 (pp. 128-129, Pl, 3, Figs. 7, 8, 12, 13) in having weaker spiral sculpture, slightly sharper carinae and also slightly more adapical carinae, compared to the English species. Otherwise, general outline and growth lines appear to agree well between *B*.

zealandica n. sp. and B. fouadi. Bathraspira zealandica n. sp. is very rare in the Late Cretaceous molluscan record of New Zealand and I am aware of only specimen having been collected to date.

Etymology.-Species named for its presence in New Zealand Cretaceous rocks.

Genus RHABDOCOLPUS Cossmann, 1906

Rhabdocolpus Cossmann, 1906, p.

Type species.-(by original designation) Melania scalariformis Deshayes, 1830; figured by Eudes-Deslongchamps, 1842.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-Described Late Jurassic to Late Cretaceous European Rhabdocolpus species are currently in a state of taxonomic flux leading to difficulties in their appropriate classification and interpretation of Procerithiidae relationships; it is apparent that a greater range of morphological features is present in Rhabdocolpus than previously determined (Abbass, 1973, p. 142). This acknowledged variability in Rhabdocolpus, especially axial sculpture, has lead me to assign this newly described, problematic, inferred latest Cretaceous, New Zealand species tentatively to this group, pending further work and more complete material. Abbass (1973, pp. 141-146) in his review of Cretaceous procerithiid taxa from England was faced with a similar dilemma in the assignment of believed procerithiid species, mostly from the Isle of Wight, and very tentatively assigned his species to Rhabdocolpus.

RHABDOCOLPUS? MINUTUS n. sp.

Plate 36 Figures 1-2

Diagnosis.-Small for genus with moderately slender spire; spire angle 20°; sculpture predominantly axial, of 12 spaced, variable, nearly straight to slightly curved, subaxially aligned, axial ribs and single, posterior, subsutural, low, undulating, spiral cord on spire; last whorl with spaced axial ribs and eight, closely spaced spiral cords on base; differs from the type species, *R. scalariforme* in being much smaller with obsolete spiral sculpture of a single undulating, subsutural cord.

Description.-Shell small, moderately solid, slender, moderately high-spired turriform; spire moderately high with four, moderately compressed, subrectangular, very gently convex whorls; whorl inflation slow, constant; spire angle 20°; protoconch unknown; suture slightly impressed; growth lines very faint, opisthocyrt, apex of sinus located medially; last whorl small, subrectangular, ornamentated with eight basal, closely spaced, spiral cords, commencing at abapical end of axial ribs, becoming more spaced adapically; axial ribs on last whorl very strong, well-spaced, variable from oblique, nearly straight ribs to slightly sinuous ribs; penultimate and earlier whorls similarly sculptured of predominating axial sculpture and obsolete spiral sculpture; penultimate and earlier whorls with 12 spaced, subaxially aligned, nearly straight to slight curved, axial ribs and a single, posterior, subsutural, slightly raised, rounded, undulating, moderately wide, spiral cord; axial ribs on spire disappear at onset of undulating spiral cord; aperture siphonostomatous with short? canal (poorly preserved on holotype); base gently convex.

Dimensions.-Holotype G 7043 (from AU 2548) height 6.75 mm incomplete, diameter of last whorl 3.0 mm.

Type.-Holotype G 7043 (AU).

Type locality.-Northeastern shore of Kaiwhata Estuary, Hokianga, Northland, O05/f136.

Figured specimen.-G 7043 (AU).

Material.-One well-preserved, nearly complete specimen.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon", formation unspecified (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Hokianga, Northland.

Discussion.-Rhabdocolpus? minutus n. sp. appears quite similar in terms of axial sculpture, overall outline and whorl profile to R. scalariforme (Eudes-Deslongchamps, 1842) (refigured by Wenz, 1940, p. 727, Fig. 2103), the type species of Rhabdocolpus, from the Middle Jurassic of Europe, except that the former New Zealand species is much smaller than the type species and has obsolete spiral sculpture. Rhabdocolpus? minutus n. sp. is more like B. scalariforme than three Cretaceous European species tentatively referred to this genus; these species are ?R. ?clementinum (d'Orbigny, 1842) (pp. 357-358, 1843, Pl. 228, Figs. 1-3; Abbass, 1973, pp. 142-143, Pl. 5 , Figs. 6, 12, 13 (d'Orbigny, 1843, p. 357, error); ?R. forbesianum (d'Orbigny, 1850) (redescribed by Abbass, 1973, p. 143-145, Pl. 5, Figs. 1-5); and ?R. melvillei Abbass, 1973 (pp. 145-146, Pl. 5, Fig. 7), all which have strong or dominant spiral sculpture compared to Rhabdocolpus s. s. which has very strong, widely spaced, axial ribs and somewhat weaker spiral cords. The near absence of spiral sculpture, except for a posterior, subsutural, undulating, low, spiral cord in *R*.? *minutus* n. sp. is most likely of subgenus-level significance, perhaps warranting separation from *Rhabdocolpus* s. s., but I defer assigning a new name at this time until more material is available. Only one specimen of *R*.? *minutus* n. sp. has been collected to my knowledge, and unfortunately most of the aperture and some of the spire is not preserved in the holotype. The uncertainties surrounding late Mesozoic species presently assigned to *Rhabdocolpus* will necessarily have to be cleared up before sound phylogenetic and paleobiogeographic interpretations can be presented.

Etymology.-Species named for its very small size.

Superfamily UNCERTAIN (HIPPONICACEA?)

Family UNCERTAIN (FOSSARIDAE?)

Genus *PROCANCELLARIA* Wilckens, 1922

Procancellaria Wilckens, 1922, pp. 21-23.

Type species.-(by monotypy) *Procancellaria parkiana* Wilckens, 1922.

Diagnosis.-"Ovate, with low spire, anomphalous; whorls convex; ornament cancellating collabral and spiral grooves, the former feebly prosocline; aperture ovate, and uninterrupted peristome, subangular adapically; columellar lip vertical, moderately expanded, without folds" (Cox *in* Knight *et al*., 1960, pp. I309-I310).

Biogeographic element.-Endemic.

Discussion.-The suprageneric classification of the endemic Late Cretaceous New Zealand gastropod *Procancellaria* is uncertain.

Procancellaria is characterised by having a low-spired ovate outline with convex whorls, an uninterupted peristome, sculpture of cancellating spiral and collabral grooves, no umbilicus, a moderately wide inductura and a columella without folds (Cox *in* Knight *et al*., 1960, pp. I309-I310). Wilckens (1922) believed that *Procancellaria*, as the name suggests, is a precursor to Tertiary *Cancellaria* species. As I have similarly shown in the discussion of *Protodolium*, Wilckens mistakenly interpreted *Procancellaria* as a precursor of *Cancellaria* through assuming that the columellar folds and siphonal canal, notably wanting in *Procancellaria*, are primitive features and that the cancellate sculpture of *Procancellaria* points to *Cancellaria* of Cancellariidae (Neogastropoda). "The channel is **in statu nascendi**. The folds of the columella and of the outer lip have not yet made their appearance." (Wilckens, 1922, p. 22). The absence of a siphonal canal and columellar plaits or folds (most cancellariid groups) precludes placement of *Procancellaria* in Cancellariidae, leading me to suggest that the similar cancellate sculpture on *Procancellaria* and *Cancellaria* is convergent.

Finlay and Marwick (1937, p. 81) stated that *Procancellaria* belonged in Littorinidae, a suggestion recently reinforced by A. Grebneff (personal commun., 1993). Wenz (1938, p. 268) delegated *Procancellaria* to Amberleyidae (now assigned to Trochidae: Eucyclinae by Hickman and McLean, 1990). Later Cox *in* Knight *et al*. (1960, pp. I309-I310) included *Procancellaria* in Archaeogastropoda as Superfamily and family uncertain. Sohl (1964, p. 170) stated that *Procancellaria* may be assignable to *Morea* of the Muricidae, but *Morea* is siphonostomatous with a pseudoumbilicus and a columellar fold, unlike *Procancellaria* which is holostomatous without a pseudoumbilicus or fold. *Procancellaria* seems most likely assignable to Archaeogastropoda, but the superfamily- and family-level assignments remain in question. The cosmopolitan Late Jurassic to latest Cretaceous genus *Ooliticia* Cossmann, 1893, of the Trochidae: Eucylinae may be a related to *Procancellaria*, but axial sculpture is wanting in *Ooliticia* and the outline of the spire is slightly different to *Procancellaria*. Another possibility is that *Procancellaria* is a relatively large primitive fossarid related to the Recent Indo-Pacific genus *Couthouyia* A. Adams, 1860; both of these genera have an uninterrupted peristome which is subangular, a gently deflected inner lip, and cancellate sculpture.

PROCANCELLARIA PARKIANA Wilckens, 1922

Plate 36 Figures 3-5, 7-8, 12

Procancellaria parkiana Wilckens, 1922, pp. 21-23, Pl. 5, Figs. 1-2; Finlay and Marwick, 1937, p. 81; Wenz, 1938, pp. 267-268, Fig. 555; Fleming *in* Wellman, 1959, p. 142; Cox *in* Knight *et al*., 1960, pp. I309-I310, Fig. 205-2; Warren and Speden, 1978, p. 50, Tab. 5, Figs. 25-14 and 15.

Morea? *parkiana* (Wilckens), Sohl, 1964, p. 170.

Supplementary description.-Shell small- to medium-sized, moderately thick, ovate; spire relatively low of three and a half narrow, convex whorls; whorl inflation very rapid from penultimate to last whorl; spire angle about 96°; protoconch paucispiral of 1½-2 whorls, cancellate ornament beginning halfway on second whorl; growth lines slightly prosocline; last whorl greatly inflated, convex, ornamented with spaced alternating collabral and spiral ribs and grooves, the intersections of which culminating in small rounded pustules; penultimate whorl with three spiral rows of ribs with pustules; aperture large, holostomatous, ovate; peristome uninterrupted; subangular abapically; inner lip smooth slightly concave, gently deflected anteriorly, expanded; inductura narrow in parietal region; outer lip thin, slightly crenulated.

Dimensions.-TM 2673 (IGNS) height 16.5 mm; TM 5380 (IGNS) height 9.5 mm incomplete; TM 7524 (IGNS) block 28.5 mm in length with three specimens; TM 7525 (IGNS) height 12.5 mm incomplete.

Types and previously figured specimens.-Lectotype TM 2673 (IGNS; Wilckens, 1922, Pl. 5, Fig. 2; Warren and Speden, 1978, Fig. 25-14); TM 2672 (IGNS; Wilckens, 1922, Pl. 5, Fig. 1 and unnumbered specimen to left of figure); TM 5380 (IGNS; Warren and Speden, 1978, Fig. 25-15).

Figured specimens herein.-TM 2672-2673, TM 5380, TM 7524, TM 7525 (all IGNS).

Material.-Seven specimens.

Localities.-West face of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 (type); lower Conway rail cutting, southern Marlbough, O32/f8793; ?railway cutting near mouth of Conway River, O32/f8221; Haumuri Bluff, O32/f9504, O32/f9505; north face of Haumuri Bluff, O32/f9530, O32/f9529; just above base of Cretaceous, Haumuri Bluff, O32/f9502; coast just south of Mikonui Stream, O32/f8774A; east wing of Haumuri Bluff, O32/f9027.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper

Campanian, Upper Cretaceous).

Geographic distribution.-Southern Marlborough, South Island.

Discussion.-Procancellaria parkiana is a problematic gastropod of uncertain affinity only recorded at present in the Okarahia Sandstone in the Haumuri Bluff area of southern Marlborough, South Island. The inferred life habits of P. parkiana are thought to have been that of an epifaunal? browsing lifestyle (Warren and Speden, 1978, p. 50, Tab. 5). The paleoautecology of Procancellaria parkiana should become clearer once the taxonomic affinity of this group is better known.

Family TURRITELLIDAE Woodward, 1851

Subfamily TURRITELLINAE Woodward, 1851

Genus COSTACOLPUS Marwick, 1966

Costacolpus Marwick, 1966, p. 79.

Type species.-(by original designation) Turritella solitaria wilckens, 1922.

Biogeographic element.-Endemic, as inferred here.

Discussion.-Costacolpus was proposed by Marwick (1966) as a monotypic Late Cretaceous genus with morphological features intermediate between Turritellidae and Loxononematacea. The generic diagnosis presented by Marwick (p. 79) is as follows (slightly modified here in modern terminology and with additional information): Shell small, turriculate, imperforate, whorls convex, suture well-defined, impressed, last whorl rounded, base undefined. Spire angle approximately 15°. Sculpture of numerous, regular, strong cords with narrow interstices, and broad, somewhat irregular, collabral ribs, strong on juvenile but weakening on adolescent and mostly obscolete on later whorls. Aperture broadly ovate, holostomatous; columella slightly concave; outer lip parasigmoid with wide lateral sinus, strongly opisthocline from adapical suture, gently convex on base. Marwick (1966, p. 81) believed that the dominant spiral sculpture of Costacolpus is more akin to Turritellidae than to Loxonematacea, but this assignment was considered arbitrary at the time since features such as "turriculate shape, imperforous base, holostomatous aperture, parasigmoid outer lip, strong spiral cords, and strong juvenile axials obsolescing later", found in Costacolpus, are consistent with both Turritellidae and Loxonematacea. Parasigmoid outer lip refers to the apex of the lateral sinus falling within about the adapical third of the whorl (Marwick, 1971, p. 10). The spiral sculpture of Costacolpus is unlike taxa within Loxonematacea which have generally smooth whorls with well-defined growth lines and/or dominantly axial sculpture, atypical of Costacolpus. The relationship of Costacolpus to Turritellidae seems more probable. Allmon et al. (1990, p. 597) suggested that all fossil and recent turritelline genus- and subgenus-level groups be assigned to Turritella s. l. as the taxonomy, especially for fossil groups, is as yet unresolved. The usage of Costacolpus is continued here in light of significant morphological differences between Costacolpus and Turritella s. s. At present Costacolpus is restricted to New Zealand.

COSTACOLPUS SOLITARIA (Wilckens, 1922)

Plate 36 Figures 6, 9-11, 13, 16-18

?Turritella sp., Trechmann, 1917, p. 299, Pl. 19, Fig. 11.

Turritella solitaria Wilckens, 1922, p. 35, Pl. 5, Fig. 20.

Costacolpus solitaria (Wilckens), Marwick, 1966, pp. 79-81, Figs. 1-4; Crampton and Moore, 1966, p. 347; ?Stilwell *in* Aitchison *et al*., 1993, p. 15.

Dimensions.-TM 2683 (IGNS) height 8.5 mm, diamter of last whorl 3.0 mm; TM 7537 (IGNS) height 4.5 mm incomplete; TM 7538 (IGNS) length of slab 32.0 mm.

Type.-Lectotype TM 2683 (IGNS; Wilckens, 1922, Pl. 5, Fig. 20; Marwick, 1966, Fig. 2).

Figured specimens.-TM 2683, topotypes TM 7537 and TM 7538 (all IGNS), all GS 293.

Material.-Four specimens and numerous fragments.

Localities.-Hapuka River, Marlborough, South Island O31/f9497 (GS 293) (type); ?long ridge above Jedburgh Station, Cheviot, southern Marlborough, South Island, O33/f9044; ?North Branch of Waianakarua River, North Otago, South Island, J42/f218; Mangahouanga Stream, western Hawke's Bay, North Island, V19/f6909B.

Stratigraphic range.-Unnamed? formation in Marlborough, Maungataniwha Sandstone, ?Katiki Formation (Upper Cretaceous).

Geographic distribution.-Hawke's Bay, North Island to possibly North Otago.

Discussion.-At the time of writings of Wilckens (1922) and Marwick (1966) the stratigraphical range of Costacolpus solitaria was uncertain, but most likely spanned part of the Teratan, Piripauan or Haumurian stages (Upper Cretaceous). The float boulder from which the type material of C. solitaria was collected in 1876 by A. McKay could not be pinned to one particular horizon. As a consequence preferably **in situ** material of C. solitaria is necessary to accurately define the stratigraphic limits of this species. Crampton and Moore (1990, p. 347) identified C. solitaria from float boulders in the Maungataniwha Sandstone of Mangahouanga Stream, western Hawke's Bay, North Island; the latter unit ranges from upper Campanian to Maastrichtian in age, further constraining the stratigraphic range and extending the geographic range of the species to include North Island. I recently collected numerous calcified, turritellid gastropods tentatively allocated to C. solitaria from the North Branch of the Waianakarua River, North Otago, South Island (J42/f218) in the Katiki Formation which also most likely ranges from upper Campanian to Maastrichtian (at this particular locality, probably Campanian).

Crampton and Moore (1990, p. 347) inferred Costacolpus solitaria to be an epifaunal deposit-feeding gastropod. Recent research on turritelline gastropods by Allmon (1988) has resulted in the discovery that Recent turritellines can be 1) sedentary to highly mobile; 2) infaunal, semi-infaunal or epifaunal in soft substrates to coarse or hard substrates; and 3) ciliary suspension-feeders and/or deposit-feeders or grazers part of the time, compared to the previous conservative view that turritellines are sedentary, infaunal gregarious detritus feeders. Whether or not C. solitaria was truly an epifaunal deposit feeder is arguable.

Superfamily STROMBACEA Rafinesque, 1815

Family APORRHAIDAE Gray, 1850

Subfamily APORRHAINAE Gray, 1850

Genus PERISSOPTERA Tate, 1865

Perissoptera Tate, 1865, p. 98.

Type species.-(by original designation) Rostellaria parkinsoni Mantell, 1822.

Biogeographic element.-Indo-Pacific/Tethyan as used here.

Discussion.-Perissoptera is a predominantly Cretaceous genus originating at some time in the Neocomian and present in Europe, Africa, southern India, North and South America, New Zealand (Wenz, 1940), Japan (Kase and Maeda, 1980; Kase, 1984), and the Antarctic Peninsula (Wilckens, 1910; del Valle et al., 1982; Stilwell and Zinsmeister, 1987c). On Seymour Island, Antarctic Peninsula, Perissoptera appears in the uppermost part of the Cretaceous/Tertiary boundary sequence and extends well up into the Sobral Formation which is Paleocene in age (Zinsmeister et al., 1989, pp. 733-734, Figs. 2-3). As far as I am aware no Perissoptera species have been recorded in rocks younger than Paleocene. In New Zealand Perissoptera is present only in Maastrichtian rocks. The type species of Perissoptera, P. parkinsoni (Mantell, 1822) was refigured and reviewed by d'Orbigny (1842, pp. 288-290, 1843, Pl. 208, Figs. 1-2) and Wenz (1940, pp. 923-924, Fig. 2706). D'Orbigny's figured specimen appears not to be conspecific with that specimen figured by Wenz as there is no anterior lobe on the outer lip. The type specimen from the Early Albian of England has a high-spired, alate, turriculate shell with stronger axial sculpture than spiral sculpture, a long, straight, narrow anterior canal, a long, narrow abaxially projecting posterior spine on the outer lip distally nearly paralleling the height of the spire and an anterior blunt-ended, slightly spatulate wing that is gently inclined anteriorly.

The life habits of Recent aporrhaid gastropod species are fairly diverse. In a recent review of Cretaceous Aporrhaidae and of the ecology of extant species, Popenoe (1983, pp. 750-752) commented that aporrhaids such as the extant *Aporrhais pespelicani* (Linné) (see Popenoe, Fig. 3, for sketch of live animal in life position) live both infaunally and epifaunally part of the time, but the relative amount of time for either habit has not been established and is debated in the literature. At least one species lives infaunally during the juvenile state and then changes to an epifaunal habit when mature. Species of *Perissoptera* were probably deposit feeders (Warren and Speden, 1978, p. 50, Tab. 5; Macellari, 1988, p. 43). Austral Cretaceous to earliest Tertiary species of *Perissoptera* show a bathymetric range from inferred shallow to at least mid shelf deposits. *Perissoptera waiparaensis* from New Zealand is recorded predominantly from fine-grained facies in the Conway Formation of South Island, a unit interpreted to be probably near-shore marine deposits (Warren and Speden, 1978, p. 28); this species also occurs in the "Northland Allochthon", in a setting inferred to be mid to outer shelf herein or deeper by Evans (1985, pp. 609, 620).

PERISSOPTERA WAIPARAENSIS (Hector, 1886)

Plate 36 Figures 14-15; Plate 37 Figures 1-12

?Rostellaria of von Haast, 1871, p. 35.

?Aporrhais of von Haast, 1879, p. 295.

Rostellaria waiparaensis Hector, 1886, p. 58, Fig. 20-3, figure only; Park, 1910, p. 92, Fig. 47-3.

Perissoptera waiparaensis Wilckens, 1922, pp. 11-12, Pl. 2, Figs. 8-9; Wilckens, 1924, p. 541; Finlay and Marwick, 1937, p. 62; Marwick and Fleming in Wellman, 1959, p. 139; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 26-5; Speden in Suggate et al., 1978, p. 363, Fig. 6.6-9; Speden and Keyes, 1981, p. 54, Pl. 22, Fig. 9; Crampton and Moore, 1990, p. 347; Stilwell in Aitchison et al., 1993, Fig. 4c.

Supplementary description.-Shell medium- to large-sized, alate, robust, high-spired turriculate; spire relatively high with at least five shouldered, convex whorls; whorl inflation relatively constant from apical to last whorl; spire angle about 30°; protoconch unknown; suture impressed; growth lines opisthocline becoming more orthocline anteriorly on last whorl; basal constriction moderately rapid; last whorl biangulate with moderately prominent posterior keel bearing blunt, rounded, axial tubercles becoming more elongated, axial, opisthocline towards the aperture and more subdued and rounded anterior keel without tubercles; spiral sculpture weak of numerous, closely spaced threads; penultimate whorl with about 15 axially extending, projecting tubercles and closely spaced spiral threads; some specimens exhibit a strong basal cord anterior to tubercle-bearing posterior keel; antepenultimate and earlier whorls similarly sculptured; aperture shape unknown; outer lip with long, narrow, mostly straight, obtusely angled posterior spine curved at base and shorter, moderately long, more blunt? anterior spine; anterior canal narrow, long?, straight?; inner lip with thick, evenly narrow callus extending from the canal to the parietal region.

Dimensions.-OU 40661 height 28.0 mm incomplete; Ge 8146.4 (AIM) height 33.5 mm incomplete; Ge 8147.6 (AIM) height 20.0 mm incomplete; Ge 8147.7 (AIM) height 22.0 mm incomplete; Ge 7655.2 (AIM) height 50.5 mm incomplete; Ge 5968 (AIM) height 7.5 mm incomplete (juvenile); G 7044 (from AU 9806) height 49.0 mm incomplete; G 7045 (from AU 2553) height 36.5 mm incomplete; TM 7539 (IGNS) height 40.5 mm incomplete;

Types and previously figured specimens.-Holotype TM 2626 (IGNS; Hector, 1886, Fig. 20-3; Wilckens, 1922, Pl. 2, Fig. 8); TM 2627 (IGNS; Wilckens, 1924, p. 541, not figured); TM 2628 (IGNS; Wilckens, 1922, Pl. 2, Fig. 9; Warren and Speden, 1978, Fig. 26-5; Speden in Suggate et al., 1978, Fig. 6.6-9; Speden and Keyes, 1981, Pl. 22, Fig. 9); OU 40661 (OU; Stilwell in Aitchison et al., 1993, Fig. 4c).

Figured specimens herein.-TM 2626 (IGNS), TM 2628 (IGNS), TM 2632 (IGNS), TM 7539 (IGNS) (from GS 9), OU 40661, G 7045 (from AU 2553), G 7044 (from AU 9806), Ge 7655.2 (AIM), Ge 8146.4 (AIM), Ge 5968 (AIM), Ge 8147.6 (AIM).

Material.-21 specimens, mostly incomplete.

Localities.-?east slopes of Barrons Hill, Otago, South Island, I44/f8510; North Branch of Waianakarua River, North Otago, South Island, J42/f218; true right bank of South Branch of Waipara River, Canterbury, M34/f74; ?east wing of Haumuri Bluff, southern

Marlborough, South Island, O32/f9032; east wing of Haumuri Bluff, O32/f9030, O32/f9031 (type); west wing of Haumuri Bluff, O32/f8025; boulders on beach, Haumuri Bluff, southeast of Black Grit reef, southern Marlborough, O32/f9542; railway cutting near mouth of Conway River, southern Marlborough, O32/f8221; ?Waitangi River, Bay of Islands, Northland, P05/f9491; ?Waitangi River above junction with Waikuku Stream, P05/f9499; Te Opu, Kaipara Harbour, Northland, Q08/f9639; Bull Point, Kaipara, Northland, Q08/f9626; ?east flowing tributary of Mangahouanga Stream, western Hawke's Bay, North Island, V19/f181A; Te Hoe River, western Hawke's Bay, V19/f129; Mangahouanga Stream, V19/f6909; ?Tuparoa Beach S. D., Raukumara Peninsula, North Island, Z15/f7498.

Stratigraphic range.-Conway Formation, Brighton Formation, Katiki Formation, unspecified horizon in Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Northland to Otago, South Island.

Discussion.-It is highly likely that Perissoptera waiparaensis represents the record of "Rostellaria" of von Haast (1871, p. 35) in his report "On the geology of the Amuri District in the Provinces of Nelson and Marlborough"; this fossil was taken from the "Amuri Bluff Beds" in the lower sandstone layer. This record by von Haast has seemingly been overlooked in the literature. Perissoptera waiparaensis was one of the first Cretaceous molluscan species to be figured in a work and was published in Hector's (1886) "Catalogue of the Indian and Colonial Exhibition" (p. 58, Fig. 20-3) as a poor woodcut drawing. The holotype (TM

2626 (IGNS)) figured in Hector's catalogue was not accurately drawn and the missing part of the outer lip was projected (in stipple) to look like the type species of *Perissoptera*, *P. parkinsoni* (Mantell, 1822), although this reconstruction was not mentioned by Wilckens (1922, p. 11) in his review of the holotype and of Hector's drawing. *Perissoptera waiparaensis* is very much different from *P. parkinsoni* in that the posterior spine is more obtuse and abaxially inclined and the posterior lobe of the latter species is absent in *P. waiparaensis*. Specimens of *P. waiparaensis* from Kaipara, Northland (Ge 7655.2 (AIM), G 7044 and G 7045 (both AU)), exhibit a second, moderately long, narrow anterior spine distinct from *P. parkinsoni*. Wilckens (1922) did not compare *P. waiparaensis* with *P. parkinsoni*. The presence of a second anterior spine may be of at least subgenus-level significance and *P. waiparaensis* could possibly represent a new group. Contrary to Wilckens' (1922) decision that *P. waiparaensis* is closely related to the coeval to slightly younger Antarctic species *P. nordenskjoeldi* Wilckens, 1910 (cf. Pl. 4, Figs. 2-5; also Macellari, 1984, Pl. 34, Figs. 5-8), the anterior portion of the outer lip of the Antarctic species apparently lacks a spine as found in *P. waiparaensis*. Also, the posterior spine in *P. nordenskjoeldi* is very curved; the spine in *P. waiparaensis* is straight. The sculpture of these two species is similar, but outer lip morphology suggests that *P. waiparaensis* and *P. nordenskjoeldi* may, indeed, not be closely related. More complete material is needed to assess the differences between the above species in detail. A revision of Antarctic Cretaceous

Aporrhaidae is currently underway by W. J. Zinsmeister (Purdue University) and M. Griffin (Museo de La Plata, Argentina).

The geographic distribution of *P. waiparaensis* in New Zealand is much more extensive than that given by Wilckens (1922, p. 12). Specimens have been recorded from localities in Northland to eastern Otago, South Island. Just recently I collected a specimen from the Katiki Formation in the North Branch of the Waianakarua River, North Otago, South Island (J42/f218) further extending the geographic range. Preparation of this specimen (OU 40661) revealed the presence of a posterior spine, rare in the material at hand.

Genus *STRUTHIOPTERA* Finlay and Marwick, 1937

Struthioptera Finlay and Marwick, 1937, pp. 61-62.

Type species.-(by original designation) *Arrhoges haastianus* Wilckens, 1922.

Biogeographic element.-Paleoaustral (Zinsmeister, 1982, p. 96, Tab. 3).

Discussion.-The late Early? Cretaceous to early Tertiary paleoaustral, aporrhaid gastropod *Struthioptera* has received considerable attention since its erection in 1937 by Finlay and Marwick (Hornibrook and Harrington, 1957; Scott, 1959; Marwick and Fleming *in* Wellman, 1959; Hornibrook, 1962; Fleming, 1962, 1965, 1979; Zinsmeister, 1977, 1979, 1982, 1986; Warren and Speden, 1978; Speden *in* Suggate *et al*., 1978; Stevens, 1980; del Valle and Medina, 1980; Speden and Keyes, 1981; Medina *et al*., 1990; Olivero *et al*., 1990; Stilwell and Zinsmeister, 1992). *Struthioptera* was known only from uppermost Cretaceous to Paleocene rocks of New Zealand for many years until it was discovered to be present in younger Eocene rocks of Seymour Island, Antarctic Peninsula, indicating that by Late Paleocene time the South American-Antarctic and New Zealand regions were for the most part isolated and further faunal interchange was unlikely between these areas (Zinsmeister, 1977, p. 402). See review of *Struthioptera* by Zinsmeister (ibid.) for in-depth details. Since the work on Eocene Antarctic *Struthioptera* by Zinsmeister this genus has come to light in the Late Cretaceous of the Lefipan Formation, Chubut, Argentina (Olivero *et* *al*., 1990, pp. 129-132; Medina *et* *al*., 1990, pp. 137-140). Not noted by Zinsmeister (1977) in his review of *Struthioptera*, Finlay and Marwick (1937, p. 62) referred *Aporrhais* *gregaria* Wilckens, 1905 (p. 16, Pl. 3, Figs. 10-12, Pl. 4, Fig. 1) to *Struthioptera*. In addition, Riccardi (1988, p. 49, Tab. 7) in his review of Late Cretaceous invertebrates from Patagonia and Chile included *Struthioptera* *pastorei* Camacho as a Campanian to Maastrichtian species. Also, just recently *Struthioptera* was found to be present in the Upper Cretaceous Kahuitara Tuff of Chatham Islands Campbell *et* *al*., 1993, Tab. 4.3).

Biala was proposed as a subgenus under *Struthioptera* by del Valle and Medina (1980, p. 59) for a Late Cretaceous taxon from Antarctic Peninsula (Cape Lamb, James Ross Island only). The main differences between *Biala*, type species *B*. *smiti* del Valle and Medina, 1980 (pp. 59-60, Pl. 4, Fig. 4) and *Struthioptera* s. s. are (translated from Spanish) that the extension of the wing in *Biala* with respect to the anterior digitation is more developed and the anterior canal is shorter compared to

Struthioptera s. s.; both taxa have a well-developed sinus (del Valle and Medina, 1980, p. 59). Del Valle *et al*. (1982, p. 278, Tab. 30.3) elevated *Struthioptera* (*Biala*) to genus rank *Biala*, but in light of the rather poor specimen figured by del Valle and Medina (1980) and the seemingly minor differences between *Biala* and *Struthioptera* s. s., the elevation of *Biala* to genus-level may not be warranted. The absence of *Struthioptera* s. s. in Upper Cretaceous sediments of Seymour Island, Antarctic Peninsula, is most likely a reflection of facies as these deposits are inferred to be mid shelf, different from the interpreted bathymetric range of New Zealand and Eocene Antarctic species which are from shallow shelf deposits. It appears that the geographic range of *Struthioptera* was greatly reduced by the Eocene, compared to the Cretaceous when the group was relatively widespread around the rim of the southern circum-Pacific. In the La Meseta Formation of Seymour Island, *Struthioptera camachoi* Zinsmeister, 1977, ranges from the basal part of Unit 2 (Telm2) up to the uppermost part of Unit 5 (Telm5) (Stilwell and Zinsmeister, 1992, p. 32, Fig. 41 and p. 34, Fig. 43). The disappearance and probably extinction of *Struthioptera* in the uppermost part of Unit 5 coincides with a major faunal transition, interpreted to be a reflection of either facies change or the documented decrease [stepwise] in temperature at the close of the Eocene (Stilwell and Zinsmeister, 1992, p. 46). The extinction of *Struthioptera* in the Late Eocene was probably temperature related.

The phylogentic significance of *Struthioptera* was addressed in a brief comment by Finlay and Marwick (1937, p. 64) in which the similarities with respect to "shape, sculpture, and contour of the outer lip" of the type species of *Struthioptera haastianus* (Wilckens, 1922) and juvenile Cretaceous *Conchothyra* (herein referred to *C. marshalli*) were noted. As addressed below in detail under the discussion of Struthiolariidae, these similarities are, indeed, most likely of phylogenetic significance, implying close ancestry. Little is known about the early history of *Struthioptera*. Wilckens (1922, p. 34, Pl. 5, Fig. 16) reported the presence of *Perissoptera* sp. in the "Cover Creek mudstones" of Coverham, Clarence Valley, South Island (now considered to be upper Lower Cretaceous in age). Review of material of this species suggests to me that it is much more closely related to *Struthioptera* than to *Perissoptera*. *Struthioptera* sp. was also reported in younger Arowhanan (Coniacian) rocks near Seymour Stream, mid Clarence Valley (Fleming *in* Wellman, 1959, p. 144). The Coverham species referred herein as *Struthioptera* sp. is remarkably similar to *S. novoseelandica* (Wilckens, 1922) (p. 13, Pl. 2, Figs. 10-14; Pl. 38 Figs. 9, 13-16, 18, this work), differences being mainly in spire height and development of grooves adjacent to spiral ridges on the wing. *Struthioptera* sp. is similar to a lesser extent to *Struthioptera haastiana* (Wilckens, 1922) (pp. 9-10, Pl. 2, Figs. 5a-b, 6-7) from the latest Cretaceous of New Zealand, the major differences being that the Coverham species is much smaller with more closely spaced tubercles and a more projecting wing without grooves. I suspect that the late Early Cretaceous species *Struthioptera* sp. from Coverham is the ancestor of Campanian to

Maastrichtian *S. novoseelandica* and also perhaps Paleocene *S. osiris* Finlay and Marwick, 1937 (p. 62, Pl. 8, Figs. 8-10), based on striking similarities in outline and sculptural plan. More well-preserved material of *S. osiris* is necessary for further assessment. Thus, the origin of *Struthioptera* may indeed be in the New Zealand region along the western rim of the circum-Pacific. If so, the group dispersed westward along the Weddellian Province during the Late Cretaceous before the final break-up of Gondwana and subsequent isolation of the group in early Tertiary time.

Struthioptera was most likely an epifaunal or semi-infaunal deposit feeder (Warren and Speden, 1978, p. 50, Tab. 5). Both lifestyles may have characterised *Struthioptera* in light of recent findings with regard to life habits of extant species of Aporrhaidae (Popenoe, 1983).

STRUTHIOPTERA HAASTIANUS (Wilckens, 1922)

Plate 38 Figures 1-8, 10-12, 17

?*Aporrhais* of von Haast, 1879, p. 295.

Aporrhais gregaria Wilckens, Trechmann, 1917, p. 304, Pl. 19, Figs. 6-7.

Arrhoges haastianus Wilckens, 1922, pp. 9-10, Pl. 2, Figs. 5a-b, 6-7; Wilckens, 1924, p. 541.

Struthioptera haastiana (Finlay and Marwick, 1937), pp. 61-62; Marwick and Fleming *in* Wellman, 1959, p. 139; Fleming *in* Wilson, 1963, p. 25; Zinsmeister, 1977, p. 402; Crampton and Moore, 1990, p. 347.

Drepanocheilus (*Struthioptera*) *haastianum* (Wilckens), Wenz, 1940, p. 912.

Supplementary description.-Shell medium-sized for genus, moderately robust, moderately alate, low turreted; spire moderately low with at least five shouldered whorls; whorl inflation rate mostly constant until penultimate whorl; spire angle about 34°; protoconch apparently smooth (first apical whorl missing), axial ornament commencing by second whorl; suture impressed; growth lines opisthocline posteriorly becoming more prosocline anteriorly at base; basal constriction strong; last whorl inflated, biangulate, with a strong posterior, inflated keel bearing about 10, widely spaced, rounded, projecting tubercles and a broad, weaker anterior keel bearing very poorly developed tubercles; spiral sculpture of more than 50 closely spaced spiral threads on last whorl; penultimate whorl with submedial, more anterior, keel with 11 sharp tubercles and about 15 spiral threads; on antepenultimate and younger whorls the tubercles become more inclined opisthoclinally and weaker; aperture elongate, sublenticular, siphonostomatous; anterior canal moderately short?; outer lip projecting into blunt, inclined lobe or wing, posteriorly pointed; callus narrow?.

Dimensions.-TM 7540 (from GS 589) height 26.5 mm incomplete; TM 7541 (from GS 589) height 40.5 mm incomplete; TM 7542 (from GS 589) height 30.0 mm incomplete; TM 7543 (from GS 14260) height 29.5 mm; OU 40978 small block 78.5 mm long.

Type and previously figured specimens.-Lectotype TM 2616 (IGNS; designated by Finlay and Marwick, 1937, p. 62; Wilckens, 1922, Pl. 2, Fig. 5); TM 2617 (IGNS; Wilckens, 1922, Pl. 2, Fig. 6); TM 2618 (IGNS; Wilckens, 1924, p. 541, not figured); TM 2619 (IGNS;

Wilckens, 1922, Pl. 2, Fig. 7); G 27428 (BMNH; Trechmann, 1917, Pl. 19, Fig. 6); G 27429 (BMNH; Trechmann, 1917, Pl. 19, Fig. 7).

Figured specimens herein.-TM 2616, TM 7540, TM 7541, TM 7542, TM 7543 (all IGNS), OU 40978 (small block with numerous specimens); G 27428-G 27429 (BMNH).

Material.-Numerous specimens, all incomplete, especially common at Shag Point, North Otago, in monotypic concentrations.

Localities.-?Eastern slopes of Barron's Hill, eastern Otago, South Island, I44/f8510; Little Pukeiwitahi Woolshed Creek, North Otago, South Island, J43/f6471; Shag Point, North Otago, ?J43/f6472, J43/f152, J43/f159, J43/f159A; Selwyn River, left bank below rapids, Malvern Hills, southern Canterbury, South Island, L35/f6008 (type); Selwyn Rapids, oyster bank on right bank, Malvern Hills, L35/f6510; ?Middle Waipara, northern Canterbury, South Island, M34/f7254, M34/f7263; Waitangi River, Bay of Islands, Northland, P05/f9491; ?Waiau River, North Island, V18/f8500; ?Looney Creek, North Island, V18/f8510; east bank of Te Hoe River, western Hawke's Bay, North Island, V19/f184, V19/f185; ?Hook Stream, western Hawke's Bay, V19/f6649; ?east-flowing tributary of Mangahouanga Stream, western Hawke's Bay, North Island, V19/f181A; Mangahouanga Stream, V19/f6909; ?Porangahau main highway just north of junction of Mangaorapa Road, North Island, V24/f6028; ?Waiapu Stream above Tikitiki southern district, North Island, Z15/f7495.

Stratigraphic range.-?Brighton Formation, Selwyn Rapids Beds, Katiki Formation (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Maungataniwha Sandstone, unspecified formation(s) in Northland (Upper Cretaceous).

Geographic distribution.-?Northland to East Otago, South Island.

Discussion.-*Struthioptera haastiana* (Wilckens, 1922) is one of the earliest members of a lineage which extends back to the late Early Cretaceous. Earlier forms of *Struthioptera*, like *S. haastiana* and *S. gregaria* (Wilckens, 1905) (p. 16, Pl. 3, Figs. 10-12, 13?, Pl. 4, Fig. 1) from southern Patagonia, have smaller shells with shorter spires, shorter anterior canals and less developed wings and posterior digitations. The observed punctuated increase in shell size, spire height, development of a posterior digitation on the wing in the lineage *S. haastiana*→*S. osiris* across the interval Maastrichtian to Danian time in New Zealand is presumably more a reflection of gaps in the fossil record than accelerated changes in shell characters over a short period of geologic time. There may be as much as five to ten million years missing between the latest occurrence of *S. haastiana* in the Maastrichtian and the earliest occurrence of *S. osiris* in the Danian, a substantial amount of missing time so that punctuated equilibrium may seem more apparent than real.

The fragmentary nature of all known South Island examples of *S. novoseelandica* (Wilckens, 1922) (pp. 13-14, Pl. 2, Figs. 10-14) makes comparisons with its congener *S. haastiana* difficult. Wilckens (1922, ibid) mentioned the problems associated with distinguishing between the above two species, especially with respect to juvenile shells.

STRUTHIOPTERA NOVOSEELANDICA (Wilckens, 1922)

Plate 38 Figures 9, 13-16, 18

Perissoptera novo-seelandica Wilckens, 1922, pp. 13-14, Pl. 2, Figs. 10-14.

Struthioptera novoseelandica (Wilckens), Finlay and Marwick, 1937, p. 62; Campbell et al., 1993, Tab. 4.3.

Struthioptera novo-seelandica (Wilckens), Marwick and Fleming in Wellman, 1959, p. 139; Fleming in Wellman, 1959, p. 143; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-10, 11.

Supplementary description.-Shell small for genus, somewhat fragile, moderately high-spired turreted, moderately alate; spire moderately high with six shouldered, ornamented whorls; whorl inflation mostly constant on spire, increasing greatly between the penultimate and last whorls; spire angle 53°; suture impressed; protoconch conical, axial sculpture beginning by second apical whorl; growth lines opisthocline; last whorl inflated, triangulate, posteriormost keel with spaced, greatly projecting, smooth tubercles and two closely spaced, moderately developed keels, situated more anteriorly, the posterior one with poorly developed tubercles and anterior one with even more poorly developed tubercles; tubercles become reduced to strong ridges on wing which are deflected abapically; sculpture also of numerous closely spaced spiral threads; penultimate and earlier whorls with about 12 projecting, spaced tubercles; on early teleoconch whorls axial sculpture is of closely spaced, inclined, coarse ribs and widely spaced spiral threads; outer lip projected into well-developed, curved, moderately long, posterior spine; outer surface of wing with deep grooves adjacent to spiral ridges; stromboid notch moderately developed; aperture axially elongated, sublenticular; anterior canal short with well-developed notch; inner lip with moderately broad thick callus.

Types and previously figured specimens.-TM 2620 (IGNS; Wilckens, 1922, Pl. 2, Fig. 12); TM 2621 (IGNS; Wilckens, 1922, Pl. 2, Fig. 13); TM 2622 (IGNS; Wilckens, 1922, Pl. 2, Fig. 14); Lectotype TM 2623 (designated herein) (IGNS; Wilckens, 1922, Pl. 2, Fig. 10; Warren and Speden, 1978, Fig. 25-10); TM 2624 (IGNS; Wilckens, 1922, Pl. 2, Fig. 11); TM 5379 (IGNS; Warren and Speden, 1978, Fig. 25-11).

Dimensions.-TM 7544 (IGNS) height 19.0 mm, diameter of last whorl 14.0 mm; TM 7545 height 19.0 mm, diameter of last whorl 13.5 mm.

Figured specimens.-TM 2620-2624 (IGNS), TM 5379 (IGNS), TM 7544 (IGNS) (from GS 12152), TM 7545 (IGNS) (from GS 12153).

Material.-Six specimens, two well-preserved.

Localities.-Shag Point, North Otago, South Island, J43/f6498, J43/f6472; Selwyn River, left bank below rapids, Malvern Hills, southern Canterbury, L35/f6008; army ammunition store, shell bed cropping out on ridge near water tanks, Malvern Hills, L35/f6511; bluffs on south side, Okarahia Stream, southern Marlborough, South Island, O32/f8852, O32/f8853; Conway River near mouth, southern Marlborough, O32/f8514; Okarahui Stream, southern Marlborough, O32/f8790; lower Conway rail cutting, southern Marlborough, O32/f8793; west wing of Haumuri Bluff, O32/f8025 (type); Haumuri Bluff, O32/f9505; ?between Kahuitara Point and Te Rangi-Taumaewa Point, eastern Pitt Island, Chatham Islands, CH/f11; northwestern side of Rockyside Bay, southwestern side of neck of Taruwhenua Peninsula, Pitt Island, CH/f257A; ?Kahuitara Point, eastern Pitt Island, CH/f319; ?north side of mouth of Tapuangi Stream, CH/f339; Rockyside, west of Flowerpot Bay, Tarawhenua Peninsula, Pitt Island, CH/f345, CH/f466.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Kahuitara Tuff, Katiki Formation (Upper Cretaceous).

Geographic distribution.-Southern Marlborough to North Otago, and Chatham Islands.

Discussion.-Rare, well-preserved examples of Struthioptera novoseelandica at hand are consistently much smaller with a higher spire angle of 54°, a triangulate profile on the last whorl, and grooves adjacent to strong spiral ridges which are deflected abaxially on the posteriormost part of the outer lip, compared to S. haastiana which is relatively much larger with a lower spire angle, a biangulate last whorl and a smooth outer lip without grooves. Until its discovery recently in the Late Cretaceous record of the Chatham Islands, S. novoseelandica (Campbell et al., 1993, Tab. 4.3) was known from mostly incomplete material. Two, nearly complete specimens of S. novoseelandica at my disposal help elucidate the morphological uncertainties surrounding this species and clearly reveal the major differences between this species and S. haastiana.

The new material of S. novoseelandica from the Chatham Islands allows a closer look at phylogenetic relationships in this solely austral group. The striking morphological affinities of Struthioptera sp. of Wilckens, 1922 (p. 34, Pl. 5, Fig. 16) [Perissoptera] (TM 2625, IGNS) from the late Early Cretaceous of New Zealand and S. novoseelandica indicates to me a close lineal relationship. Struthioptera sp. is roughly the same size as S.

novoseelandica and apart from a slightly lower spire, a slightly less projecting posterior spine on the outer lip and shallower grooves adjacent to spiral ridges on the wing in *S*. sp., few differences can be detected between these Cretaceous species. The major differences between *S*. *haastiana* and *S*. sp. suggest to me that *S*. sp. is not the ancestor of *S*. *haastiana* and that this latter species arose from an unknown ancestor. The presence/absence of grooves adjacent to strong spiral ridges on the wing in *Struthioptera* is assumed here to be of important phylogenetic significance. Further work may result in the division of *S*. *novoseelandica* and *S*. *haastiana* at least at subgenus-level.

Subfamily ARRHOGINAE Popenoe, 1983

Genus *ARRHOGES* Gabb, 1868

Arrhoges Gabb, 1868, p. 145.

Type species.-(by original designation) *Chenopus occidentalus* Beck, 1847.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Subgenus *LATIALA* Sohl, 1960

Latiala Sohl, 1960, p. 101.

Type species.-(by original designation) *Anchura lobata* Wade, 1926.

Biogeographic element.-Indo-Pacific/Tethyan (cf. Sohl, 1960, p. 101; cf. Popenoe, 1983, p. 763).

Discussion.-Sohl (1960, p. 101) erected *Latiala* as a subgenus of *Arrhoges* Gabb, 1868, for a group similar to the type species of *Arrhoges*, *A*. *occidentalis* (Beck, 1847) (see Wenz, 1940, pp. 911-

912, Fig. 2680; Popenoe, 1983, Fig. 6D, 6G) and related species, but different with respects to "an angulate outer lip, extended at both anterior and posterior lateral corners, with a longer and more pronounced anterior rostrum, and with fewer axial ribs in general" (Popenoe, 1983, p. 763). The stratigraphic range of *Arrhoges* (*Latiala*) spans at least Turonian to Maastrichtian time (Popenoe, 1983, p. 763) and the geographic range of this group extends from North America to southern India and southern Africa (Sohl, 1960, p. 101). Wenz (1940, p. 912) questioned the presence of *Arrhoges* in the Late Cretaceous record of New Zealand; this was presumably based on the use of the combination of *Arrhoges haastianus* Wilckens, 1922 (now relegated to *Struthioptera*). Trechmann (1917, p. 304, Pl. 19, Fig. 5) proposed *Alaria suteri* for a single specimen from Selwyn Rapids believed to be more related to Aporrhaidae such as *Aporrhais* than to *Scalaria* of Epitoniidae. The nature and style of ornamentation of *Alaria suteri* is unlike that in other more certain species of *Alaria* (*Alaria* is a synonym of *Dicroloma* Gabb, 1868, according to Wenz, 1940, p. 922.). The type species of *Dicroloma*, *D. lorierei* (A. d'Orbigny) (refigured by Wenz, 1940, p. 922, Fig. 2702) from the Middle Jurassic of Europe, is only remotely similar to *A. suteri* which has strong axial and spiral components without carinae, unlike *D. lorierei* which is strongly bicarinate on the last whorl and unicarinate on older whorls. I suggest that the incomplete example of *A. suteri* figured by Trechmann is related closer to *Arrhoges* (*Latiala*), which has pronounced axial and spiral sculpture, rather than to *Dicroloma*. *Alaria suteri* apparently escaped the attention of Wilckens (1922) in his monograph on Late Cretaceous New Zealand gastropods, perhaps as Trechmann's material was sent to the British Museum (Natural History) (now called the Natural History Museum, London) and no further specimens of this species were available to him. In a summary of Late Cretaceous New Zealand mollusc taxa, Marwick and Fleming *in* Wellman (1959, p. 139) assigned *A*. *suteri* questionably to *Dicroloma*.

ARRHOGES (*LATIALA*) *SUTERI* (Trechmann, 1917)

Plate 39 Figures 1-2

Alaria *suteri* Trechmann, 1917, p. 304, Pl. 19, Fig. 5.

Dicroloma? *suteri* (Trechmann), Marwick and Fleming *in* Wellman, 1959, p. 139.

Type.-Holotype G 27453 (BMNH; Trechmann, 1917, Pl. 19, Fig. 5).

Type *locality*.-Exact locality not known, Selwyn Rapids, southern Canterbury, South Island.

Figured *specimen* *this* *work*.-G 27453 (BMNH). G 7046 (from AU 2564) may represent this species.

Material.-A poor specimen from Rout Point, Kaipara, Northland, may represent this species.

Stratigraphic *range*.-Selwyn Rapids Beds and ?unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic *distribution*.-Known for certain only from Selwyn Rapids, southern Canterbury, South Island.

Discussion.-*Arrhoges* (*Latiala*) *suteri* (Trechmann, 1917) is known for certain only from the holotype. From Trechmann's bald locality descriptions it is not possible to track down the exact locality in Selwyn Rapids from which A. (L.) suteri or other species were collected. Collection manager J. Cooper (BMNH; personal commun., 1992) informed me that there is no further locality information available on Trechmann's collection.

Arrhoges (Latiala) suteri is believed to be closely related to the coeval North American latest Cretaceous species A. (L.) lobata (Wade, 1926) (pp. 150-151, Pl. 52, Figs. 11-12; Sohl, 1960, pp. 101-102, Pl. 11, Figs. 9, 13-15); A. (L.) suteri has more closely spaced axial ribs and stronger spiral sculpture than A. (L.) lobata. Arrhoges (Latiala) suteri seems also to be related to coeval southern Indian species Alaria papilionacea Goldfuss, 1844 (discussed and figured by Stoliczska, 1868, pp. 31, Pl. 2, Figs. 9-10) and Alaria tegulata Stoliczska, 1868 (p. 32, Pl. 2, Figs. 11-13), but the former New Zealand species has more widely spaced axial ribs and more convex whorls compared to the southern Indian species. As far as I am aware no new material has come to light since the holotype was collected during the early part of this century.

Family STRUTHIOLARIIDAE Fischer, 1887

Discussion.-The roots of the Struthiolariidae probably extend at least back into the Late Cretaceous, well before the appearance of the bizarre gastropod Conchothyra in upper Campanian shallow marine deposits of South Island, New Zealand. No Conchothyra-like gastropod has been reported in rocks older than Campanian. Although several authors have discussed the taxonomy and have presented plausible phylogenetic scenarios (e. g. Marwick, 1924, 1950; Finlay and Marwick, 1937; Zinsmeister, 1976a, 1976b;

Zinsmeister and Camacho, 1980; Beu and Maxwell, 1990; Darragh, 1991), the relationship of Conchothyra to other members of the Struthiolariidae and Strombacea remains poorly understood. Of these papers only Marwick (1924, 1950), Zinsmeister (1976a) and Zinsmeister and Camacho (1980) have reviewed the phylogeny of the Struthiolariidae in any detail. New data, additional study and the recognition of two struthiolariid taxa in uppermost Cretaceous rocks of New Zealand assist in unraveling the uncertainties surrounding the phylogenetic relationships within this solely austral and biostratigraphically important family.

Members of the Struthiolariidae, extinct and extant, are present in New Zealand (latest Cretaceous to Recent), Antarctica (Early? Paleocene to Late Eocene or earliest Oligocene?), South America (Early? Paleocene to Oligocene) and Australia (Early Miocene to Recent). Some of these ranges were not mentioned by Darragh (1991, p. 151) who seemed unaware of new data from Antarctica and southern South America. The paleobiogeographic distribution of the Struthiolariidae during the latest Mesozoic and Cenozoic is inferred to be a consequence of the final break-up of Gondwana during this time; the separation of the two subfamilies Struthiolariinae and Struthiolarellinae coincides with the fragmentation of Australia, New Zealand, Antarctica and South America and concomitant isolation of these fragments during the early Tertiary (Zinsmeister and Camacho, 1980, p. 1).

The struthiolariid record in New Zealand from Late Cretaceous to Recent is relatively complete except for short hiatuses spanning latest Maastrichtian to early Danian time (approximately 5 m. y.) and a gap from the late Paleocene to earliest Eocene (approximately 10 m. y.). Five genera or subgenera of Struthiolariidae are represented in New Zealand: Conchothyra Hutton, 1877; Monalaria Marwick, 1924; Perissodonta Martens, 1878; Pelicaria Gray, 1847; Struthiolaria Lamarck, 1816; and Struthiolaria (Callusaria) Finlay, 1926. Beu and Maxwell (1990) considered the latter taxon to be a subgenus of Struthiolaria. Species-level diversity of Struthiolariidae was low during latest Cretaceous to Paleogene time and increased substantially during the Neogene, especially during the late Neogene when the family became more speciose than at any other time. Diversity of Struthiolariidae is reportedly higher in New Zealand than anywhere else. Conchothyra appears in rocks of the upper Campanian (Piripauan Stage) of Haumuri Bluff, southern Marlborough and disappears by probably mid Paleocene ("Wangaloan"; mid Teurian Stage) time. Perissodonta, contrary to Camacho and Zinsmeister's (1989) report of this group as fossil only in Antarctica, is known also from the Early Paleocene to Middle? Eocene of New Zealand. After the disappearance of Perissodonta from the mid Eocene record in New Zealand, this genus reappears in Upper Eocene to possibly lowermost Oligocene rocks of Seymour Island, Antarctic Peninsula. Today Perissodonta inhabits subantarctic waters of South Georgia and Kerguelen Land (Morton, 1956, p. 515). Monalaria made its first appearance in the late Early Eocene (Waipawan or Heretaungan? Stage) and becomes extinct by the Middle Eocene (Bortonian Stage), a range longer than that given recently by Beu and Maxwell (1990, p. 37, Fig. 6e,). Pelicaria ranges from Late Miocene to Recent (Powell, 1979, p. 143; Beu and Maxwell, 1990, p. 37, Fig. 6e). Struthiolaria (Callusaria) ranges from Late Oligocene to Early Pliocene (Beu and Maxwell, 1990, p. 37, Fig. 6e). Struthiolaria s. s. extends from the Late Oligocene to Recent (Beu and Maxwell, ibid). The Struthiolariidae has not been reported, fossil or Recent, from the Chatham Islands.

In Antarctica including the Peninsula and Ross Sea area three genera of struthiolariid gastropods have been recognised and have been used in the biostratigraphical zonation of the La Meseta Formation of Seymour Island (Camacho and Zinsmeister, 1980; Stilwell and Zinsmeister, 1992). Antarctodarwinella Zinsmeister, 1976, makes its first appearance in the Lower? Paleocene Sobral Formation (Zinsmeister in Stilwell and Zinsmeister, 1992, p. 21) on Seymour Island and ranges into the Middle to Late? Eocene. Struthiolarella Steinmann and Wilckens, 1908, makes its first appearance in Unit 3 of the La Meseta Formation (Middle to Late Eocene) where it ranges into the lowermost part of Unit 6 and is succeeded in Units 6 and 7 by Perissodonta (Upper Eocene to lowermost? Oligocene) (Stilwell and Zinsmeister, 1992, p. 23).

Antarctodarwinella was reported recently in Paleogene rocks of southern South America for the first time (Camacho and Zinsmeister, 1989) where it ranges from Middle? to Late Eocene. However, Griffin and Hünicken (1994, p. 260) reassigned this species, A. senoniana, to Struthiolarella. Struthiolarella is present in southern South America in Paleocene to Oligocene rocks. Struthiolariidae have not been recorded in rocks older than Paleocene age and younger than Oligocene in South America.

The endemic genus Tylospira Harris, 1897, is the sole reported representative of the Struthiolariidae in Australia. The relatively short range of Early Miocene to Recent for Tylospira (Darragh, 1991) indicates a probable early or mid Tertiary migration of Struthiolariidae to Australia from the New Zealand region or Antarctica. Migration of Struthiolariidae to Australia would have been made possible as a result of changes in austral, early Tertiary oceanic circulation patterns in association with the final fragmentation of Australia with eastern Antarctica, hence the end of Gondwana.

Because it has been proposed as a probable or possible progenitor to Cenozoic Struthiolariidae, Conchothyra requires attention. The abrupt appearance of Conchothyra in New Zealand Campanian rocks limits the detail to which the phylogeny and early origins of the Struthiolariidae can be worked out as no putative ancestors are present. The specialised shell of Conchothyra parasitica Hutton, 1877, complicates easy assessment of phylogenetic relationships. Because no Conchothyra-like gastropods have been recorded from pre-Campanian rocks, Conchothyra has either been interpreted as an early, short-lived offshoot of the evolutionary lineage (Zinsmeister, 1976a, p. 612, text-fig. 2; Zinsmeister and Camacho, 1980, p. 11, text-fig. 7; cf. Darragh, 1991) or the progenitor of Cenozoic struthiolariid groups (Zinsmeister, 1976b, p. 112; cf. Beu and Maxwell, 1990). The morphological similarity of Conchothyra with Cretaceous members of the Aporrhaidae (Superfamily Strombacea) suggests to me that the origin of the Struthiolariidae lies within a mid or early Late Cretaceous aporrhaid ancestor structurally and phylogenetically intermediate between Conchothyra and Tephlon Popenoe, 1983 (Aporrhainae). Increased shell thickness and callus development in early struthiolariid gastropods as in Conchothyra may have been a response to predation pressures which relented after the Cretaceous, as discussed in the Conchothyra section below. Furthermore, the depauperate fossil record for early struthiolariid groups may be more real than previously supposed, and not due in totality to a poor record. The possibility remains that the evolution of early Struthiolariidae from a strombacean, probable aporrhaid ancestor, occurred not too long before the appearance of Conchothyra during the Campanian. A low diversity for Struthiolariidae during the latest Cretaceous to early Tertiary would then not be unexpected.

Tephlon is characterised by having "noded tabulate whorls, dominantly spiral sculpture and with a single spur-shaped posterolateral labral spine bent posteriorly in the middle. Adult shells usually covered with heavy callus" (Popenoe, 1983, p. 761). Popenoe's use of "posterolateral labral spine" for Tephlon is misleading; this feature could, in my opinion, be better described as a blunt, relatively narrow, projecting wing that is posteriorly inclined. Tephlon is a monotypic genus, with the type species Pugnellus tumidus Gabb, 1860 (see Philippi, 1887, p. 34, Pl. 1, Fig. 3; Wilckens, 1904, pp. 205-207, Pl. 18, Fig. 2a-b; Popenoe, 1983, Fig. 5G, 5H), at present only recorded from the Maastrichtian Quiriquina Formation of central Chile. Gross morphological similarities between Conchothyra and Tephlon are striking. The diagnostic features of *Conchothyra* are: a subglobose outline; very thick shell; sinuous growth lines forming lamellae; a thick callus enveloping the spire; tubercles and spiral threads in two species (*C. marshalli* (Trechmann, 1917) and *C. australis* (Marshall, 1916b)); cinguli; and a blunt, produced wing. Decreasing the length of anterior canal, increasing the thickness and extent of callus and prominence of sinuous growth lamellae relative to *Tephlon* would result in a gastropod very similar to *Conchothyra*. If *Conchothyra* is related closely with *Tephlon*, the extremely thick, extensive callus may actually not be much more specialised than in heavily callused aporrhaid gastropods such as *Tephlon* and *Pugnellus*. Of note, late last century Hutton (1885, p. 205) believed that *Conchothyra* is allied to the Cretaceous aporrhaid genus *Pugnellus* Conrad.

Having arrived at a similar conclusion as Finlay and Marwick (1937, pp. 64-65) as to an aporrhaid ancestry for Struthiolariidae, I now address Finlay and Marwick's suggestion of *Struthioptera*'s affinity and interpreted close relationsip to *Conchothyra*. Finlay and Marwick stated (p. 64) that the "course of development being from *Struthioptera* to *Conchothyra* [is] by reduction in height of spire and length of outer lip process, and increase of deposition of callus." The "course of development" from *Struthioptera* to *Conchothyra* appears to be more extreme than that of *Tephlon* to *Conchothyra* which may be more plausible. Unfortunately, Popenoe (1983) excluded *Struthioptera* in his review of the Aporrhaidae.

Previous workers have concluded that the ancestor of the Struthiolariidae was either a "convex-whorled ancestor with fairly strong, spaced spirals, probably of Cretaceous age" (Marwick, 1924a, p. 170) or a primitive genus likened to an unspecialised *Perissodonta* (Morton, 1956, p. 522; Zinsmeister and Camacho, 1980, p. 12). Beu and Maxwell (1990, p. 81), however, implied that *Struthiolaria* was derived from *Conchothyra* or related form, based on the similar sculptural plan of early *Struthiolaria* species and the Paleocene species *Conchothyra australis* (Marshall, 1916b). Alternatively, if there is a close relationship between *Conchothyra* and Aporrhaidae (e. g. *Tephlon*), the ancestor of the Struthiolariidae may lie not far from a *Tephlon*- and *Conchothyra*-like form discussed above. To invoke a *Perissodonta*-like ancestor for Struthiolariidae would result in a lineage beginning in an "unspecialised" (e. g. without thick callus) state in the mid or latter part of the Cretaceous, then evolving into a specialised state in the latest Cretaceous if *Conchothyra* did, indeed, play a major part in the early lineage of Struthiolariidae, and again in the Tertiary evolving into an unspecialised state by early Paleogene time. An aporrhaid-like ancestor for *Conchothyra* makes much more sense than an unspecialised *Perissodonta*-like form especially when an aporrhaid ancestry for Struthiolariidae is invoked. Of note, what appears to a pathologic specimen of *Conchothyra* from Tokomairiro Mouth near Wangaloa, southeastern Otago (OU 11176) has a *Struthioptera*-like form with a higher spire and less extensive callus than more representative *Conchothyra*; this example is not a specimen of *Struthioptera*.

Perhaps too much emphasis has been placed on the ontogeny of particular groups in Struthiolariidae in classification and projection of early ontogenetic forms with respect to phylogeny. It is, however, probably significant that the early whorls and teleoconch sculpture of Cretaceous aporrhaid groups (cf. *Pyktes* Popenoe, 1983 and *Struthioptera* Finlay and Marwick, 1937) and outer lip morphology (cf. *Tephlon*) are quite reminiscent of and not too far removed from *Conchothyra* and *Monolaria*, for example. Availability of material of Cretaceous aporrhaid groups in the early juvenile state should help solve some of the relationships between Struthiolariidae and Aporrhaidae. Unfortunately, relationships of Cretaceous Aporrhaidae are "hampered from the beginning by ignorance of the shell ontogeny" (Popenoe, 1983, p. 747); most descriptions and diagnoses of these taxa (as well as interpreted broader relationships) are based on late adult, callus-covered shells. In a nutshell, the possibility cannot be ignored that the roots of the Struthiolariidae may actually be found in a "moderately specialised" *Conchothyra*-like gastropod akin to Aporrhainae and quite different from a small and unspecialised *Perissodonta*-like form.

Divergence in callus development (e. g. thick or thin, enveloping spire or not) and shell thickness in Paleocene species of *Conchothyra* and *Perissodonta* could, to some authors, be sufficient grounds for inferring a polyphyletic origin for the Struthiolariidae. The balance of other features, however, may obviate polyphyly. The tempo of evolutionary split from a *Conchothyra*-like form to *Perissodonta* may have been rapid bearing in mind the less than 10 m. y. gap in our record from Maastrichtian to Early to mid Paleocene time. No *Perissodonta*-

like gastropods have been recorded in the Cretaceous. The evolutionary significance of apical whorl sculpture, various sculptural plans, shell thickness and callus development in Struthiolariidae needs to be addressed in detail. The phylogenetic importance of these characters has to be studied intensively before a monophyletic or polyphyletic origin for Struthiolariidae can be deduced. The similarities of outer lip contour, hence growth line symmetry, general sculpture and overall outline between Conchothyra and Perissodonta is striking; there seems little doubt that these two groups are closely related. I prefer tentatively a monophyly scenario for Struthiolariidae taking into account the inferred rapidity of evolution in particular established Tertiary lineages such as Antarctodarwinella sp.→Antarctodarwinella ellioti→A. nordenskjoeldi during the early Paleogene in Antarctica (Stilwell and Zinsmeister, 1992) and Monolaria n. sp. (this work)→Monolaria gracilis→Monolaria concinna during the Early to Middle Eocene in New Zealand. Evolution from a Conchothyra-like ancestor to Perissodonta may have taken place in a relatively short space of time.

The proposed convergence in morphology of inferred homeomorphs Conchothyra, Antarctodarwinella and Tylospira, interpreted by Darragh (1991, p. 153), seems unlikely in light of the very specialised nature of the shell in these three groups and also similar age of the former two genera. Darragh needs independent evidence that relationships of each of these three genera lie elsewhere. The similarities of Conchothyra parasitica and Struthiolarella nordenskjoeldi Wilckens, 1911 (= Antarctodarwinella nordenskjoeldi **sensu** Zinsmeister, 1976b, p. 112), have been commented on by, for example, Marwick (1924a, p. 165), Wilckens (1922, p. 17), Zinsmeister (1976b, p. 112), and Zinsmeister and Camacho (1980, pp. 7-8). Both Conchothyra and Antarctodarwinella have a subglobose outline, a very thick callus, strong sinuous growth laminae and a blunt wing. The callus in Conchothyra is more extensively developed, covering a larger portion of the spire compared to Antarctodarwinella, and the columella is less concave. Overall morphological similarities suggest that Antarctodarwinella could have been derived from Conchothyra perhaps sometime during the Late Cretaceous; the oldest Antarctodarwinella species is Paleocene in age. The absence of Antarctodarwinella in uppermost Cretaceous deposits of Antarctica may be due to lack of preserved, suitable facies (shallow shelf), as the Campanian to Maastrichtian deposits of Antarctica are most likely mid shelf. Such facies contrast with the shallow shelf deposits in New Zealand containing Conchothyra or shallow Paleocene and Eocene deposits in Antarctica containing Antarctodarwinella. Mentioned earlier, an Early Miocene specialised Australian species, Tylospira glomerata Darragh, 1991 (p. 154, Fig. 1B, C, H-J), the oldest reported species of Tylospira, is strikingly similar to species of Conchothyra and Antarctodarwinella with respect to callus development, growth lines and subglobose outline. Morton's (1956) claim that Tylospira evolved from Struthiolaria needs reassessment in light of the newly described T. glomerata's similarity and presumed affinity with Antarctodarwinella.

Darragh (1991, p. 151) was convinced that the similarity of *T. glomerata* and *Antarctodarwinella* is superficial. However, the specialised shell characters (e. g. subspherical shell, very low spire, capacious last whorl, thick callus, slightly sinuous growth lines) of *T. glomerata* are distinct from coeval New Zealand struthiolariid species, indicating that the stock of Australian Struthiolariidae arose from an unknown Australian Paleogene ancestor or that the origin of *Tylospira* lies in *Antarctodarwinella*. Dispersal of this group during the mid to late Paleogene was possibly in response to changes in oceanic circulation in the Austral Realm after Antarctica's separation from Australia. Such changes in circulation/paleogeography may have allowed wider dispersal than previously in the earliest Paleogene during which time the various Gondwana "fragments" were well isolated. Indeed, correlation coefficient values of coeval molluscan faunas between the various continental "fragments" show an increase during the Late Eocene. This increase indicates an increasing degree of similarity between the faunas presumably due to changes in oceanic circulation in response to the final fragmentation of Gondwana (unpublished data, 1991). I prefer the latter scenario when the Australian struthiolariid fossil record is considered. The tylospirid growth habit is too similar to *Antarctodarwinella* to ignore as due to convergence. Darragh (1991) dismissed the possibility of *Antarctodarwinella* being the progenitor of *Tylospira* and suggested that the origin of *Tylospira* may lie with *Monalaria*, but then presented no further discussion.

Similarities between *Tylospira* and *Antarctodarwinella* lead me to discount a close *Tylospira*-*Monalaria* link. The rather specialised shell of *Monalaria* lacks an extensive callus, has a higher spire and also has well-developed sculpture quite distinct from *Tylospira* or *Antarctodarwinella*. Marwick (1950, p. 236) recognised the closeness in morphology between *Monalaria* *concinna* and *Conchothyra* *australis*, suggesting that the Otaio Gorge species [*M*. *gracilis*] was intermediate between the two former species, but that the outer lip contour and shape in *M*. *gracilis* is more like *Monalaria*. A new species (this work) inferred to be of Waipawan to Heretaungan age (Early to earliest Middle Eocene) from the Waihao River, South Island (Kauru Formation) is intermediate between *Monalaria* and *Perissodonta* in having a very distinct biangulate whorl profile, outline and sinuous, thickened outer varix like *Monalaria*, but has the subdued spiral and axial sculpture of *Perissodonta*. This new species, interpreted to be a "missing link" in the Struthiolariidae lineage, is placed here in *Monalaria* attesting to inferred closer relationship with this group. It probably forms the earliest stock of the genus little removed from *Perissodonta*. *Perissodonta* and *Monalaria* appear closely related. Beyond the scope of this study a major revision of the Struthiolariidae is needed to accurately assess phylogenetic relationships and enough data are seemingly available to present a phylogeny for the family. A cladistic analysis using many morphological parameters available in Struthiolariidae may assist in delineating lineages and corroborate other (e. g. stratophenetic) means of inferring phylogeny.

Zinsmeister and Camacho (1980) divided the Struthiolariidae into two subfamilies, Struthiolariinae and Struthiolarellinae, based mainly on differences in ornamentation of the apical whorls. This scheme is used here. However, some workers have not used the scheme proposed by Zinsmeister and Camacho, without comment (Ponder and Warén, 1988; Vaught, 1989; Beu and Maxwell, 1990). Phillip A. Maxwell (personal commun., 1993) regards Zinsmeister and Camacho's separation of Struthiolariidae into subfamilies based on protoconch sculptural features as trivial and unwarranted. The identifying feature of early whorls of Struthiolariinae is fine closely spaced spiral threads; in the Struthiolarellinae the apical whorls have both spiral and axial threads that appear at about the same position on the second whorl (Zinsmeister and Camacho, 1980, p. 4). The Struthiolariinae was inferred by the authors to consist of *Conchothyra* (protoconch described apparently for the first time in this thesis), *Monalaria*, *Struthiolaria* and subgenera *Callusaria* and *Pelicaria* and *Tylospira*. The Struthiolarellinae was stated to comprise *Perissodonta*, *Antarctodarwinella* and *Struthiolarella*. The protoconch of *Tylospira glomerata* Darragh was not observed (1991, p. 154), but it seems probable per figures of this species in Darragh's paper that the protoconch would have been paucispiral and seemingly large similar to *Antarctodarwinella*. *Conchothyra australis* has apparently smooth apical whorls with axial sculpture commencing on the first inferred teleoconch whorl. *Conchothyra marshalli* has developed axial sculpture by the first inferred teleoconch whorl and has a pausispiral protoconch of 1½ to 2 apparently mostly smooth whorls although vestiges of axial sculpture are present on one specimen (OU 40987) just after the first apical whorl. Unfortunately, the earliest whorl of this specimen is slightly eroded. Material at hand of an inferred Perissodonta sp. from the mid to Late Paleocene show mostly smooth early apical whorls with again axial sculpture by the third whorl (first teleoconch whorl). The apical whorls of most New Zealand Paleogene struthiolariid species have not been well documented. Subsequently, the assignment of species and genera such as Conchothyra parasitica, C. australis, Monalaria n. sp., and M. concinna, etc. to Struthiolariinae or Struthiolarellinae can only be considered tentative. The key diagnostic feature of Zinsmeister and Camacho (1980)--sculpture of the apical whorls--has still to be established for most of these species.

Genus CONCHOTHYRA Hutton, 1877

Conchothyra Hutton, 1877, p. 37, footnote (p. 35, Hutton, 1893, error).

Diagnosis.-(revised from Hutton, 1893 and Wilckens, 1922) Shell rather small- to large-sized, solid, very thick, globose to subglobose; spire low to blunt-conical of four to five whorls, about 20% of shell height; spire and last whorl either mostly covered in callus or partially exposed with prominent cinguli bearing nodes and spiral threads; ratio of height to diameter approximately 1:1; protoconch paucispiral, seemingly smooth; last whorl greatly inflated; posterior sinus angle large, sinus deep to moderately deep; last whorl with thick, broad callus mostly enveloping spire, sculpture of closely spaced sinuous growth lamellae becoming more closely spaced on wing; aperture long, narrow, sublenticular; anterior canal short; columella slightly curved to nearly straight; fasciole well-developed; outer lip produced into wing with subparallel sides.

Type species.-(by monotypy) Conchothyra parasitica (McCoy MS) Hutton, 1877.

Synonyms.-Conchotyra (error pro Conchothyra) Marwick, 1950, p. 238; Concothyra (error pro Conchothyra Hutton), Hornibrook, 1962, p. 298; Conchotya (error pro Conchothyra Hutton), Camacho and Zinsmeister, 1989, p. 99.

Biogeographic element.-Endemic, as inferred here.

Discussion.-The bizarre, heavily callused gastropod Conchothyra has received a great deal of attention since the name first appeared in print in 1870 in the Catalogue of the Colonial Museum, Wellington as "Aporhais (Conchithyra parasitica. McCoy.?)" (sic.) (see p. 193, Section G-II-2) ((see Haast, 1871, 1872, 1879; Hutton, 1874, 1877 (first description, not detailed), 1885, 1893 (further description, more detailed); Hector, 1879, 1886 (first figure); McKay, 1886, 1887; Park, 1888, 1910; Wilckens, 1904, 1905, 1922 (first detailed work), 1924; Marshall in Chilton, 1909; Marshall, 1912b, 1916; Trechmann, 1917; Marwick, 1924, 1932, 1950, 1960; Stewart, 1927; Speight, 1928; Finlay and Marwick, 1937; Wenz, 1940; Cotton, 1955; Hornibrook and Harrington, 1957; Marwick and Fleming in Wellman, 1959; Marwick, 1960; Sohl, 1960; Hornibrook, 1962; Fleming in Wilson, 1963; Scott in Gage, 1970; Zinsmeister, 1976a, 1976b, 1979, 1982; Warren and Speden, 1978; Zinsmeister and Camacho, 1980; Keyes, 1981; Speden and Keyes, 1981; Popenoe, 1983; Fleming, 1987; Crampton, 1988c; Camacho and Zinsmeister, 1989; Clarke and Crame, 1989; Beu and Maxwell, 1990; Olivero _et al._, 1990; and Darragh, 1991).

Little mention has been made in the literature of the possible life habits and functional morphology of _Conchothyra_, except that the genus was listed as either an "epifaunal or semi-infaunal deposit feeder (or ? browser)" by Warren and Speden (1978, p. 50, Tab. 5). A live specimen of _Conchothyra parasitica_ would today be a most interesting and intriguing sight, especially with respect to its unusual shell, head-foot and shell colour. Although we will never know the true colour pattern of the shell, it can be postulated that the colour pattern was one of alternating dark and light bands, paralleling the sinuous growth lines, similar to Recent struthiolariids. I deduce that the foot of _Conchothyra_ was very powerful and muscular given the massive, dense shell. The operculum may have been somewhat larger compared to Recent struthiolariids with a reduced terminal spike. Recent struthiolariids, such as _Pelicaria vermis_ (Martyn, 1784), have a small operculum with a spiked terminus which is used when the gastropod becomes overturned to right itself and also to dig into the sediment (Powell, 1979, p. 142, see Plate 7, Fig. 4 for live example with operculum). The siphon may have been reduced in _Conchothyra_ if the animal lived above or just below the seafloor-water interface or may have been of similar proportions to Recent struthiolariid species that live slightly deeper in the sediment. The inference here of an epifaunal habit suggests that the siphon was probably shorter in _Conchothyra_ compared to Recent struthiolariids because a long siphon would not be needed unless the shell was well beneath the sea-floor surface. Conchothyra probably had nutrient requirements like its modern struthiolariid counterparts. Struthiolariids today consume a host of fine, nutritive deposits, including diatoms, dinoflagellates and other detritus which is rolled into continuous food strings and then passed via a mucus-lined food groove along the floor of the mantle cavity (Morton and Miller, 1968, pp. 492-493).

The extremely thick shell of Conchothyra may have served as a predatory defense against durophagous predators (e. g. ammonites, belemnites, teleost fish, rays, marine reptiles, etc., especially crabs and chimaeras), if the genus was semi-infaunal or epifaunal, the latter being most likely. It could be argued that the increased shell thickness in Conchothyra evolved so that an epifaunal lifestyle, unlike Recent struthiolariid taxa, was possible; hence protection from predators was perhaps at a maximum in earlier forms. To invoke a semi-infaunal or even more unlikely infaunal mode seems unnecessary; the thick shell of Conchothyra would probably have been cumbersome beneath the sea bottom surface and passage through the sediment difficult depending on mass of soft tissue. Also, a very thick shell would be unnecessary if Conchothyra was infaunal, especially against nektic predators; however, one cannot exclude the possibility of Cretaceous rays having fed on Conchothyra. On the sea-floor surface Conchothyra parasitica probably moved with ease if indeed the head-foot was very muscular and the produced wing was used as a balance.

Observed reduction in callus extent, shell thickness and hence overall shell volume in Conchothyra over the Cretaceous/Tertiary interval may reflect a decrease in predation during this time especially in light of the extinction of ammonites, belemnites and marine reptiles, one or all which may have fed on Conchothyra. As stated above particular groups of decapods and molluscivorous fish may have preyed as well on Conchothyra. If rays were a principal predator on Conchothyra during the latest Cretaceous and early Tertiary in the infaunal realm, one could argue that the shell thickness and volume should have stayed relatively the same, but this is not observed. The cause(s) of the apparent extinction of Conchothyra by mid Paleocene time in New Zealand is uncertain, but loss of or decrease in suitable shallow shelf habitat and/or temperature change may have been factors influencing the eventual demise of this group which presumably had poor larval dispersal capabilities. Although the protoconch is unknown in Conchothyra parasitica, the early teleoconch whorls suggest that the protoconch is paucispiral and large, consistent with a nonplanktotrophic mode of development. Dispersal of Conchothyra larvae would have seemingly been restricted to within a relatively narrow geographic zone; indeed, the group is known only from what are interpreted as very shallow marine deposits from southern Marlborough to southern Canterbury. Distribution of Conchothyra australis (Marshall, 1916) during the Paleocene was as restricted geographically or slightly more than in the Cretaceous. The presence of Conchothyra australis in Paleocene rocks much further south during this time compared to the Cretaceous distribution may be a reflection of New Zealand's northward movement into lower latitudes and hence the southward migration of the group along the paleocoastline in keeping with the narrow environmental tolerance interpreted for Conchothyra. (Absence of suitable facies and fossil record for Cretaceous and early Paleogene Conchothyra may bias this interpretation to some degree and cannot be disregarded as a possible reason for the observed geographical pattern.) This very restricted geographic zone in New Zealand for Conchothyra during the latest Cretaceous may reflect not only poor dispersal capabilities, but also differential tolerances to latitude and hence sea-surface temperature, food availability, competition, substrate preference or combination of these or other parameters. The above factors would probably outweigh the importance or significance of the interpreted decrease in predation on Conchothyra during the Paleocene.

Paucity of preserved, fossiliferous mid-early Late Cretaceous and Upper Paleocene to Lower Eocene shallow marine deposits in New Zealand biases our biostratigraphic record to some extent; Conchothyra may have survived into the Late Paleocene, but it is not possible to know for certain when it became extinct. The stratigraphic record for New Zealand Eocene rocks is far better than that for Paleocene rocks.

As a final comment Hutton (1893, pp. 358-359) was mistaken in stating that the name of this taxon first appears in the Catalogue of the Colonial Museum (1870) and in more recent works as Conchothyra parasitica McCoy (probably a manuscript name sent by Sir F. McCoy to Sir J. von Haast); the name given in the Catalogue of Colonial Museum (p. 193) is actually "Aporhais (Conchithyra parasitica). McCoy?". The reason(s) for the change of the genus name from Conchithyra to Conchothyra is unknown, but may be a typographical error which propagated through time unnoticed. Because the name Conchothyra is well established in the literature, no attempt is made here to change it to the former name of Conchithyra, especially since ICZN (1985, Article 12(a)) stated that "To be available every new scientific name published before 1931 must satisfy the provisions of Article 11 and must have been accompanied by a description or a definition of the taxon that it denotes, or by an indication". Hutton (1877) satisfied this criterion.

CONCHOTHYRA PARASITICA Hutton, 1877

Plate 39 Figures 3-17; Plate 40 Figures 1-3

Aporhais (Conchithyra parasitica. McCoy. ?), Catalogue of the Colonial Museum, Wellington, 1870, p. 193.

Conchothyra parasitica (McCoy MS), von Haast, 1871, p. 10; von Haast, 1872, pp. 10, 68; Hutton, 1874, p. 515; Hutton, 1877a, pp. 37 (footnote), 38 (first description, very brief); Hutton, 1885a, p. 205; von Haast, 1879, p. 295; Hector, 1879, p. 12; Hector, 1886, p. 58, Fig. 20-4 (first figure, very poor woodcut); McKay, 1886, p. 37; McKay, 1887, p. 233; Park, 1888, p. 30; Hutton, 1893, pp. 358-359, Pl. 43, Figs. 1-5 (first in-depth description and figures); Wilckens, 1904, p. 207, Pl. 18, Figs. 3a-3b; Wilckens, 1905, pp. 19-20, see footnote 2 on pp. 19-20 also; Marshall in Chilton, 1909, p. 700; Park, 1910, pp. 90-91, Pl. 5, Figs. 1-5, p. 92, Fig. 47-4, p. 93; Trechmann, 1917, pp. 301-302, Pl. 20, Figs. 4-5; Wilckens, 1922, pp. 14-17, Pl. 3, Figs. 1a-b, 2a-c, 3a-b and 4 only; Marwick, 1924, pp. 165, 170-171; Wilckens, 1924, p. 544; Speight, 1928, pp. 25-26; Finlay and Marwick, 1937, pp. 63-65; Marwick, 1950, pp. 236-237, Fig. 10 only; Marwick and Fleming *in* Wellman, 1959, p. 139; Fleming *in* Wellman, 1959, p. 142; Fleming *in* Wilson, 1963, p. 25; Scott *in* Gage, 1970, p. 538; Zinsmeister, 1976a, p. 616; Zinsmeister, 1976b, p. 112; Speden *in* Suggate *et al*., 1978, p. 364, Fig. 6.7-1; Warren and Speden, 1978, p. 50, Tab. 5; Zinsmeister, 1979, p. 352; Zinsmeister and Camacho, 1980, pp. 7-8; Keyes, 1981, pp. 33-38; Speden and Keyes, 1981, p. 56, Pl. 23, Fig. 1; Andrews *et al*., 1987, p. 18; Fleming, 1987, pp. 50-51; Crampton, 1988, p. 977; Beu and Maxwell, 1990, p. 81; Darragh, 1991, pp. 152-153.

Conchothyra parsisitica (McCoy), Hector, 1886, p. 58, error.

Pugnellus (*Conchothyra*) *parasiticus* (McCoy), Wenz, 1940, p. 941, Fig. 2749.

Conchothyra paraistica (Hutton), Zinsmeister, 1976a, p. 616, error.

Supplementary description.-Shell medium- to large-sized, solid, very thick, globose; spire low, approximately 20% of total shell height, of four apparently smooth, slightly convex whorls, partially imperceptible due to last whorl mostly concealing earlier whorls with thick callus; whorl inflation extremely rapid from penultimate to last whorl; ratio of shell height to diameter of last whorl about 1:1; protoconch concealed by callus in adult specimens; suture nearly flush on spire whorls; growth lines of last whorl sinuous, mostly orthocline medially on wing; posterior sinus angle (PSA) about 75°; posterior sinus broad, deep to moderately deep; last whorl capacious with extensive callus mostly enveloping spire, slightly biangulate (on some specimens), greatly inflated, sculptured with numerous, closely spaced, sinuous, very prominent growth increments or lamellae, becoming more closely spaced on wing; growth increments on wing number about 10 per cm; aperture long, narrow, sublenticular, slightly constricted adapically, approximately 73% of total shell height; siphonal canal short, somewhat blunt, narrow, moderately deep, oblique v-shaped; columella slightly curved, concave, broad; siphonal fasciole demarcated by low, rounded ridge on anteriormost portion of last whorl; inner lip with thick, massive callus pad covering large portion of last whorl and nearly all of spire, mostly of even thickness from apex to anterior portion of inner lip, broadening significantly on wing and at point of intersection between abapical part of inner lip and advent of anterior canal constriction; outer lip produced into wing with subparallel sides (slightly more inclined abapically) and flattened more thickened end, some specimens with more produced wing than others; inner part of outer lip smooth.

Dimensions.-OU 40979 height 48.0 mm, diameter of last whorl 47.0 mm; OU 40980 height 46.0 mm, diameter of last whorl 47.0 mm.

Types and figured specimens.-TM 2633 (IGNS; Wilckens, 1922, Pl. 3, Fig. 1); TM 2634 (IGNS; Wilckens, 1922, Pl. 3, Fig. 2); TM 2635 (lectotype?) (IGNS; Wilckens, 1922, Pl. 3, Fig. 3; Wenz, 1940, Fig. 2749; Speden in Suggate et al., 1978, Fig. 6.7-1; Speden and Keyes, 1981, Pl. 23, Fig. 1); TM 2636 (IGNS; Wilckens, 1922, Pl. 3, Fig. 4).

Figured specimens this work.-TM 2633-2638 (IGNS), G 27421 (BMNH), OU 40979-40980.

Material.-43 specimens.

Localities.-"Hutton cliff", Otorama, Waimakariri River west bank, southern Canterbury, South Island (type), L35/f6013, L35/f6013A; Selwyn River, Malvern Hills, South Canterbury, L35/f6017; Selwyn River, left bank below rapids, Malvern Hills, L35/f6008; Selwyn Rapids, L35/f6510; McKays Creek, Mid Waipara, northern Canterbury, M34/f7254; Mid Waipara coal beds, northern Canterbury, M34/f7305; Birch Hollow, left branch on south side, northern Canterbury, M34/f1; South Branch of Waipara River, west of Doctors Gorge, northern Canterbury, M34/f7658; Boby's Creek, Waipara, North Canterbury, N34/f6257; ?Cretaceous glauconitic concretion in creek bed east of Trig G, southern Marlborough, South Island, O32/f8113; Cretaceous beds east-southeast of Trig G, O32/f8117; west wing of Haumuri Bluff, southern Marlborough, O32/f8025; at Cretaceous-Torlesse contact on coast just south of Mikonui Stream, southern Marlborough, O32/f8774A.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Conway Formation (= Saurian Sands), Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Southern Marlborough to southern Canterbury.

Discussion.-*Conchothyra parasitica* has been recorded from many localities throughout southern Marlborough to southern Canterbury only and in some localities forms near monotypic concentrations such as the well-known Conchothyra beds along the Waimakariri River (Conway Formation) in northern Canterbury, South Island (L35/f6013) (Figures 19-22 herein). At this locality there are two beds about 0.5 m thick of randomly oriented wholly adult shells of Conchothyra parasitica of nearly all the same size. Few other taxa are present, including Pacitrigonia sylvesteri Marwick, Panopea malvernensis Woods, a poorly preserved venerid (probably Aphrodina (Tikia)), and Dimitobelus sp. in very low abundance. The shell beds are separated by partially laminated (or indistinctly decimetre bedded), mostly massive, medium-grained grey sandstone. The absence of juveniles, the similarity of shell size, clast supported nature of the deposits and inferred life habits of Conchothyra all point to a sorting phenomenon for the beds. The subglobose nature of Conchothyra would have made transport along the sea-floor bottom relatively easy. Other debris may have been selectively taken away by winnowing; after the event which "dumped" these shells current velocities waned and only fine to medium sand remained. The assemblage can be considered a parautochthonous one with the shells being transported a minimal distance from their nearby habitat.

Supposed juvenile forms of Conchothyra parasitica (referred previously to C. marshalli (Trechmann, 1917) (p. 302, Pl,. 19, Figs. 1-4; Wilckens, 1922, pp. 15-16, Pl. 3, Figs. 5-6, Pl. 4, Figs. 1-2)) are interpreted here as distinct both from C. parasitica and from the sole representative of the genus in the Tertiary, the Paleocene species C. australis (Marshall, 1916b)

(p. 120, Pl. 11, Figs. 1-3; Trechmann, 1917, p. 303, Pl. 20, Figs. 1a-b only; Finlay and Marwick, 1937, pp. 64-65, Pl. 8, Figs. 5-6). The supposed juvenile, Conchothyra marshalli (below), has smaller shell (dimensions ~ height 22.0 mm, diameter of last whorl 20.0 mm), higher posterior sinus angle, spire with five sculptured whorls, a less extensive callus and a blunt, extended, central tubercle or thickening on the inner lip parallel to the anterior cinguli, compared to C. parasitica. Conchothyra australis is somewhat smaller with well-developed sculpture on the last whorl of prominent nodules on the angulations and spiral threads on the regions not covered in callus, has a slightly thinner shell, less extensive callus and developed cinguli, compared to C. parasitica which is larger with sculpture of sinuous growth lamellae, has a thicker shell, and a more extensive callus.

It seems likely that Conchothyra parasitica (Late Cretaceous) evolved into C. australis (senior synonym of C. expedita Finlay and Marwick, 1937) given relatively small differences between these two species. Conchothyra parasitica is probably the progenitor of late Paleogene to Recent groups such as Struthiolaria, but more work is needed to document firm relationships.

CONCHOTHYRA MARSHALLI (Trechmann, 1917)

Plate 40 Figures 4-25

Pugnellus marshalli Trechmann, 1917, pp. 302-303, Pl. 19, Figs. 1-4; Finlay and Marwick, 1937, p. 64.

Conchothyra parasitica (McCoy MS) Hutton, Wilckens, 1922, p. 15, Pl. 3, Figs. 5a-b, 6a-b, Pl. 4, Figs. 1a-c, 2a-b, only; Marwick, 1950, Fig. 11 only.

Conchothyra marshalli (Trechmann), Marwick, 1924, pp. 170-171, Fig. 10.

Supplementary description.-Shell small, moderately solid to solid, thick, only slightly globose; spire moderately low, approximately 40% of total shell height, of five shouldered, convex whorls; spire mostly emergent, only partially concealed adaxially by callus; whorl inflation very rapid from penultimate to last whorl; ratio of height to diameter of last whorl slightly greater than 1:1; protoconch paucispiral, conical of 1½ to 2 smooth, moderately large, convex whorls; suture slightly impressed to slightly channelled; growth lines of last whorl sinuous, opisthocline posteriorly becoming more prosocyrt medially on wing; posterior sinus angle (PSA) high, about 85°; posterior sinus broad, deep; last whorl capacious, greatly inflated, triangulate, cingulate; posterior angulation strongest, ornamented with at least ten projecting, rounded, spaced nodes (some nodes obscurred by callus); middle cingulum with obsolescent nodes and anteriormost cingulum poorly developed; middle and anterior cinguli more closely spaced than posterior and middle cinguli; spiral sculpture weak of numerous, closely spaced threads; axial sculpture wanting except for occasional growth lines and lamellae on varix; posterior ramp on last whorl steep, slightly concave; sculpture on spire whorls commences with first teleoconch whorl, ornamented with numerous, small, spaced, more anterior, subsutural nodes; basal constriction moderately rapid; growth increments on wing closely spaced; aperture long, narrow, sublenticular, slightly constricted abapically, approximately 67% of total shell height; siphonal canal short, moderately blunt, narrow, moderately deep; columella curved, concave, moderately long; siphonal fasciole prominent, demarcated by pronounced, raised ridge on anterior portion of last whorl; apertural callus very prominent, moderately thickened, thickest from a point beginning at middle cingulum and ending below anterior cingulum where it forms a large, elongated swelling or extended, blunt tubercle; callus of more-or-less uniform width, smooth, slightly broader in a narrow zone parallel to basal constriction; callus extends up spire to top of penultimate whorl forming a thick, relatively broad, flattened, raised varix on sinuous labrum, broadest on wing; callus only partially covers spire; outer lip produced into variably extended wing with obliquely inclined end and nonparallel sides; posterior side subhorizontal and anterior side moderately steeply inclined abapically; distal part of wing very slightly more thickened; wing with very slight, poorly developed notch anteriorly; inner part of outer lip smooth.

Dimensions.-OU 40981 (from OU 10980) height 23.0mm, diameter of last whorl 19.5 mm; OU 40982 height 20.5 mm, diameter of last whorl 18.0 mm; OU 40983 height 22.5 mm nearly complete, diameter of last whorl 20.5 mm; OU 40987 height 19.5 mm incomplete.

Types, previously figured specimens, museum specimens.-Lectotype G 27413 (designated herein) (BMNH; Trechmann, 1917, Pl. 19, Fig. 1); syntype G 27414 (BMNH; Trechmann, 1917, Pl. 19, Fig. 2); syntype G 27415 (BMNH; Trechmann, 1917, Pl. 19, Fig. 3); syntype

G 27416 (BMNH; Trechmann, 1917, Pl. 19, Fig. 4); G 27417 (BMNH); G 27418 (BMNH); G 27419 (BMNH); TM 2637 (IGNS; Wilckens, 1922, Pl. 3, Fig. 5); TM 2638 (IGNS; Wilckens, 1922, Pl. 3, Fig. 6); TM 2640 (IGNS; Wilckens, 1922, Pl. 4, Fig. 1); TM 2641 (IGNS; Wilckens, 1922, Pl. 4, Fig. 2); TM 2642 (IGNS; Trechmann, 1917, p. 302); TM 2643 (IGNS; Trechmann, 1917, p. 302); TM 2644 (IGNS; Trechmann, 1917, p. 302); TM 2645 (IGNS; Trechmann, 1917, p. 302).

Figured specimens.-G 27414-27419 (BMNH), TM 2638-2644 (IGNS), OU 40981-40983, OU 40987 (all from OU 10980).

Material.-14 specimens, mostly complete.

Localities.-Selwyn River, left bank below rapids, Malvern Hills, southern Canterbury, South Island, L35/f6008, c.L35/f6510).

Stratigraphic range.-Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Southern Canterbury, South Island.

Discussion.-Wilckens (1922, pp. 15-16) believed that *Pugnellus marshalli* Trechmann, 1917 (p. 302, Pl. 19, Figs. 1-4) represented the juvenile form of *Conchothyra parasitica* Hutton, 1877, but did not cite reasons. Later workers have followed Wilckens' decision (e. g. Marwick, 1924; Finlay and Marwick, 1937) without further comment. In the early stages of this review of the Struthiolariidae I could not help noticing major differences between the specimens at hand of *C. marshalli* and *C. parasitica*. All of the 14 specimens of *C. marshalli* at my disposal are consistently smaller compared to *C. parasitica* without any gradation in size. The posterior sinus angle of *C. marshalli* is at least 10 degrees more compared to *C. parasitica* and the spire is higher than in adult shells of *C. parasitica*. Furthermore, specimens of *C. marshalli* have well-developed sculpture not seen in *C. parasitica*, a more concave columella and also a moderately well-developed blunt tubercle or thickening on the callus positioned on the central portion of the inner lip. One would expect to see a gradation in size if these examples are in fact merely juveniles of *C. parasitica*. These differences are believed to be tentatively of species-level significance, and not intraspecific as previously supposed.

The closeness in overall morphology between *C. marshalli* and *Monalaria gracilis* Finlay and Marwick, 1937, may attest to a close relationship phylogenetically. The overall outline and sculpture of these two species is very similar, except that the callus is not as extensive in *M. gracilis*, the cinguli are not as developed and the outer lip is not as thick.

Superfamily HIPPONICACEA Troschel, 1861

Family VANIKORIDAE Gray, 1840

Genus *VANIKORO* Quoy and Gaimard, 1832

Vanikoro Quoy and Gaimard, 1832, p. 232.

Type species.-(by original designation) *Sigaretus cancellatus* Lamarck, 1822.

Synonym.-*Merria* Gray, 1839 (Abbott, 1974, p. 137).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

VANIKORO? n. sp.

Plate 41 Figures 1-2

Dimensions.-Ge 7629 (AIM) height 5.5 mm incomplete, diameter of last whorl 5.25 mm.

Figured specimen.-Ge 7629 (AIM).

Material.-One specimen.

Locality.-Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-A specimen discovered in the collections at the Auckland Institute and Museum is reminiscent in whorl profile and opisthocyrt growth lines to *Calliomphalus* s. l. *hickmanae* n. sp., but the spiral sculpture of spaced, unequal, pronounced cords which become more widely spaced towards the umbilical region suggest that this probable new species is distinct from *C*. s. l. *hickmanae* n. sp. The specimen appears to be anomphalous, but the umbilical area of this specimen is partially covered by well-cemented, very fine-grained matrix. Most of the matrix has been cleared away. In overall features this specimen seems more appropriately placed in *Vanikoro* Quoy and Gaimard, 1832, than to *Calliomphalus*. *Vanikoro*? n. sp. is very similar to the type species, *V*. *cancellata* (Lamarck, 1822) (see Wenz, 1940, p. 885, Fig. 2604; Cernohorsky, 1972, p. 86, Pl. 21, Fig. 8; Abbott and Dance, 1983, p. 71, middle figure on top row), from the Recent of the central and southwestern Pacific, but the New Zealand species has a less compressed and more inflated last whorl, a larger penultimate whorl and weaker growth lines.

Superfamily CALYPTRAEACEA Blainville, 1824

Family CALYPTRAEIDAE Blainville, 1824

Genus *SIGAPATELLA* Lesson, 1830

Sigapatella Lesson, 1830, p. 389.

Types species.-(by subsequent designation, Gray, 1847) *Calyptraea* (*Sigapatella*) *novazeladiae* Lesson, 1830.

Biogeographic element.-Paleoaustral as interpreted here.

SIGAPATELLA? *SOLITARIA* (Wilckens, 1922)

Plate 41 Figure 3

Calyptraea solitaria wilckens, 1922, p. 6, Pl. 1, Fig. 10.

Type.-Lectotype TM 2610 (designated herein) (IGNS; Wilckens, 1922, Pl. 1, Fig. 10).

Type locality.-Boby's Creek, Waipara, Canterbury, South Island, M34/f7257.

Stratigraphic range.-Saurian beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Waipara, Canterbury, South Island.

Discussion.-Only the holotype, represented by a poorly preserved cast, of *Sigapatella*? *solitaria* (Wilckens, 1922) exists. As far as I am aware no further material of this species has been recorded. This species probably represents an early member of *Sigapatella*, but is too poorly preserved for further comment.

Genus *CREPIDULA* Lamarck, 1799

Crepidula Lamarck, 1799, p. 78.

Type species.-(by original designation) *Crepidula fornicata* (Linné, 1758).

Synonyms.-Numerous, including *Maoricrypta* Finlay, 1927, and *Zeacrypta* Finlay, 1927 (Vaught, 1989, p. 32; Beu and Maxwell, 1990, p. 259).

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-The origins of *Crepidula* extend back at least into the Upper Cretaceous (Wenz, 1940, p. 903). *Crepidula hochstetteriana* Wilckens, 1922, a rare species from the Late Cretaceous of New Zealand, is one of the earliest members of the group. *Crepidula hochstetteriana* is inferred to have been a sedentary filter feeder that attached itself to stones, shells, etc. similar to limpets.

CREPIDULA HOCHSTETTERIANA Wilckens, 1922

Plate 41 Figures 5-6

Crepidula hochstetteriana Wilckens, 1922, pp. 5-6, Pl. 1, Figs. 9a-b; von Ihering, 1924, p. 310.

Maoricrypta hochstetteriana (Wilckens), Finlay and Marwick, 1937, p. 46; Fleming *in* Wellman, 1959, p. 142; Warren and Speden, 1978, p. 50, Tab. 5.

Type.-Lectotype (designated herein) TM 2608 (IGNS; Wilckens, 1922, Pl. 1, Fig. 9).

Figured specimen.-TM 2608 (IGNS).

Localities.-West wing of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 (type) (GS 2 and GS 13).

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, Upper Campanian, Upper Cretaceous).

Geographic distribution.-Haumuri Bluff, southern Marlborough.

Discussion.-*Crepidula hochstetteriana* is one of the oldest species of the group from the fossil record. Finlay and Marwick (1937, p. 46) commented on the significance of the early record of *Crepidula* (= *Maoricrypta*) in the Late Cretaceous of New Zealand and noted the similarity between *C. hochstetteriana* and *C. radiata* (Hutton, 1873a) (= *C. wilckensi* Finlay) from the

Dannevirke? Series to Nukumaruan Stage (uppermost Pliocene-lowermost Pleistocene) of New Zealand. To my knowledge no new material of C. hochstetteriana has come to light since the original collection of two, poor specimens by A. Mackay in the 1870's.

Family CAPULIDAE Fleming, 1822

Discussion.-Two probable capulid species are represented in the New Zealand Late Cretaceous record, cf. Capulus? sulcatus Wilckens, 1910, and Gigantocapulus n. sp., the latter of which is currently under study by A. Beu of Institute of Geological and Nuclear Sciences, Lower Hutt.

Genus CAPULUS Montfort, 1810

Capulus Montfort, 1810, p. 54.

Type species.-(by original designation) Patella hungaricus Linné, 1767.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

cf. CAPULUS? SULCATUS Wilckens, 1910

Plate 41 Figures 7-8

cf. Capulus? sulcatus Wilckens, 1910, pp. 76-77, Pl. 3, Fig. 27.

Dimensions.-G 7047 (from AU 2574) height 8.5 mm nearly complete.

Figured specimen.-G 7047 (AU).

Material.-One specimen.

Locality.-Bull Point, Kaipara, Northland, Q08/f9909.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland; ?southern

Marlborough, South Island.

Discussion.-A cap-shaped, decorticated gastropod collected during the mid 1960s from uppermost Cretaceous calcareous siltstones of Bull Point, Kaipara compares well with a very rare coeval capulid gastropod Capulus? sulcatus Wilckens, 1910 (pp. 76-77, Pl. 3, Fig. 27) from Snow Hill Island, Antarctic Peninsula, in terms of outline, size, and position of grooves radiating from the apex. Evidence of fine radial ribbing is present on the base of G 7047 (AU). The two species, if not indeed conspecific, are at least congeneric. The apex is missing in G 7047. Cf. Capulus? sulcatus is also reminiscent of some Cretaceous siphonariid gastropods such as Anisomyon centrale Meek, 1871 (see Sohl, 1967, pp. B38-B40, Pl. 9, Figs. 1-2; Pl. 10, Figs. 1-15; Pl. 11, Figs. 1-7, 9), but position of radial grooves in cf. C.? sulcatus are quite different from A. centrale. Anisomyon? sp. was reported by Warren and Speden (1978, p. 50, Tab. 5) from the Tarapuhi Grit of Haumuri Bluff, southern Marlborough, but the relationship of this species to cf. C.? sulcatus is unknown. Disparity of shell outline, position of apex, and sculpture of both C.? sulcatus and cf. C.? sulcatus compared with the type species of Capulus, C. hungaricus (Linné, 1767) (refigured by Wenz, 1940, p. 897, Fig. 2640), may prove sufficient ground for separation of these groups at genus-level.

Family TRICHOTROPIDAE Gray, 1850

Genus TRICHOTROPIS Broderip and Sowerby, 1829

Trichotropis Broderip and Sowerby, 1829, p. 373.

Type species.-(by original designation) Trichotropis bicarinata (Sowerby, 1825).

Subgenus *CERITHIODERMA* Conrad, 1860

Cerithioderma Conrad, 1860, p. 295.

Type species.-(by monotypy) *Cerithioderma primum* Conrad, 1860.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-*Cerithioderma* has been considered in the past to be a synonym of *Trichotropis* Broderip and Sowerby, 1829 (Abbott, 1974, p. 138; Vaught, 1989, p. 32), but examination of figures of the types of *Cerithioderma*, *C*. *primum* Conrad, 1860 (see Wenz, 1941, p. 982, Fig. 2623), from the Middle Eocene of Alabama, and *Trichotropis*, *T*. *bicarinata* (Sowerby, 1825) (see Hirase, 1936, Pl. 91, Fig. 14; Wenz, 1941, p. 890, Fig. 2618) from the Recent of Japan to the Arctic Ocean suggests to me that significant sculptural, apertural and outline differences warrant at least subgenus-level separation of these groups. *Trichotropis bicarinata* has, hence the species-level name, two strong spiral carinae at the periphery of the last whorl absent in *Cerithioderma primum* and has no noticeable axial component which is moderately strong in *C*. *primum*. The spire in typical *Cerithioderma* is higher that in typical *Trichotropis* and the anterior canal in *Cerithioderma* is more produced and oblique than in *Trichotropis* which has a vague, poorly developed canal. Finlay and Marwick (1937, p. 43) and Maxwell (1966, p. 452; 1992, pp. 93-94) discussed at length the similarities and differences between *Cerithioderma* and *Trichosirius* Finlay, 1926, but did not compare *Cerithioderma* with *Trichotropis* s. s.

Trichotropis (*Cerithioderma*) has been recorded from Upper Cretaceous to upper Paleogene rocks of Europe, North America and

Australia. The recognition of this group in Upper Cretaceous New Zealand rocks for the first time extends considerably the geographic range of T. (Cerithioderma).

TRICHOTROPIS (CERITHIODERMA) WAIMARAMAENSIS n. sp.

Plate 41 Figures 4, 11, 18

Diagnosis.-Moderately large T. (Cerithioderma) with spire angle of 57°; growth lines faint, suborthocline; axial sculpture strong of about 10 raised, thickened, pronounced collabral varices separated from each other by deeply excavated smooth intervariceal areas, and about 25 moderately strong spiral cords; anterior canal short, narrow, oblique; distinguished from T. (C.) primum Conrad, 1860, in having a larger shell, a more inflated last whorl and much stronger collabral varices.

Description.-Shell moderately large, somewhat thin but solid, high-spired turbinate; spire high of at least four, gently convex, highly sculptured whorls; whorl inflation mostly constant from early whorls to penultimate whorl, rapidly increasing from penultimate to last whorl; spire angle 57°; protoconch unknown; suture impressed; growth lines suborthocline; last whorl inflated sculptured with about 10 very strong, raised, separated, thickened collabral varices and about 25 moderately strong, subequally spaced spiral cords, present also on varices; deeply excavated between varices; varices on penultimate and older whorls more subdued; aperture siphonostomatous, large, rounded; anterior canal short, narrow, oblique.

Dimensions.-Holotype TM 7546 (IGNS) (GS 2566) height 28.5 mm nearly complete, diameter of last whorl 21.0 mm; paratype TM 7547 (IGNS) (GS 2566) height 19.5 mm incomplete, diameter of last whorl 16.0 mm.

Types.-Holotype TM 7546 (IGNS); paratype TM 7547 (IGNS).

Figured specimens.-TM 7546, TM 7547 (IGNS).

Type locality.-Waimarama, southern Hawke's Bay, North Island, V22/f8492 (GS 2566).

Stratigraphic range.-Formation uncertain (Mangaotanean to Piripauan? stages, Santonian to upper Campanian, Upper Cretaceous).

Geographic distribution.-Southern Hawke's Bay, North Island.

Discussion.-*Trichotropis* (*Cerithioderma*) *waimaramaensis* n. sp. represents the only known occurrence of this group in the New Zealand fossil record and is recorded from a single locality in southern Hawke's Bay, North Island. *Trichotropis* (*Cerithioderma*) *waimaramaensis* n. sp. is morphologically very similar to the Eocene type species *T*. (*C*.) *primum* Conrad, 1860, but *T*. (*C*.) *waimaramaensis* n. sp. is much larger with a more inflated last whorl and a stronger axial component compared to *T*. (*C*.) *primum*. *Trichotropis* (*Cerithioderma*) *waimaramaensis* n. sp. seems unrelated to coeval South Indian taxa such as *Trichotropis konincki* (Müller, 1851) (Stoliczka, 1867, pp. 158-159, Pl. 13, Figs. 7-9) and *T*. *nodulosa* Stoliczka, 1867 (pp. 159-160, Pl. 13, Fig. 10).

Superfamily NATICACEA Gray, 1840

Family NATICIDAE Gray, 1840

Subfamily POLINICINAE Gray, 1847

Genus *EUSPIRA* Agassiz *in* J. Sowerby, 1837

Euspira Agassiz *in* J. Sowerby, 1837, p. 14.

Type species.-(by subsequent designation, Bucquoy, Dautzenberg, and Dollfus, 1883) *Natica glaucinoides* J. Sowerby, 1812 (**non** Deshayes, 1832) [= *Natica labellata* Lamarck, 1804] (Kabat, 1991, p. 429).

Synonyms.-Numerous, including *Lunatia* Gray, 1847; *Laguncula* Benson, 1842; *Bensonia* Gray, 1847; *Ampullonatica* Sacco, 1890 (Kabat, 1991, p. 429).

Biogeographic element.-Cosmopolitan, as interpreted here.

Discussion.-Stoliczka (1868, p. 296) determined that *Lunatia* is a junior subjective synonym of *Euspira*; this decision has been followed by several subsequent workers including Dall (1908), Sohl (1960, 1967), Marincovich (1977) and Kabat (1991), and is followed here. Other workers, Finlay and Marwick (1937), Beu and Maxwell (1990), and Maxwell (1992) considered *Lunatia* and *Euspira* to be distinct genera. Maxwell (1992, p. 105) stated that the type species of *Euspira*, *E*. *glaucinoides* (Sowerby, 1812) can be differentiated from *Lunatia heros* and *L*. *catena* (da Costa, 1776) "in having an ovate rather than a globose shell, in its more conic spire, and in having a distinct lobe on the inner lip at the posterior end of the umbilicus" (mostly taken from Wrigley, 1949). Maxwell (1992) did not compare *Euspira glaucinoides* with the type species of *Lunatia*, *L*. *ampullaria* Lamarck, 1822 (see Wenz, 1941, p. 1034, Fig. 2959; Abbott (1974, p. 155) stated that *L*. *heros* (Say, 1822) (see Abbott, ibid, Fig. 1690) is the type species of *Lunatia*); both *E*. *glaucinoides* and *L*. *ampullaria* are morphologically very similar. More work is clearly needed to settle the dispute as to whether *Euspira* and *Lunatia* are indeed congeneric; these two taxa appear "closely related, if not perhaps congeneric, depending on weight given to minor differences to inner lip and shell outline of these variable groups" (Stilwell, 1992, pp. 51-52). Euspira glaucinoides is separated from L. ampullaria in having a somewhat smaller shell, a slightly more globose last whorl and a slightly wider inductura in the parietal region; these differences are probably not significant at genus-level. As a sidenote, Marincovich (1993, p. 31) in a paper on Danian Arctic molluscs preferred the placement of Euspira as a subgenus of Polinices Montfort, 1810.

Euspira has a fossil record extending back into the Aptian (Early Cretaceous) of Japan (Kase, 1984, p. 156); species diversity of Euspira was high by the Late Cretaceous and continues to remain high today. Cretaceous species of Euspira were probably epifaunal or semi-infaunal carnivores.

EUSPIRA SELWYNIANA (Wilckens, 1922)

Plate 41 Figures 9-10, 12-17, 19-25

Natica (Euspira) variabilis Moore, Trechmann, 1917, pp. 299-300, Figs. 8a-b, 9a-b, 10a-b.

Natica selwyniana Wilckens, 1922, pp. 6-7, Pl. 2, Fig. 1a-b; Griffin and Hünicken, 1994, p. 264.

Natica ingrata Wilckens, 1922, pp. 7-8, Pl. 2, Fig. 2a-c.

Lunatia selwyniana (Wilckens), Finlay and Marwick, 1937, pp. 56, 59; Fleming in Wilson, 1963, p. 25.

Lunatia selwynensis (Wilckens), Marwick and Fleming in Wellman, 1959, p. 139.

Supplementary description.-Shell small- to medium-sized, moderately solid, semi-globose; spire low of at least three convex whorls, about 12% of total shell height; whorl inflation extremely rapid from penultimate to last whorl; spire angle approximately 115°; protoconch paucispiral; suture slightly impressed; growth lines prosocline; last whorl greatly inflated; shell mostly smooth except for variably fine to coarse growth lines; aperture large, elongate subovate, holostomatous; umbilicus moderately wide; inductura moderately thick, apparently narrow on available specimens.

Dimensions.-OU 40984 height 9.5 mm; TM 7548 (IGNS) height 15.5 mm, diameter of last whorl 13.0 mm; TM 7549 (IGNS) height 10.0 mm, diameter of last whorl 8.5 mm.

Types and previously figured specimens.-G 27422 (BMNH; Trechmann, 1917, Pl. 19, Fig. 8a-b); G 27423 (BMNH; Trechmann, 1917, Pl. 19, Fig. 9a-b); G 27424 (BMNH; Trechmann, 1917, Pl. 19, Fig. 10a-b); G 27425 (BMNH; not figured); G 27426 (BMNH; not figured); Lectotype TM 2612 (designated herein) (IGNS; Wilckens, 1922, Pl. 2, Fig. 1).

Figured specimens.-TM 2611-2612 (IGNS), TM 6879 (IGNS), TM 7548-7549 (IGNS) (from GS 14260), OU 40984 (from OU 5452).

Material.-Four specimens.

Localities.-Selwyn River, left bank below rapids, Malvern Hills, southern Canterbury, South Island, L35/f6008 (type); middle Waipara, southern Canterbury, South Island, M34/f7263; ?Left bank of Kaiwara River, Marlborough, South Island, N33/f9811; ?east wing of Haumuri Bluff, southern Marlborough, O32/f9029; ?Okarahui Stream, southern Marlborough, O32/f8790; ?Haumuri Bluff, O32/f9504; ?north face of Haumuri Bluff, O32/f9529; ?long ridge above Jedburgh Station, Cheviot, southern Marlborough, O33/f9044;

?Waitangi River, Bay of Islands, Northland, P05/f9491; east bank of Te Hoe River, western Hawke's Bay, North Island, V19/f185; V19/f6511; ?lower Mangahouanga Stream, western Hawke's Bay, V19/f6649.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous); ?Silverstream Formation, ?Katiki Formation, Brighton Formation, Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Only southern Canterbury, South Island, for certain.

Discussion.-Finlay and Marwick's (1937, p. 59) decision that Natica ingrata Wilckens, 1922 (pp. 7-8, Pl. 2, Fig. 2a-c) is a juvenile of N. selwyniana Wilckens, 1922 (pp. 6-7, Pl. 2, Fig. 1a-b), is upheld here. Available material reveal a gradation in size and features such as prosocline growth lines, slightly impressed sutures and moderately wide umbilicus; any differences are most likely a reflection of ontogeny. Natica ingrata is synonymised with N. selwyniana. Updating the taxonomy of this group, N. selwyniana is now placed in Euspira. It could be argued that the species name be changed from "selwyniana" to "selwynensis" to conform with the International Code of Nomenclature (1985) as "Selwyn" is a place name requiring that "-ensis" be placed after the name, especially since the species is most likely named after the type locality of Selwyn River and not Bishop Selwyn of New Zealand.

A New Zealand Paleocene species, Lunatia fyfei (Marwick, 1924b) (p. 569, Pl. 59, Figs. 8-9; Finlay and Marwick, 1937, p. 59, Pl. 7, Figs. 5, 6, 9, 10) was determined by Finlay and Marwick (1937, p. 59) to be the descendant of *L. selwyniana* (Wilckens) on the basis of similarities in "general shape, impressed suture, course of growth-lines [= prosocline], and umbilicus". *Euspira selwynensis* is an uncommon species in the Late Cretaceous gastropod fauna of New Zealand and well-preserved specimens are rare.

Genus *EUNATICINA* Fischer, 1885

Eunaticina Fischer, 1885, p. 768.

Type species.-(by monotypy) *Nerita papilla* Gmelin, 1791.

Synonyms.-*Naticina* Gray, 1847; *Sigaretotrema* Sacco, 1890; *Propesinum* Iredale, 1924; *Pervisinum* Iredale (Kabat, 1991, p. 429).

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-The relationship of previously described Cretaceous and Recent species of *Eunaticina* is unclear. Late Cretaceous species previously referred to *Eunaticina*, such as *E. arctowskiana* Wilckens, 1910, from the latest Cretaceous of Antarctic Peninsula, and the newly described congeneric New Zealand species below, *E. omapereensis* n. sp. have less globose shells with much higher spires and shallower umbilici compared to the type species, *E. papilla* (Gmelin, 1791). This variation is probably supraspecific and hence, a new genus name should be warranted. The exquisitely preserved material of *E. arctowskiana* from Seymour Island, Antarctic Peninsula (J. D. S., pers. obs.), could form the basis of a new genus, much more so than the depauperate collection of *E. omapereensis* n. sp. of New Zealand.

EUNATICINA? OMAPEREENSIS n. sp.

Plate 42 Figures 1, 3, 6

Diagnosis.-Weakly umbilicate, subglobose to subtrochiform species with spire angle of 74°; posterior slope of last whorl slightly concave; spiral sculpture dominant of about 15 cords; axial sculpture somewhat weaker of prosocline growth increments; differs from *E.? arktowskiana* in having fewer spiral ribs, a slightly concave posterior slope and less inflated penultimate whorl.

Description.-Shell medium-sized, moderately thin, subglobose to subtrochiform, umbilicate; spire high and inflated for family of at least three mostly straight-sided whorls; spire angle 74°; protoconch unknown; suture slightly impressed to nearly flush on older whorls; growth lines prosocline; last whorl moderately inflated, posterior slope slightly concave; spiral sculpture dominant of about 15 slightly raised, broad, spaced, spiral cords; axial sculpture of weaker growth increments, creating subreticulate pattern with very weak nodes at intersection of spiral and axial elements; penultimate and older whorls with about 10 spiral ribs; aperture holostomatous, subcircular; umbilicus shallow; inductura thin; outer lip thin.

Dimensions.-Holotype TM 7550 (IGNS) height 30.0 mm, diameter of last whorl 27.0 mm; TM 7551 (IGNS) (from GS 6027) height 29.0 mm, diameter of last whorl 26.5 mm.

Types.-Holotype TM 7550; paratype TM 7551 (both IGNS).

Type locality.-Exact locality unknown, Lake Omapere, North Auckland, North Island, c. P05/f9646.

Material.-Two specimens.

Stratigraphic range.-?Otamatea Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Lake Omapere, Northland.

Discussion.-*Eunaticina*? *omapereensis* n. sp. is morphologically very similar to the coeval species *Eunaticina*? *arktowskiana* Wilckens, 1910 (pp. 78-80, Pl. 3, Figs. 29a-b; Macellari, 1984, Pl. 34, Figs. 11-12, Pl. 35, Fig. 11 (*E*. *arctowskiana* (sic.), error)) from Seymour, Snow Hill, James Ross (Stilwell and Zismeister, 1987b), Humps (Stilwell and Zinsmeister, 1987c) and ?Cockburn (Stilwell and Zinsmeister, 1987a) islands along the Antarctic Peninsula, James Ross Basin. *Eunaticina*? *omapereensis* n. sp. has fewer more widely spaced spiral cords and a slightly concave posterior slope on the last whorl and a more inflated penultimate whorl compared to *E*.? *arktowskiana* which has a more convex posterior slope, numerous closely spaced spiral cords or ribs and an inflated penultimate whorl with a slightly convex profile. *Vanikoropsis* *nebrascensis* (Meek and Hayden, 1860) (discussed and figured by Sohl, 1967, pp. B22-B23, Pl. 5, Figs. 1, 5-10, 12, 14, 17; Pl. 6, Figs. 1-4, 11) from the Late Cretaceous of western North America is reminiscent of *E*.? *omapereensis* n. sp., but the last whorl of the latter New Zealand species is less globose with a much steeper posterior slope and more prominent growth increments compared to *V*. *nebrascensis*.

Etymology.-Species named after its occurrence near Lake Omapere, North Auckland.

Genus *AMAUROPSONA* Finlay and Marwick, 1937

Amauropsona Finlay and Marwick, 1937, pp. 56-57.

Type species.-(by original designation) *Nucleopsis major* Marshall, 1917.

Biogeographic element.-Endemic.

Discussion.-*Amauropsona* is an endemic, short-lived polinicine group, known before this work only from the Paleocene. Species of *Amauropsona* have ovate, medium-sized, smooth or spirally lirate shells with channelled sutures, an antecurrent [prosocline] outer lip ("nearly straight, but lightly and broadly sinused below"), a relatively small umbilicus and a thin parietal callus (Finlay and Marwick, 1937, pp. 56-57). A well-preserved specimen (Ge 8144 (AIM)) from Te Opu, Kaipara, Northland, has features consistent with *Amauropsona*. Unfortunately, some of the inner lip and apical whorls of this specimen is covered by fine, well-cemented sandstone matrix; only a tentative assignment is given here. If specimen Ge 8144 from the Maastrichtian of New Zealand does indeed represent a species of *Amauropsona*, it is the earliest record of the genus.

A possible record of *Amauropsona* was noted by Dell and Fleming (1975, p. 693) from Oligocene-Miocene sediments of Site 270, Ross Sea, Antarctica (Deep Sea Drilling Project, Leg 28). Although Dell and Fleming recognised the similarities, especially with respect to spiral sculpture, of the Ross Sea species to *Amauropsona major* (Marshall) (more so than Recent Antarctic and Subantarctic species of *Amauropsis*) they curiously placed the Ross species tentatively in *Amauropsis*.

AMAUROPSONA? n. sp.

Plate 42 Figures 2, 4

(?) *Amauropsona*? sp. of Marwick and Fleming *in* Wellman, 1959, p. 139.

Description.-Shell small, thin, polished, ovate; spire moderately high of at least two convex whorls; ratio of shell height to diameter of last whorl nearly 1:1; last whorl 75% of total shell height; whorl inflation rapid from penultimate to last whorl; protoconch unknown; suture channelled; growth lines faint, prosocline; last whorl moderately to highly inflated, convex; sculpture vague of very fine growth lines and microscopic wavy, spiral lines; aperture sublenticular to subovate, holostomatous; umbilicus moderately shallow; inductura thin?; outer lip thin, prosocline.

Dimensions.-Ge 8144 (AIM) height 8.0 mm, diameter of last whorl 7.0 mm; G 7048 (AU) height 5.0 mm, diameter of last whorl 5.0 mm.

Figured specimens.-Ge 8144 (AIM), G 7048 (AU).

Material.-Three specimens, one moderately well-preserved.

Localities.-Te Opu, Kaipara, Northland, Q08/f9639; Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-*Amauropsona*? n. sp. seems most similar to the New Zealand Paleocene species *Amauropsona teres* (Marwick, 1924b) (p. 577, Pl. 60, Fig. 20; Finlay and Marwick, 1937, p. 60, Pl. 6, Fig. 1; Fleming, 1966, p. 296, Fig. 1196) from the lower Paleocene Wangaloa Formation of South Island, but *A*.? n. sp. is larger with a slightly larger penultimate whorl and has microscopic wavy spiral lines absent in *A. teres*. *Amauropsona*? n. sp. may be the ancestor of *A. teres*, but more material of the former Maastrichtian species is needed to confirm this relationship.

NATICIDAE gen. et sp. indet.

Plate 42 Figures 5, 7-8, 12

Dimensions.-TM 7555 (IGNS) height 8.5 mm, diameter of last whorl 8.5 mm; TM 7554 (IGNS) height 8.5 mm, last whorl incomplete.

Figured specimens herein.-TM 7552-7554 (IGNS).

Material.-Four poorly preserved specimens.

Locality.-Manu Creek, Mangaporo, North Island, Z14/f8492 (GS 1087).

Stratigraphic range.-Formation uncertain (considered to Piripauan Stage, upper Campanian, Upper Cretaceous).

Discussion.-Late Cretaceous gastropods labelled as "*Natica*" n. sp. were noted in the collections housed at the Institute of Geological and Nuclear Sciences. These poorly preserved specimens can be distinguished from *Euspira selwyniana* (Wilckens, 1922) and *Amauropsona*? n. sp. in having moderately coarse, widely spaced spiral ribs (worn on the examples) and an apparently deep umbilicus unlike the above named species. A genus-level and subfamily-level determination is not possible at this time. It seems likely that these specimens represent a new species. Late Cretaceous naticids from Waimarama (GS 4894), TM 7552 and TM 7553 (both IGNS, Pl. 42, Figs. 5, 7 this work) also represent new species of uncertain affinity.

Superfamily EPITONIACEA S. S. Berry, 1910

Family EPITONIIDAE S. S. Berry, 1910

Subfamily EPITONIINAE S. S. Berry, 1910

Genus *ACIRSA* Mörch, 1857

Acirsa Mörch, 1857, p. 77.

Type species.-(by subsequent designation, Cossmann, 1912) *Turritella costulata* Mighels and Adams, 1841 (= *Scalaria borealis* Beck).

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Subgenus *NOTACIRSA* Finlay, 1926

Notacirsa Finlay, 1926a, p. 231.

Type species.-(by original designation) *Turbonilla* (*Pyrgiscus*) *oamarutica* Suter, 1917.

Biogeographic element.-Paleoaustral as interpreted here.

Discussion.-Wilckens (1922, p. 8) assigned a Late Cretaceous New Zealand epitoniid group to *Scalaria* (*Cirsotrema*?) *pacifica*. Species of *Cirsotrema* have high-spired elongate shells without an umbilicus, have a pronounced basal cord and have sculpture of "fine spiral striae crossed by axial riblets, thus giving a curious "pitted" appearance to the surface..."" (cf. Abbott, 1974, p. 114). The absence of a basal disc or cord in *S*. (*C*.?) *pacifica* excludes this species from *Cirsotrema*. The absence of an umbilicus and presence of spiral cords also excludes *S*. (*C*.?) *pacifica* from *Epitonium* Bolten *in* Röding, 1798. The sculpture of *S*. (*C*.?) *pacifica* seems more consistent with *Acirsa* (*Notacirsa* Finlay, 1926), type species *N*. *oamarutica* (Suter, 1917) (p. 16, Pl. 1, Fig. 7), from the late Early Miocene of New Zealand, except that the former Late Cretaceous species has lower spired shell with more spiral ribs and steeper basal constriction. The absence of complete material of S. (C.?) pacifica leads me to tentatively assign this species to A. (Notacirsa).

Acirsa (Notacirsa) has been previously reported from the Eocene to Miocene of Australia and New Zealand (Wenz, 1940, p. 789). If a member of A. (Notacirsa), S. (C.?) pacifica would be the oldest known species in the genus.

ACIRSA (NOTACIRSA?) PACIFICA (Wilckens, 1922)

Plate 42 Figures 9, 13

Scalaria (Cirsotrema?) pacifica Wilckens, 1922, p. 8, Pl. 2, Fig. 3.

"Scalaria" pacifica Wilckens, Marwick and Fleming in Wellman, 1959, p. 139; Fleming in Wellman, 1959, p. 142.

Scalaria? pacifica Wilckens, Warren and Speden, 1978, p. 50, Tab. 5.

"epitonium" (sic.) pacifica (Wilckens), Crampton and Moore, 1990, p. 347.

Dimensions.-TM 7556 (IGNS) height 13.0 mm, diameter of last whorl 7.0 mm.

Type.-Lectotype (designated herein) TM 2615 (IGNS; Wilckens, 1922, Pl. 2, Fig. 3).

Figured specimens.-TM 2615, TM 7556 (both IGNS).

Material.-Two specimens.

Localities.-Selwyn River, left bank below rapids, Malvern Hills, southern Canterbury, South Island, L35/f6008; north face of Haumuri Bluff, southern Marlborough, O32/f9529; west face of Haumuri Bluff, O32/f8025 (type); ?fallen block on beach below rail cutting at north end of beach receiving mouth of

Pariwhakatou Stream, southern Marlborough, O32/f8773; Waiau River, western Hawke's Bay, North Island, V18/f8500; also Manghouanga Stream float *3 of Crampton and Moore (1990).

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous); Maungataniwha Sandstone (Upper Cretaceous).

Geographic distribution.-Eastern North Island to central eastern South Island.

Discussion.-Acirsa (Notacirsa?) pacifica (Wilckens, 1922), a rare species in the Late Cretaceous molluscan fauna of New Zealand, seems most closely related to a recently described Late Eocene species, A. (Notacirsa) vetusta Maxwell, 1992 (pp. 118-119, Pl. 14, Fig. 1), from the Kaiatan Stage of southern Canterbury, South Island, New Zealand. Acirsa (Notacirsa?) pacifica has a much shorter spire, a broader shell, a sharper anterior angulation on the last whorl and slightly more pronounced, suborthocline axial ribs compared to A. (N.) vetusta which has high turreted spire, a slender shell, a more rounded basal angulation and subdued axial costae.

Acirsa (Notacirsa?) pacifica was an epifaunal? browser according to Warren and Speden (1978, p. 50, Tab. 5) and Crampton and Moore (1990, p. 347), but epitoniids today are carnivores or parasites on coelenterates; A. (N.?) pacifica was doubtfully a browser.

Genus OPALIA H. and A. Adams, 1853

Opalia H. and A. Adams, 1853, p. 222.

Type species.-(by subsequent designation, Boury, 1886) Scalaria australis Lamarck, 1822.

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-Opalia is recorded in the Late Cretaceous New Zealand gastropod fauna for the first time and represents the oldest known record of the genus. Previously in New Zealand, Opalia was reported in Middle Eocene rocks (Beu and Maxwell, 1990, p. 411; Maxwell, 1992, p. 114). Elsewhere, cf. Opalia was reported by Kollmann and Peel (1983, pp. 53-54) from the Paleocene of Nûgssuaq, West Greenland; mention also was made of Paleocene Opalia from Copenhagen and the Ukraine. The main features of Opalia include a relatively solid shell without an umbilicus, usually strong axial ribs, fine spiral sculpture of fine threads (Abbott, 1974, p. 115) and intritacalx (Beu and Maxwell, 1990, p. 55). The type species of Opalia, O. australis (Lamarck, 1822) (see descriptions and specimens figured in Wenz, 1940, pp. 790-791, Fig. 2297; Wilson and Gillett, 1974, p. 34, Pl. 13, Fig. 2a-b) from the Recent of Australia, has a high-spired narrow shell with impressed sutures, no umbilicus, about eight pronounced varices or suborthocline axial ribs and an anterior thickened spiral cord at the base of the last whorl. The new Late Cretaceous New Zealand species, here referred as Opalia cramptoni n. sp., is strikingly similar to O. australis, but has a more slender, higher spire, slightly less impressed sutures and hence a more gently convex whorl profile, and a more subdued basal spiral cord compared to O. australis. The strong morphological similarities in Cretaceous to Recent species of Opalia suggests that the group remained morphologically conservative through time with little change.

OPALIA CRAMPTONI n. sp.

Plate 42 Figures 10-11

Diagnosis.-Moderately small Opalia with high, slender spire of at least eight gently convex whorls; spire angle 17°; last whorl with 11 unevenly spaced orthocline axial costae or varices and very fine, near microscopic spiral threads; anterior basal spiral cord moderately strong; aperture circular.

Description.-Shell moderately small for genus, relatively solid, elongate, high-spired turreted; spire high of at least eight, gently convex whorls; whorl inflation constant; spire angle 17°; protoconch unknown; suture moderately impressed; last whorl convex, only slightly inflated, ornamented with 11 orthocline unevenly spaced varices or strong axial costae, a moderately strong basal spiral cord, and very fine, near microscopic, numerous, closely spaced spiral threads; whorls on spire similarly sculptured with axial costae extending from suture to suture, costae equally as strong as those on last whorl; basal spiral cord marks weak anterior angulation; basal constriction moderately rapid; aperture holostomatous, circular; peristome continuous; outer lip slightly broken; basal lip truncated; inner lip slightly thickened.

Dimensions.-Holotype TM 7557 (IGNS) height 15.5 mm, diameter of last whorl 5.5 mm.

Type.-Holotype TM 7557 (IGNS) (GS 2566).

Type locality.-Waimarama, southeastern North Island, V22/f8492.

Material.-One nearly complete specimen.

Stratigraphic range.-Stage and formation uncertain, possibly Mangaotanean to Piripauan Stages (Santonian to upper Campanian, Upper Cretaceous).

Geographic distribution.-Southeastern North Island.

Discussion.-*Opalia cramptoni* n. sp. has a smaller shell, less convex whorls and a weaker anterior basal spiral cord compared to *O. mackayi* Maxwell, 1992 (p. 114, Pl. 15, Fig. a) from the Late Eocene (Kaiatan Stage) and *O. tenuispiralis* (Marshall, 1919) (pp. 227-228, Pl. 17, Fig. 6) from the Middle Eocene (Bortonian Stage) of New Zealand. *Opalia cramptoni* n. sp. seems most like *Opalia*? n. sp. B of Maxwell (1992, p. 114, Pl. 15, Fig. b), also from the Kaiatan Stage of New Zealand, in terms of sculpture and shell size, but the axial costae of *O. cramptoni* n. sp. are slightly more orthocline and the basal anterior spiral rib less well-developed. *Opalia cramptoni* n. sp., very rare in the Late Cretaceous gastropod fauna of New Zealand, was probably an carnivore or parasite on coelenterates.

Etymology.-New species named for J. S. Crampton, formerly of University of Cambridge, England (now at IGNS) for his work on Late Cretaceous Mollusca of New Zealand.

Order NEOGASTROPODA Thiele, 1925

Suborder RACHIGLOSSA Gray, 1853

Superfamily MURICACEA da Costa, 1776

Family FASCIOLARIIDAE Gray, 1853

Genus *CRYPTORHYTIS* Meek, 1876

Cryptorhytis Meek, 1876, pp. 356, 365.

Type species.-(by original designation) *Gladius*? *cheyennensis* Meek and Hayden, 1860.

Biogeographic element.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-Cryptorhytis has been recognised in Upper Cretaceous deposits of Europe, North and South Africa, South India, North America, New Zealand (Wenz, 1943, p. 1308) and the Antarctic Peninsula (Wilckens, 1910, pp. 94-95). The only extensive review of Cryptorhytis in recent times was that by Sohl (1960, pp. 231-232) who questioned the previous assignments of Cretaceous African species to this genus. Unfortunately, Meek's type material of Cryptorhytis, C. cheyennensis (Meek and Hayden, 1860) (see Wenz, 1943, p. 1308, Fig. 3728), is poorly preserved and no complete specimens exist; as a consequence "...it is hazardous to assign species to the genus" (Sohl, ibid, p. 231).

"CRYPTORHYTIS" VULNERATA Wilckens, 1922

Plate 42 Figures 14-15

Cryptorhytis vulnerata Wilckens, 1922, p. 21, Pl. 4, Fig. 13a-b.

"*Cryptorhytis*" *vulnerata* Wilckens, Marwick and Fleming *in* Wellman, 1959, p. 139.

Type.-Lectotype (designated herein) TM 2652 (IGNS; Wilckens, 1922, Pl. 4, Fig. 13a-b).

Figured specimen herein.-TM 2652 (IGNS).

Locality.-Selwyn Rapids Beds, Malvern Hills, South Canterbury, South Island, ?L35/f6008 (type).

Stratigraphic range.-Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-South Canterbury, South Island.

Discussion.-Wilckens (1922, p. 21) based Cryptorhytis vulnerata on two sculptured casts and compared C. vulnerata with the Late

Cretaceous Antarctic species *C*. *philippiana* Wilckens, 1910 (pp. 94-95, Pl. 4, Figs. 20-21; Macellari, 1984, Pl. 36, Figs. 1-9 (not all of the specimens figured by Macellari are conspecific); Macellari, 1988, pp. 31-35). *Cryptorhytis* *philippiana* was found by Wilckens to have shorter shoulder than *C*. *vulnerata*. As far as I am aware no new material of *C*. *vulnerata* has come to light since Wilckens (1922). Due to uncertainties surrounding the significance and value of the type material of *Cryptorhytis* the New Zealand species is referred here as "*C*." *vulnerata*.

FASCIOLARIA? sp.

not figured

Fasciolaria? sp., Warren and Speden, 1978, p. 50, Tab. 5.

Discussion.-Warren and Speden (1978) identified and listed *Fasciolaria*? sp. as present in the Okarahia Sandstone (Piripauan Stage, upper Campanian) of Haumuri Bluff, southern Marlborough, South Island. Re-examination by me of the specimen referred to as *Fasciolaria*? sp., housed in the macroinvertebrate collections of the Institute of Geological and Nuclear Sciences, Lower Hutt, indicates a misidentification and mixing of younger material in a supposed fossil collection of Late Cretaceous age. The collection (GS 4, O32/f9027) including supposed *F*.? sp. was made by A. MacKay in 1876 on the east wing of Haumuri Bluff. It would appear that MacKay inadvertently placed a specimen of the cancellariid gastropod *Maorivetia* *brevirostris* (Hutton, 1877) (Altonian Stage, upper Lower Miocene) (= *Fasciolaria*? sp. of Warren and Speden, 1978), transported from an overlying stratigraphic unit in his collection of supposed solely Cretaceous fossils. In light of this error by MacKay and Warren and Speden early fossil collections should be critically re-examined for possible contamination and hence mixing of fossils of different ages. As a further comment, the presence of *Conus*? sp. of Warren and Speden (1978, p. 50, Tab. 5; also Wilckens, 1922, p. 23, Pl. 5, Fig. 3) in the Conway? Formation of Haumuri Bluff, not located in the collections of the Institute of Geological and Nuclear Sciences, can only be taken as unlikely and questionable considering that the oldest *Conus* species recorded are from Tertiary rocks.

Family MELONGENIDAE Gill, 1867

Genus *SYCOSTOMA* L. R. Cox, 1931

Sycostoma Cox, 1931, p. 291.

Type species.-(by original designation) *Fusus bulbiforme* Lamarck, 1803.

Biogeographic distribution.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-*Sycostoma* has been reported previously from the Late Cretaceous to Paleogene of Europe, Madagascar and North America (Wenz, 1943, p. 1222) and Paleocene of Greenland (Kohlmann and Peel, 1987, pp. 77-78). *Austroficopsis* Stilwell and Zinsmeister, 1992, from the Eocene of Antarctica may be a closely related genus. Marwick and Fleming *in* Wellman (1959, p. 139) first noted the presence of aff. *Sycostoma* n. sp. in Haumurian (Maastrichtian, uppermost Cretaceous) rocks of Kaipara, Northland; this record of *Sycostoma* in the New Zealand Late Cretaceous is confirmed here with recent work.

Melongenid gastropods are extremely rare in the Cretaceous and Tertiary fossil record of New Zealand. Only two genera are known, Sycostoma from the Haumurian Stage and Fascioplex Marwick, 1934, which spans Waipawan? to Bortonian stages (lower Lower to upper Middle Eocene).

SYCOSTOMA NOTIALE n. sp.

Plate 43 Figures 1-4

Diagnosis.-Spire moderately high of three convex apical whorls and three mostly straight-sided post-apical whorls; spire angle approximately 68°; protoconch obtusely conical of three smooth whorls; shell mostly smooth except for complex reticulation pattern of mostly straight to sporadically wavy moderately strong spiral ribs and moderately strong prosocline to opisthocyrt growth lines; siphonal canal long, straight and narrow; differs from Sycostoma bulbiforme (Lamarck, 1803) in having more flush sutures and hence less exaggerated whorl profiles, a slightly longer canal and less developed inductura.

Description.-Shell medium-sized, moderately thick, pyriform; spire moderately high of three convex nuclear whorls and three post-nuclear mostly straight-sided whorls, very weakly concave posteriorly; whorl inflation constant; spire angle about 68°; protoconch moderately obtusely conical, of three convex, smooth whorls; suture nearly flush; growth lines weakly prosocline posteriorly near suture becoming more opisthocyrt medially and anteriorly; last whorl inflated, evenly convex, anteriorly gently constricted and declivous; basal constriction moderately rapid; last whorl mostly smooth apart from a rather complex network of reticulated, wavy to sporadically straight, moderately fine to coarse, closely spaced spiral ribs that are bunched posteriorly near suture, and moderately strong growth lines; penultimate and antepenultimate whorls similarly sculptured as in last whorl; fasciole moderately poorly developed; aperture siphonostomatous, narrowly sublenticular; columella moderately concave; siphonal canal long, narrow, straight; inductura relatively thin, narrow along canal broadening slightly in parietal region.

Dimensions.-Holotype TM 7558 (IGNS) height 52.5 mm mostly complete, diameter of last whorl 28.5 mm mostly complete; G 7049 (from AU 2571) paratype height 55.0 mm, diameter of last whorl 23.0 mm mostly complete; Ge 7891 (AIM) height 53.5 mm incomplete.

Types.-Holotype TM 7558 (IGNS), paratypes G 7049 (AU), Ge 7891 (AIM).

Type locality.-Kaipara Harbour, Northland, exact locality uncertain, probably near Bull Point, Q08/f9626; holotype collected by P. Marshall probably before 1926.

Figured specimens.-TM 7558 (IGNS), G 7049 (AU), Ge 7891 (AIM).

Material.-Nine specimens.

Localities.-Mototoa, North Island, O06/f90; Bull Point, Kaipara, Northland, Q08/f9626; Nedlers Homestead, Whangaroa, Northland, P04/f8596; Batley, Kaipara, Q08/f9636.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland.

Discussion.-*Sycostoma notiale* n. sp. is remarkably similar to the type species of *Sycostoma*, *S. bulbiforme* (Lamarck, 1803) from the Eocene of Europe (figured by Swainson, 1840, p. 308, Fig. 75;

Wenz, 1943, p. 1222, Fig. 3475). *Sycostoma notiale* n. sp. has flush sutures and hence a nearly straight whorl profile, a slightly longer canal and a less developed inductura compared to *S. bulbiforme*. As far as I know no similar coeval species have been recorded from Antarctic, Australian or southern South American rocks.

Etymology.-Species named from the Latin "notialis" (= southern).

Family TUDICLIDAE Cossmann, 1901,
emend. Finlay and Marwick, 1937

Discussion.-As reviewed in detail recently by Stilwell (1993) the family-level position of genera assigned to Tudiclidae is in a state of flux and is still unresolved. An attempt in early 1994 by the author to collect as yet unknown live specimens of the Recent, endemic southeastern India tudiclid *Tudicla spirillus* (Linné, 1767) in the coastal areas of Madras was unsuccessful. Dissection soft parts of live specimens of *T. spirillus* should prove useful in resolving the uncertainties surrounding the taxonomy of this group. I only encountered dead examples of this species. Opinions on the taxonomic significance of Tudiclidae are divided in the molluscan scientific community. This dispute is discussed elsewhere in this work in the section on Paleocene New Zealand tudiclids. Little recent work has been published on Late Cretaceous Austral Tudiclidae; this shortcoming has contributed to our poor understanding of the phylogeny of the group and resultant confusion of the various previously proposed and assigned species- and genus-group names in the literature.

n. gen.? aff. *Pyropsis* Conrad, 1860

n. gen.? aff. *Pyropsis* Conrad, 1860, p. 288.

Biogeographic distribution.-Indo-Pacific/Tethyan, as interpreted here.

Discussion.-Tudicula ex. aff. tumida Wilckens of Wilckens, 1922 (pp. 20-21, Pl. 4, Figs. 12a-b) from the Late Cretaceous of New Zealand, Heteroterma zelandica Marshall, 1917 (p. 453, Pl. 35, Figs. 20-21; Finlay and Marwick, 1937, pp. 84-85, Pl. 10, Figs. 8-10; Beu and Maxwell, 1990, pp. 84-86, Pl. 2, Fig. p) from the Paleocene of New Zealand, and Cominella? praecursor Wilckens, 1905 (pp. 21-22, Pl. 3, Figs. 14-15) are all considered here to be congeneric forms, but have been given different names. In contrast Popenoe and Saul (1987, p. 28) believed that Cominella? praecursor may belong in the Late Cretaceous genus Christitys proposed by Popenoe and Saul in the same paper, but the axially elongated nature of the tubercles is somewhat different from species of Christitys and may preclude its placement in this group. Relationships are not clear at this time. It should also be mentioned that the genus-level placement of Paleocene species such as "?Pyropsis gabbi (Stanton, 1896)" of Saul (1988, pp. 885-886, Figs. 2.3, 3.26-3.30, 3.33-3.34) is also problematic; this species is strikingly similar to H. zelandica. Stilwell (1993) stated that the genus-level placement of Heteroterma zelandica is uncertain and may represent a new genus, pending further study. Recent work by the author has resulted in the realisation that H. zelandica represents a new genus, named here Saulopsis. Discussion of Saulopsis is presented in the section on Paleocene Gastropoda of New Zealand.

n. gen.? n. sp.? aff. Pyropsis

Plate 43 Figures 8-10, 16

Tudicula ex. aff. tumida Wilckens, Wilckens, 1922, pp. 20-21, Pl. 4, Figs. 12a-b; Fleming in Wilson, 1963, p. 25.

"Tudicla ex aff. turnida Wilck." (sic.), Marwick and Fleming in Wellman, 1959, p. 139, error.

?Pyropsis(?) sp., Stilwell in Aitchison et al., 1993, p. 52.

Dimensions.-TM 2660 (IGNS) height 28.0 mm incomplete, diameter of last whorl 27.0 mm; G 7051 (from AU 484) height 31.0 mm incomplete, diameter of last whorl 27.0 mm; G 7050 (from AU 484) height 30.0 mm nearly complete, diameter of last whorl 14.0 mm.

Previously figured specimen.-TM 2660 (IGNS; Wilckens, 1922, Pl. 4, Fig. 12).

Figured specimens this work.-TM 2660 (IGNS); G 7050-7051 (both from AU 484).

Material.-Six poorly preserved steinkerns.

Localities.-?North Branch of the Waianakarua River, North Otago, South Island, J42/f218; Selwyn Rapids, Malvern Hills, southern Canterbury, South Island, L35/f6017; Bush Gully, Coalgate, southern Canterbury, L35/f6646.

Stratigraphic range.-Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous); ?Katiki Formation (Upper Cretaceous).

Geographic distribution.-Southern Canterbury to possibly North Otago, South Island.

Discussion.-Tudicula ex. aff. tumida (Wilckens) of Wilckens, 1922, is not a Tudivasum pro Tudicula, but is most likely an early member of a short-lived latest Cretaceous to earliest Tertiary new group which includes Heteroterma (= Saulopsis n.

gen.) zelandica Marshall, 1917, and Cominella? praecursor Wilckens, 1905. All available of material of T. ex. aff. tumida (Wilckens), herein referred as n. gen.? aff. Pyropsis n. sp.?, is poorly preserved so that an accurate assessment of affinities beyond the relationships stated above are not possible at this time. All three species listed above have a pyriform outline, a short spire, a very long siphonal canal and a strong axial component, the latter feature being inconsistent with described species of Pyropsis. One specimen of n. gen.? aff. Pyropsis n. sp.? has a canal that is slightly more than 50% of the total shell height; remnant sculpture on this specimen reveals closely spaced spiral ribs. Dr. L. Saul (personal commun., 1990) of Natural History Museum of Los Angeles County, California, stated that "Heteroterma zelandica and those of its ilk might better receive a new generic name". A new name for this group is warranted, but will necessarily be based on the New Zealand Paleocene material which is much better preserved than the Late Cretaceous New Zealand and South American material. A close ancestor to descendent relationship between n. gen.? n. sp.? aff. Pyropsis and Heteroterma (= Saulopsis) zelandica seems probable.

Genus PSEUDOPERISSOLAX Clark, 1918

Pseudoperissolax Clark, 1918, p. 180.

Type species.-(by original designation) Pseudoperissolax blakei (Conrad, 1855).

Biogeographic element.-Indo-Pacific/Tethyan?

PSEUDOPERISSOLAX? SIMILIS (Wilckens, 1922)

Plate 43 Figures 5-7, 12-15, 18-19

?Tudicula biangulata Hector, 1886, p. 58, Fig. 20.

Tudicula alta Wilckens, 1922, p. 20, Pl. 4, Figs. 7-11; Rosenberg and Petit, 1987, Appendix A, p. 60.

Struthiolariopsis similis Wilckens, 1922, pp. 17-18, Pl. 4, Fig. 6.

"Struthiolariopsis" similis Wilckens, Marwick, 1924a, p. 162, Fig. 2.

Tudiclana? alta (Wilckens), cf. Finlay and Marwick, 1937, p. 70; Fleming *in* Wellman, 1959, p. 142; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-16.

?Tudicla (?) (s. lat.) n. sp. of Fleming *in* Wellman, 1959, p. 139.

Description.-Shell large, solid, low-spired, pyriform; spire low of at least three shouldered, moderately inflated whorls; whorl inflation extremely rapid from penultimate to last whorl; spire angle 105°; protoconch paucispiral?; suture slightly impressed; growth lines extremely faint, subopisthocyrt?; last whorl capacious, strongly biangulate, sculptured with two spiral rows at the periphery of moderately closely spaced nodes and at least 13 spaced, moderately strong spiral cords; axial component present but weak; penultimate whorl shouldered, moderately inflated ornamented with about five spiral cords; remnant spiral sculpture present on antepenultimate whorl; basal constriction rapid after anterior angulation; aperture siphonostomatous, subovate?; anterior canal moderately long on one incomplete specimen.

Dimensions.-TM 2658 (IGNS) height 9.0 mm incomplete, diameter of last whorl 8.5 mm incomplete (juvenile); G 7052 (from AU 2580) height 61.0 mm incomplete, diameter of last whorl 52.0 mm; OU 11129 height 37.5 mm incomplete, diameter of last whorl incomplete.

Types and previously figured specimens.-Syntype TM 2654 (IGNS; Wilckens, 1922, Pl. 4, Fig. 11); TM 2655 (IGNS; Wilckens, 1922, Pl. 4, Fig. 10); TM 2656 (IGNS; Wilckens, 1922, Pl. 4, Fig. 9; TM 2657 (IGNS; Wilckens, 1922, Pl. 4, Fig. 7); TM 2658 (IGNS; Wilckens, 1922, Pl. 4, Fig. 8; Warren and Speden, 1978, Fig. 25-16); TM 2659 (IGNS; Wilckens, 1922, Pl. 4, fig. 12; Marwick, 1924a, Fig. 2).

Figured specimens.-TM 2654-2659 (IGNS), G 7052 (AU).

Material.-Four specimens.

Localities.-Shag Point, North Otago, South Island, J43/f6544 (OU 11129); ?middle Waipara, northern Canterbury, South Island, M34/f7263; west wing of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 (type); Haumuri Bluff, O32/f9028, O32/f9502; ?near Kekerengu River, Marlborough, P30/f8702; Bull Point, Kaipara, Northland, Q08/f9626.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Katiki Formation (?Piripauan Stage); unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland to North Otago, South Island.

Discussion.-This species, previously referred to as Tudiclana? alta (Wilckens, 1922) by Finlay and Marwick (1937, p. 70), Fleming *in* Wellman (1959, p. 142) and Warren and Speden (1978, p. 50, Tab. 5), is not a *Tudiclana*. Furthermore, Marwick (1924a, p. 162) and Finlay and Marwick (1937, p. 70) noted the strong similarities between *Struthiolariopsis similis* and *Tudicula alta* and synonymised the latter species with *S*. *similis* which has page precedence. The species name may need to be revised further if indeed Hector's (1886) poor woodcut of *Tudicula biangulata* proves to be conspecific with *P*.? *similis*. The strongly biangulate profile of the last whorl and inflated, shouldered penultimate and older whorls is not consistent or characteristic of previously described species of *Tudiclana*, *T*. *simulator* Finlay and Marwick, 1937 (p. 70, pl. 9, Figs. 4-6) from the Paleocene of South Island, New Zealand and *T*. *byrdi* Stilwell and Zinsmeister, 1992 (pp. 140-141, Pl. 19, Figs. j, k) from the Middle? to Late Eocene of Seymour Island, Antarctic Peninsula. Although an ontogenetic series of well-preserved individuals of *S*. *similis* is not available to me, the biangulate profile, sculpture and penultimate whorl features such as shouldered profile and moderately inflated whorl point to *Pseudoperissolax* Clark, 1918, or a closely related tudiclid taxon. I tentatively assign the Late Cretaceous New Zealand species to *Pseudoperissolax*? *similis* pending further work and material. *Pseudoperissolax*? *similis* was probably an epifaunal carnivore (cf. Warren and Speden, 1978, p. 50, Tab. 5).

Family PERISSITYIDAE Popenoe and Saul, 1987

Genus *PERISSITYS* Stewart, 1927

Perissitys Stewart, 1927, p. 426.

Type species.-(by original designation) *Perissolax brevirostris* Gabb, 1864.

Biogeographic distribution.-Indo-Pacific/Tethyan?

Discussion.-*Perissitys* species have been recorded to date from Coniacian (Upper Cretaceous) to Selandian (middle Paleocene) rocks of the west coast of North America and perhaps Japan (Popenoe and Saul, 1987, p. 12). Specimen Ge 7651 (AIM) from Te Opu, Kaipara, Northland has a spire outline, opisthocyrt growth lines posteriorly, a posterior ramp profile and sculpture of closely spaced spiral ribs on the spire and posterior nodes on the last whorl consistent with described species of *Perissitys* such as the Late Cretaceous (Campanian) type, *P. brevirostris* (Gabb, 1864) (p. 91, Pl. 19, Fig. 43; see also Wenz, 1943, pp. 1304-1305, Fig. 3718; Popenoe and Saul, 1987, pp. 16-17, Figs. 10, 11, 42-61). Unfortunately, Ge 7651 is incomplete as most of the last whorl is fragmentary. Until more material is collected the species is referred tentatively as *Perissitys*? sp.

PERISSITYS? sp.

Plate 42 Figures 16-17

Dimensions.-Ge 7651 (AIM) height 34.5 mm, diameter of last whorl incomplete.

Figured specimen.-Ge 7651 (AIM).

Material.-One fragmentary specimen.

Locality.-Te Opu, Kaipara, Northland, Q08/f9639.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-The genus-level assignment of this probable new species is uncertain as stated above, but most likely lies with the Late Cretaceous to earliest Tertiary perissityid genus *Perissitys*. Other New Zealand Late Cretaceous pyriform gastropods such as n. gen.? n. sp.? aff. *Pyropsis* are not closely related. *Tudicla* (?) (s. lat.) n. sp. of Marwick and Fleming *in* Wellman (1959, p. 139), noted by them to be present in uppermost Cretaceous rocks of Kaipara, probably does not represent this species.

Subclass OPISTHOBRANCHIA Milne Edwards, 1848

Order CEPHALASPIDEA Fischer, 1883

Suborder ACTEONIDEA d'Orbigny, 1842

Superfamily ACTEONACEA d'Orbigny, 1842

Family ACTEONIDAE d'Orbigny, 1842

Genus *TORNATELLAEA* Conrad, 1860

Tornatellaea Conrad, 1860, p. 294.

Type species.-(by monotypy) *Tornatellaea bella* Conrad, 1860.

Biogeographic element.-Indo-Pacific/Tethyan (cf. Fleming, 1967, p. 117).

Discussion.-*Tornatellaea* is recognised in uppermost Cretaceous New Zealand rocks for the first time, marking the earliest known occurrence of the genus in New Zealand. Previously the oldest occurrence of *Tornatellaea* was reported to be Paleocene (Finlay and Marwick, 1937; Beu and Maxwell, 1990) which coincidentaly marks also the apparent disappearance of the genus in the New Zealand fossil record. *Tornatellaea* has been recorded elsewhere from the Late Jurassic to late Paleogene of Europe, North Africa, North America (Wenz and Zilch, 1959, pp. 7-8), Early Cretaceous of Japan (Kase, 1984, pp. 168-169) and the Eocene of Antarctica (Stilwell and Zinsmeister, 1992, pp. 168-169).

Tornatellaea is easily distinguished from *Acteon* Montfort, 1810, in having two well-separated columellar folds in contrast to *Acteon* which has a single columellar fold.

TORNATELLAEA *EVANSI* n. sp.

Plate 44 Figures 2-5

Diagnosis.-Medium-sized *Tornatellaea*; spire angle 63°; growth lines faint, opisthocline tending to be more orthocline anteriorly; shell polished ornamented with closely spaced flat-topped punctuate wavy spiral ribs; aperture length about 70% of total shell height; differs from *T*. *bella* Conrad, 1860, in having a slightly more inflated last whorl, weaker spiral sculpture of numerous closely spaced wavy ribs and a smooth outer lip.

Description.-Shell medium-sized for genus, thin, elongate-ovate; spire gradate, moderately high of at least four subquadrate to very gently convex whorls; whorl inflation mostly constant on spire whorls, rapidly increasing from penultimate to last whorl; spire angle 63°; protoconch concealed in well-cemented matrix; suture somewhat channelled; growth lines faint, opisthocline posteriorly becoming more orthocline anteriorly; last whorl inflated, convex, polished, mostly smooth except for faint growth lines and more than 60 weak closely spaced, flattened, microscopically punctate, wavy spiral ribs and adjacent narrow furrows; penultimate and earlier whorls similarly sculptured with 20 wavy flattened spiral ribs; aperture narrow, elongate, holostomatous; aperture length about 70% of total shell height;

callus narrow?; columella with two strong well-separated folds; outer lip thin.

Dimensions.-Holotype Ge 7669 (AIM) height 10 mm, diameter of last whorl 6.0 mm; paratype Ge 8141.1 (AIM) height 12.5 mm, diameter of last whorl 7.0 mm; paratype Ge 8141.2 (AIM) height 7.5 mm, diameter of last whorl 4.0 mm.

Types.-Holotype Ge 7669 (AIM), paratypes Ge 8141.1, Ge 8141.2 (both AIM).

Figured specimens.-Ge 7669 (AIM), Ge 8141.1 (AIM), Ge 8141.2 (AIM).

Material.-Six specimens; two other poor examples may represent this species.

Localities.-Northeastern shore of Kawitu Estuary, Hokianga, Northland, O05/f136; Te Opu, Kaipara and promontory between Te Opu and Whakapirau Creeks, Kaipara, Q08/f9639 (type); Bull Point, Kaipara, Q08/f9626.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-*Tornatellaea evansi* n. sp. is distinguished from the type species of *Tornatellaea*, *T. bella* Conrad, 1860 (see Wenz, 1959, pp. 7-8, Fig. 9; Toulmin, 1977, p. 230, Pl. 29, Fig. 1), of the Eocene of Alabama, North America, in having a slightly more inflated last whorl, subdued sculpture of more numerous, closely spaced wavy spiral ribs and a smooth outer lip, compared to *T. bella* which has coarse spiral sculpture and a crenulated outer lip. *Tornatellaea cretacea* Wade, 1926 (pp. 103-104, Pl. 34, Figs. 3-4; Sohl, 1964, pp. 291-292, Pl. 47, Figs. 23, 29-33) from the Late Cretaceous of Mississippi and Texas, North America, is reminiscent of *T. evansi* n. sp., but again as in *T. bella* the spiral sculpture in *T. evansi* n. sp. is much weaker and the outer lip much smoother compared to these taxa. *Tornatellaea evansi* n. sp. seems most closely related to *T. saucia* Finlay and Marwick, 1937 (p. 90, Pl. 13, Figs. 11, 15) from the late Early Paleocene of New Zealand and represent a lineage; *T. evansi* n. sp. has more numerous wavy spiral ribs, but otherwise *T. saucia* and *T. evansi* n. sp. are very close morphologically.

Etymology.-Species named after R. Evans, New Zealand, for his work in the 1980s on the stratigraphy and paleoecology of Northland Cretaceous faunas.

Family RINGICULIDAE Philippi, 1853

Genus *ERIPTYCHA* Meek, 1876

Eriptycha Meek, 1876, p. 283.

Type species.-(by original designation) *Auricula decurtata* Sowerby, 1831.

Synonym.-*Euptycha* Meek, 1863, **non** Hübner, 1826 (Wenz and Zilch, 1959, p. 23; Kase and Maeda, 1980, p. 317).

Biogeographic element.-Indo-Pacific/Tethyan as interpreted here.

Discussion.-*Eriptycha* was a common element in Cretaceous gastropod faunas around the globe and has been recorded from several localities in Europe, North and East Africa, North America, New Zealand (Wenz and Zilch, 1959, p. 23), Japan (Kase and Maeda, 1980, p. 317), southern South America (Riccardi, 1988, p. 49) possibly Australia and perhaps Antarctica as well, but more work needs to be done on Cretaceous Ringiculidae of the latter continents. In New Zealand *Eriptycha* first appeared in lower? Upper Cretaceous rocks (?Arowhanan Stage) and disappeared in uppermost Cretaceous rocks (Piripauan Stage or Haumurian Stage). Popenoe (1957, p. 440) was of the opinion that *E. punamutica* Wilckens, 1922, of the Late Cretaceous of New Zealand resembles some species of *Biplica* Popenoe, 1957, but was uncertain of its proper genus-level placement. *Eriptycha* is characterised by having a globose shell, a denticulate labrum and inner lip modified by a variable number of columellar plaits and tubercles (Popenoe, 1957, p. 432). Globose ringiculids such as *Eriptycha* Meek, 1876, *Avellana* d'Orbigny, 1842, *Cinulia*, Gray, 1847, *Oligoptycha* Meek, 1876, *Biplica* Popenoe, 1957, *Gilbertina* Morlet, 1888, and *Superstes* Finlay and Marwick, 1937, are difficult at best to differentiate as the outlines and outer lips of these shells are generalised. Separation of these genera named above on the basis of inner lip morphology and structure is also not always clear-cut even in well-preserved specimens. Without details of the inner lip a genus-level assignment is tentative. A comprehensive review of these genera is needed in light of the plethora of genus-group names in the literature. Furthermore, in authoritative reviews of globose Ringiculidae such as Popenoe (1957) and Wenz and Zilch (1959), the endemic New Zealand genus *Superstes* Finlay and Marwick, 1937, has curiously escaped the attention of these authors.

ERIPTYCHA PUNAMUTICA Wilckens, 1922

Plate 44 Figures 6-15, 18-20, 23-24

Eriptycha punamutica Wilckens, 1922, pp. 23-24, Pl. 5, Figs. 5a-c; Finlay and Marwick, 1937, p. 109; Fleming *in* Wellman, 1959, p. 142; Warren and Speden, 1978, p. 50, Tab. 5; Speden *in* Wiffen, 1980, p. 527; Moore *et al*., 1988, p. 59, Tab. 1; Crampton and Moore, 1990, p. 347; Griffin and Hünicken, 1994, p. 270.

Ringiculidarum genus et species indet., Wilckens, 1924, p. 542.

"*Eriptycha*" (= *Biplica*?) *punamutica* Wilckens, Popenoe, 1957, p. 440.

Ringiculidae (gen. et sp. indet.), Marwick and Fleming *in* Wellman, 1959, p. 139.

"*Eriptycha*" sp. of Marwick and Fleming *in* Wellman, 1959, p. 139.

Eriptycha cf. *punamitica* Wilckens, Crampton, 1988, p. 8.

Supplementary description.-Shell large for genus and family, thin, globose to subovate; spire very low, inclined, obtuse, dome-shaped, partially immersed, of 2½-3 lightly convex whorls; spire about 15-20% of total shell height; ratio of shell height to diameter of last whorl slightly greater than 1:1; whorl inflation from penultimate to last whorl extremely rapid; protoconch heterostrophic of 1-1½ smooth whorls; suture impressed; last whorl greatly inflated, polished, convex, mostly smooth apart from about 32 spiral punctate grooves with variably broad flat interspaces; punctae ovate, connected under SEM; penultimate whorl with fewer than ten spiral, punctate grooves; aperture moderately broad, obliquely teardrop-shaped, posteriorly very constricted; columella gently concave with two well-developed, well-separated plaits, posterior plait subhorizontal, anterior one shorter slightly curved; inner lip with thick callus, thinning and narrowing posteriorly; siphonal notch shallow; outer lip moderately prosoline thickened externally by low, broad varix about 5mm wide on adult examples.

Dimensions.-OU 40985 height 11.0 mm, diameter of last whorl 15.0 mm (specimen deformed and flattened); TM 7559 (IGNS) (from GS 1175) height 9.0 mm, diameter of last whorl 8.5 mm; Ge 8137.1 (AIM) height 6.5 mm, diameter of last whorl 5.5 mm nearly complete; Ge 7638 (AIM) height 3.5 mm, diameter of last whorl 2.5 mm (juvenile); Ge 8139.1 (AIM) height 7.5 mm, diameter of last whorl 7.0 mm nearly complete; G 7053 (from AU 1716) height 12.5 mm, diameter of last whorl 10.5 mm nearly complete.

Type.-Lectotype TM 2674 (IGNS; Wilckens, 1922, Pl. 5, Fig. 5) (designated herein).

Figured specimens.-TM 2674 (IGNS), TM 7559 (IGNS), OU 40985, Ge 8137.1 (AIM), Ge 7638 (AIM), Ge 8139.1 (AIM), G 7053 (AU).

Material.-57 specimens.

Localities.-Brighton, Otago, South Island, I44/f8489; Fairfield Quarry, Otago, c.I44/f173; South Branch of the Waianakarua River, North Otago, South Island, J42/f127; North Branch of the Waianakarua River, J42/f178, J42/f215, J42/f218; Shag Point, North Otago, J43/f159; ?south side of Motakione Peninsula, Northland, O05/f9505; west wing of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 (type); east wing of Haumuri Bluff, O32/f9025; north face of Haumuri Bluff, O32/f9529; tributary of Mikonui Stream, southern Marlborough, O32/f8788; ?Jedburgh Station, Cheviot, North Canterbury, O33/f9044; Waitangi River, Northland, P05/f9499; Batley, Kaipara, Northland, Q08/f9023; Bull Point, Kaipara, Q08/f9626, Q08/f9909; Te Opu and promontory between Te Opu and Whakapirau Creeks, Kaipara, Q08/f9639; south side of Whakapirau Creek, east of Rout Point, Kaipara, Q08/f9637; shore of Otamatea River, northwest of Batley, Q08/f9636; Nedlers, Whangaroa, P04/f9499; Gittos Point, Kaipara, Q09/f9503; Waikokopu Stream, tributary of Waihoroihika Stream, western Hawke's Bay, North Island, W18/f26.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Brighton Formation, unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon", (Hamurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland to Otago, South Island.

Discussion.-The geographic distribution of *Eriptycha punamutica* has been greatly extended since the work by Wilckens (1922) who recorded this species from only two localities at Haumuri Bluff, southern Marlborough. *Eriptycha punamutica* has been recorded from over 15 localities from Northland to Otago, South Island. Some inferred gerontic specimens of *E. punamutica* reach heights of nearly 25 mm and diameters of last whorls approaching 23 mm and are amongst the largest ringiculids known.

The protoconch and microsculpture of *Eriptycha punamutica* is described and illustrated here for the first time; the description of these features is made possible by exquisitely preserved material from Kaipara, Northland. The protoconch of *E. punamutica* is heterostrophic of 1½-2 smooth whorls and spiral furrows have punctae that are ovate and connected to each other.

Eriptycha punamutica is thought to have been an epifaunal? browser (Warren and Speden, 1978, p. 50, Tab. 5), but was more likely a carnivore.

Genus *RINGICULA* Deshayes, 1838

Ringicula Deshayes, 1838, p. 342.

Type species.-(by subsequent designation, Gray, 1847) *Auricula ringens* Lamarck, 1804.

Biogeographic distribution.-Cosmopolitan (Zinsmeister and Stilwell, 1990, p. 373).

Discussion.-*Ringicula* has its roots in Cenomanian Cretaceous rocks and has a worldwide distribution which extends to the present day. Recently, *Ringicula* was reported for the first time in Cenozoic rocks (Eocene) of Antarctica, extending the genus to include all continents of the southern hemisphere (Zinsmeister and Stilwell, 1990, p. 343). *Ringicula* s. s. is recorded in New Zealand Cretaceous rocks for the first time greatly extending the previous oldest occurrence of late Early Eocene (Mangaorapan Stage) by Beu and Maxwell (1990, p. 386).

Ringicula is characterised by having a small low-spired globose to subglobose shape, sculpture of spirally incised lines or furrows, a posteriorly constricted aperture, a denticulate labrum, a varix-like, a single denticle or fold on the parietal wall, usually a well-margined outer lip and columella with two strong folds (Sohl, 1964, p. 293; Zinsmeister and Stilwell, 1990, pp. 374-375). A subgenus *R*. (*Ringiculina*) Monterosato, 1884, is closely related to *R*. s. s. and is distinguished on the basis of the former having an obsolete parietal plait and a smooth, typically thinner outer lip (Beu and Maxwell, 1990, p. 386); *R*. (*Ringiculina*) has not been to my knowledge recorded from

Cretaceous rocks.

RINGICULA s. s. ZIGZAGIA n. sp.

Plate 45 Figures 1-8

Superstes? sp., Marwick and Fleming in Wellman, 1959, p. 138.

Superstes n. sp., Crampton, 1988, p. 8.

Diagnosis.-Large Ringicula with moderately high spire of straight-sided to gently convex whorls; spire angle 83°; growth lines faint, slightly sinuous, suborthocline becoming more prosocline anteriorly; last whorl with about 70 incised closely spaced spiral grooves bearing a semi-even zigzag trace; parietal wall with strong, raised, smooth, long, oblique plait; separated from R. s. s. yochelsoni Sohl, 1964, by having a lower spire, more closely spaced spiral furrows with a zigzag trace and a more blunt, wider, rounded parietal plait.

Description.-Shell large for genus, moderately solid, moderately thin, elongate-ovate; spire moderately high of at least four straight-sided to very gently convex whorls; whorl inflation very rapid from penultimate to last whorl, fairly constant on spire whorls; spire angle 83°; protoconch dome-like, paucispiral, smooth of at least 1½ whorls, part of initial whorl immersed; growth lines faint, slightly sinuous, suborthocline posteriorly and medially to very slightly prosocline anteriorly; suture slightly channelled to nearly flush; last whorl capacious, greatly well inflated, convex, mostly smooth except for faint growth lines an approximately 70 incised very closely spaced spiral grooves having a semi-even zigzag trace; zigzag spiral grooves separated by subequal, closely spaced, flattened interspaces; under SEM zigzag spiral rows overlap with one another by a series of sharp tooth-like coalescing plates; penultimate whorl similarly sculptured with about 10 zigzag spiral grooves, sculpture becoming more cancellate posteriorly near suture; aperture moderately broad, constricted posteriorly, anteriorly with shallow channel; columella moderately concave, short, bearing two well-developed, separated folds; parietal wall with strong, raised, smooth, long, oblique plait; columella with thick callus; outer lip relatively thin.

Dimensions.-Holotype Ge 8140.1 (AIM) height 7.5 mm, diameter of last whorl 6.5 mm nearly complete; paratype TM 7560 (IGNS) (from GS 6959) height 7.0 mm.

Types.-Holotype Ge 8140.1 (AIM); paratype TM 7560 (IGNS).

Figured specimens.-Ge 8140.1 (AIM), TM 7560 (IGNS).

Type locality.-Te Opu, Kaipara, Northland, Q08/f9639.

Material.-Five specimens.

Localities.-Te Opu, Kaipara, Northland, Q08/f9639; Bull Point, Kaipara, Q08/f9909; Nedlers, Whangaroa, Northland, P04/f9499.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland.

Discussion.-*Ringicula* s. s. *zigzagia* n. sp. seems most closely related to a coeval Maastrichtian species *R*. s. s. *yochelsoni* Sohl, 1964 (pp. 294-295, Pl. 48, Figs. 20-26 (Sohl, ibid, Pl. 49, error)), from the Ripley Formation of Mississippi, North America. *Ringicula* s. s. *zigzagia* n. sp. is distinguished from *R*. *yochelsoni* in having a lower spire, more numerous closely spaced spiral furrows with a zigzag trace and a more blunt, wider, rounded parietal plait. Zinsmeister and Stilwell (1990, p. 374) noted that many previously assigned species of *Ringicula* s. s. have features that vary to an extent that may actually overstep the genus-level boundary of the group when compared to *R. ringens* (Lamarck, 1804). The taxonomic significance of the unusual spiral zigzag trace present in some *Ringicula* species including *R. zigzagia* n. sp. has yet to be addressed; further work may show that at least a subgenus-level separation of species bearing this sculpture is warranted.

Etymology.-Species named after its characteristic spiral zigzag sculpture.

Family ?APLUSTRIDAE Gray, 1847

Genus N. GEN.? aff. *APLUSTRUM* Schumacher, 1817

N. GEN.? aff. *APLUSTRUM SELWYNENSIS* Trechmann, 1917

Plate 44 Figures 16-17, 19, 21-22

Aplustrum (?) *selwynensis* Trechmann, 1917, pp. 337-338, Pl. 21, Figs. 1-3.

Aplustrum ? *selwynense* Trechmann, Wilckens, 1922, p. 32 (error).

Dimensions.-TM 7562 (IGNS) height 19.5 mm, diameter of last whorl 13.5 mm; TM 7563 (IGNS) height 17.5 mm nearly complete, diameter of last whorl 13.5 mm.

Types.-Holotype ?G 27431 (BMNH; Trechmann, 1917, Pl. 21, Fig. 1); syntype G 27432 (BMNH; Trechmann, 1917, Pl. 21, Fig. 3); syntype G 27433 (BMNH; Trechmann, 1917, Pl. 21, Fig. 2); museum specimens G 27434-G 27439 (BMNH; unfigured).

Localities.-"Selwyn Rapids, rather common in one piece of rock" (Trechmann, 1917, p. 338), no other information available (type), L35/f6510.

Figured specimens herein.-G 27431-27432 (BMNH); TM 7562, TM 7563 (both IGNS).

Stratigraphic range.-Selwyn Rapids Beds (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Selwyn Rapids, southern Canterbury, South Island.

Discussion.-The genus- and species-level affinities of these small gastropods collected by C. T. Trechmann in the early part of this century remain uncertain. Trechmann (1917, p. 337) believed that the specimens were more closely related to the acteonacean genus Aplustrum Schumacher, 1817, than to Bullidae, of which I concur. However, the protoconch of Aplustrum? selwynensis is more emergent than that of typical Aplustridae genera including Aplustrum. Other genera reminiscent with A.? selwynensis in outline, sculpture and spire morphology only include Crommium Cossmann, 1888, of Naticidae and Bernaya Jousseame, 1884, of Cypraeidae. Aplustrum? selwynensis may represent a new genus.

Superfamily CYLICHNACEA A. Adams, 1850

Family CYLICHNIDAE A. Adams, 1850

Genus CYLICHNANIA Marwick, 1931

Cylichnania Marwick, 1931, p. 153.

Type species.-(by original designation) Cylichnania bartrumi Marwick, 1931.

Biogeographic element.-Paleoaustral, as interpreted here.

Discussion.-Maxwell (1988, p. 19) remarked that Cylichnania is possibly endemic to New Zealand where it is "typically present in off-shore sands and siltstones" and ranges from Wangaloan to Tongaporutuan stages spanning most of the Tertiary period. A middle shelf to upper bathyal habitat range was given by Beu and Maxwell (1990, p. 238). The believed presence of Cylichnania in the Late Cretaceous of New Zealand Finlay and Marwick (1937, p. 13) including the near-shore facies of the Okarahia Sandstone suggests that species at the inferred base of the radiation of the group also inhabited shallow waters. Although formerly believed to be an endemic New Zealand genus Cylichnania has recently come to light in mid Paleocene rocks of southeastern Australia (T. A. Darragh, pers. commun., 1991).

Cylichnania is discriminated from other cylichnid genus-group taxa by its "subcylindical shape, its sculpture of even, low, flat-topped spiral cords, and its deep apical depression, with the outer lip extending well posteriorly to the inner lip" (Beu and Maxwell, 1990, p. 238).

CYLICHNANIA THOMSONIANA (Wilckens, 1922)

Plate 45 Figures 10, 13, 16-17; Plate 46 Figures 1-3, 5-6

Cylichna thomsoniana Wilckens, 1922, p. 24, Pl. 5, Figs. 6-7.

Cylichnania thomsoniana (Wilckens), Finlay and Marwick, 1937, pp. 13, p. 129.

"Cylichna" thomsoniana Wilckens, Fleming *in* Wellman, 1959, p. 140.

Cylichna? thomsoniana Wilckens, Warren and Speden, 1978, p. 50, Tab. 5; Crampton and Moore, 1990, p. 347, Fig. 8K.

Supplementary description.-Shell medium- to large-sized, relatively thin, cylindrical, involute; shell umbilicate; growth lines gently sinuous, suborthocline; axial and spiral sculpture of subequal strength; axial sculpture of moderately weak of slightly raised, subequally closely spaced threads paralleling growth lines; spiral sculpture of numerous closely spaced incised lines separating flattened cords; inner and outer lip details insufficiently preserved on available material.

Dimensions.-TM 7561 (IGNS) (from GS 750) height 18.0 mm; Ge 7671.1 (AIM) height 5.5 mm nearly complete, diameter of last whorl 4.0 mm; Ge 7628.1 (AIM) height 4.5 mm, diameter of last whorl 2.5 mm; G 7054 (from AU 2553) height 2.5 mm.

Type.-Holotype TM 2653 (IGNS; Wilckens, 1922, Pl. 5, Fig. 7).

Previously figured specimens.-TM 2671 (IGNS; Wilckens, 1922, Pl. 5, Fig. 6); TM 6876 (IGNS; Crampton and Moore, 1990, Fig. 8K).

Figured specimens this work.-TM 2653, TM 2671, TM 6876, TM 7561 (all IGNS) (from GS 750); Ge 7628.1 (AIM); Ge 7671.1 (AIM); G 7054 (AU).

Material.-Eight moderately well-preserved specimens, a few with well-preserved shell material.

Localities.-West wing of Haumuri Bluff, southern Marlborough, South Island, O32/f8025 (type); ?tributary of Mikonui Stream, southern Marlborough, O32/f8788; Haumuri Bluff, O32/f9505; ?long ridge above Jedbugh Station, Cheviot, South Island, O33/f9044; conglomerate in Waitangi River, Northland, P05/f9499; ?Batley, Kaipara, Northland, Q08/f9023; Bull Point, Kaipara, Q08/f9909, Q08/f9626; Te Opu, Kaipara, Q08/f9639; ?east bank of Te Hoe River, western Hawke's Bay, North Island, V19/f184, V19/f185; ?Mangahouanga Stream, western Hawke's Bay, V19/f6909.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); Maungataniwha Sandstone (Upper Cretaceous); unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Northland to southern Marlborough, South Island.

Discussion.-Most specimens known of *Cylichnania thomsoniana* are fragmentary due to the thin, delicate shell of this species. Wilckens' original material of *C*. *thomsoniana* consisted of six incomplete, mostly decorticated examples from a single locality (O32/f8025) at Haumuri Bluff, southern Marlborough, South Island. Numerous cylichnid specimens from the North Island, here referred to as an ontogenetic series of juveniles to adults of *C*. *thomsoniana*, exhibit microsculpture in nice detail (e. g. Ge 7628.1 (AIM)) including presence of microscopic reticulate threads and punctae.

Cylichnania thomsoniana may be congeneric with *Bulla chilensis* d'Orbigny (refigured by Philippi, 1887, p. 103, Pl. 13, Fig. 23) and *B*. *remondi* Philippi (p. 103, Pl. 13, Fig. 7) from the latest Cretaceous of southern South America, but aperture details are needed of *C*. *thomsoniana* before affinities can be worked out in detail.

Subclass EUTHYNEURA Spengel, 1881

Order ENTOMOTAENIATA Cossmann, 1896

Superfamily PYRAMIDELLACEA Gray, 1840

Family PYRAMIDELLIDAE Gray, 1840

Subfamily ODOSTOMIINAE Pelseneer, 1928

Genus ODOSTOMIA Fleming, 1813

Odostomia Fleming, 1813, p. 76.

Type species.-(by subsequent designation, Gray, 1847) Turbo plicatus Montagu, 1803.

Biogeographic distribution.-Cosmopolitan.

Discussion.-Odostomia is a cosmopolitan Late Cretaceous to Recent group. In New Zealand Odostomia species have been described from Paleocene to Recent. This is the first record of the Pyramidellidae in the New Zealand Cretaceous. Odostomia "is a very "generalised" pyramidellid characterised by its relatively low spire, its absence of definite sculpture, its single strong columellar plait, and its smooth outer lip." (Beu and Maxwell, 1990, p. 388). Odostomia species are also elongate-conic or ovate-conic and have smooth, polished shells; many species "straddle" previously proposed subgenera (Abbott, 1974, p. 291). Pyramidellids including Odostomia are ectoparasites on other invertebrates, mainly feeding on molluscs and marine worms (Abbott, 1974, p. 291; Powell, 1979, p. 262; Beu and Maxwell, 1990, p. 398).

ODOSTOMIA? PALEOZELANDICA n. sp.

Plate 45 Figures 12, 14-15, 18

Diagnosis.-Shell moderately high elongate-conic; whorls moderately convex; spire angle 22°; growth lines faint, opisthocyrt.

Description.-Shell medium-sized, thin, moderately high elongate-conic; spire relatively high with at least four smooth, moderately convex whorls; whorl inflation constant; spire angle approximately 22°; protoconch unknown; suture moderately impressed; growth lines faint, opisthocyrt; last whorl only slightly inflated, smooth, polished with faint microscopic growth lines; older whorls similarly sculptured; aperture details concealed.

Dimensions.-Holotype Ge 7903 (AIM) height 4.5 mm incomplete, diameter of last whorl 2.0 mm; paratype G 7055 (from AU 2553) height 4.5 mm incomplete, diameter of last whorl 2.0 mm.

Types.-Holotype Ge 7903 (AIM); G 7055 (from AU 2553).

Figured specimens.-Ge 7903 (AIM); G 7055 (AU).

Material.-Two specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626 (type); Te Opu, Kaipara, Q08/f9639.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-*Odostomia*? *paleozelandica* n. sp. is tentatively placed in this pyramidellid genus at this time as apertural details in the two specimens at hand are concealed by well-cemented fine-grained sandstone matrix. No other similar gastropod has been recorded from the New Zealand Cretaceous record. *Odostomia*? *paleozelandica* n. sp. is remarkably similar to the recent type species, *O. plicata* (Montagu, 1803) (figured by Wenz, 1940, p. 856, Fig. 2507) with respect to whorl profile and shell outline; unfortunately apertural details could not be compared. I know of no other Austral coeval species of *Odostomia*.

Etymology.-Species named for its early occurrence in Cretaceous rocks of New Zealand.

Class SCAPHOPODA Bronn, 1862

Discussion.-See Steiner (1992) for a first attempt at performing a cladistic analysis of relationships between families in the Scaphopoda and a presentation of a phylogeny and classification of the group based on new anatomical data; evolution of Scaphopoda from Rostroconchia was advocated.

At least two species of scaphopod are represented in New Zealand Upper Cretaceous rocks; these are *Antalis grantmackiei* n. sp. (Dentaliidae) and *Dentalium* (*Laevidentalium*) *morganianum* (Wilckens, 1922).

Order DENTALIIDA Da Costa, 1776

Family DENTALIIDAE Gray, 1834

Genus *ANTALIS* H. and A. Adams, 1854

Antalis H. and A. Adams, 1854, p. 457.

Type species.-(by subsequent designation, Pilsbry and Sharp, 1897) *Dentalium entalis* Linné, 1758.

Biogeographic element.-Cosmopolitan (Ludbrook *in* Knight *et al*., 1960, p. I38).

Discussion.-*Antalis* is recognised in the New Zealand Late Cretaceous fossil record for the first time. *Antalis* was previously recorded in New Zealand from Early Paleocene ("Wangaloan" Stage) to Recent (Beu and Maxwell, 1990, p. 42, Fig. 6j). The main external diagnostic features of *Antalis* are: weak longitudinal ribs; apical section not polygonal; apex with a V-shaped notch on or near convex side; and a solid plug with a solid plug with central orifice or pipe (Ludbrook *in* Knight *et al*., 1960, p. I38; Abbott, 1974, p. 384; Powell, 1979, p. 353).

ANTALIS GRANTMACKIEI n. sp.

Plate 46 Figure 12

?*Dentalium* n. sp. of Marwick and Fleming *in* Wellman, 1959, p. 139.

Diagnosis.-Small-to medium-sized *Antalis* with very gently tapered apex and slightly curved shell; sculpture of about 40 low, weak, closely spaced longitudinal costae which decrease in strength anteriorly; growth lines vague; cross-section subovate to subcircular.

Description.-Shell small- to medium-sized (approximately 15.0 mm long), moderately thick; shell tubular, very gently tapered to narrow posterior apex, gently curved; shell open at anterior and posterior ends; sculpture weak of about 40 very low, closely spaced longitudinal costae and shallowly concave interspaces; longitudinal sculpture decreases in strength from posterior to anterior; growth lines faint, more apparent at anterior end where longitudinal sculpture is weakest; cross-section subcircular to subovate; apex details unknown.

Dimensions.-Holotype Ge 7905 (AIM) length 13.5 mm nearly complete, diameter of anterior end 3.0 mm; paratype M 143 (from AU 2574) length 6.0 mm incomplete.

Types.-Holotype Ge 7905 (AIM); paratype M 143 (AU).

Type locality.-Bull Point, Kaipara, Northland, Q08/f9626.

Figured specimen.-Ge 7905 (AIM).

Material.-Two specimens.

Localities.-Bull Point, Kaipara, Northland, Q08/f9626, Q08/f9909.

Stratigraphic range.-Unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian

Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Kaipara, Northland.

Discussion.-*Antalis grantmackiei* n. sp., rare in the Late Cretaceous New Zealand molluscan record, is distinguished from the Early Paleocene New Zealand species, *A. multistricta* (Finlay and Marwick, 1937) (p. 93, Pl. 13, Fig. 3; Fleming, 1966, p. 228, Pl. 65, Fig. 736; Beu and Maxwell, 1990, p. 424) in having stronger longitudinal costae and an evenly tapered shell, unlike *A. multistricta* which has extremely weak longitudinal lines and and gentle, periodic constrictions along the shell. The longitudinal sculpture of *A. grantmackiei* n. sp. is also stronger than that of the type species, *A. entalis* (Linné, 1758) (figured by Brown, 1844, p. 117, Pl. 56, Fig. 7; Ludbrook *in* Knight *et al*., 1960, pp. I37-I38, Fig. 30-5a, 5b). *Antalis grantmackiei* n. sp. was probably a detritivore that lived on the inferred mid to outer shelf.

Etymology.-Species name in honour of J. A. Grant-Mackie, Auckland University, for his lifetime of work on New Zealand fossils.

Family LAEVIDENTALIIDAE Palmer, 1974

Genus *DENTALIUM* Linné, 1758

Dentalium Linné, 1758, p. 785.

Type species.-(by subsequent designation, Montfort, 1810) *Dentalium elephantinum* Linné, 1758.

Subgenus *LAEVIDENTALIUM* Cossmann, 1888

Laevidentalium Cossmann, 1888, p. 7.

Type species.-(by original designation) *Dentalium incertum* Deshayes, 1825 (Deshayes, 1826, according to Maxwell, 1988b, p. 76).

Biogeographic element.-Cosmopolitan (Ludbrook *in* Knight *et al*., 1960, p. I39).

Discussion.-*Dentalium* (*Laevidentalium*) is a long-ranging Triassic to Recent cosmopolitan scaphopod subgenus that is distinguished from *Antalis* H. and A. Adams, 1854, in having a moderate to large smooth shell with growth lines only without longitudinal sculpture. The New Zealand fossil record for *D*. (*Laevidentalium*) is very patchy with *D*. (*L*.) *morganianum* Wilckens, 1922, as the earliest member of the genus (Piripauan to Haumurian Stages, uppermost Cretaceous), followed by *D*. (*L*.) *fodinense* Maxwell, 1988b (Waiauan Stage, upper Middle Miocene) and *D*. (*L*.) *waihoraense* Emerson, 1954 (Altonian to Clifdenian Stages, upper Lower Miocene to lower Middle Miocene).

DENTALIUM (*LAEVIDENTALIUM*) *MORGANIANUM* (Wilckens, 1922)

Plate 46 Figures 7-11, 13

Dentalium sp., Trechmann, 1917, p. 299, Pl. 21, Fig. 10.

Dentalium (*Laevidentalium*) *morganianum* Wilckens, 1922, pp. 24-25, Pl. 5, Figs. 8, 9); Medina and del Valle, 1985, p. 4.

Laevidentalium *morganianum* (Wilckens), Marwick and Fleming *in* Wellman, 1959, p. 139.

Dentalium *morganianum* Wilckens, Fleming *in* Wellman, 1959, p. 142; Warren and Speden, 1978, p. 50, Tab. 5, Fig. 25-18; Campbell *et al*., 1993, Tab. 4.3).

Dentalium cf. *morganianum* Wilckens, Wilckens, 1924, p. 424; Crampton and Moore, 1990, p. 347, Fig. 8J.

Supplementary description.-Shell large (adult about 55 to 75 mm long), moderately thick, evenly tapered from anterior to posterior end; shell very slightly curved, more so posteriorly near apex; shell smooth apart from faint transverse growth lines; cross-section subcircular.

Dimensions.-TM 7760 (IGNS) length 57.5 mm; M 144 (AU) (from AU 2553) length 10.0 mm nearly complete; M 145 (AU) (from AU 2574) length 13.5 mm; Ge 8617 (AIM) length 7.5 mm incomplete.

Types, previously figured specimens and museum specimens.-Lectotype TM 2677 (IGNS; Wilckens, 1922, Pl. 5, fig. 9; Warren and Speden, 1978, p. 38, Fig. 25-18); TM 2675 (IGNS; Wilckens, 1922, Pl. 5, Fig. 8); TM 2676 (IGNS; Wilckens, 1924, p. 543); TM 6875 (IGNS; Crampton and Moore, 1990, p. 340, Fig. 8J).

Figured specimens.-TM 2677 (IGNS); TM 7760 (IGNS); Ge 8617 (AIM); M 144-145 (AU).

Material.-12 specimens.

Localities.-Green Island, Otago, South Island, I44/f8489; ?east slope of Barron's Hill, Otago, I44/f8510; ?just north-northwest of junction of Taieri Beach and Taieri Mouth Road, Otago, I45/f8517; ?south end of 1978 railway deviation cutting, North Otago, J43/f115; ?Mount Pukeiwitahi, North Otago, J43/f6494; Selwyn Rapids, Canterbury, South Island, L35/f6008; ?arm of Parengarenga Harbour, Northland, N02/f9626; ?left bank of Kaiwara River, South Island, N33/f9811; ?west side of Oneke Peninsula, Hokianga Harbour, Northland, O05/f9572; Penehi Point, north side of Hokianga Harbour, O05/f9573; ?north side of Hokianga Harbour, O05/f9607; south side of Motakione Peninsula, Northland, O05/f9505; ?Ngamahanga point, north side of Hokianga Harbour, O06/f7574; Okarahia Stream, southern Marlborough, South Island, O32/f8790; lower Conway rail cutting, southern Marlborough, O32/f8793; tributary of Okarahia Stream, O32/f8787; ?east of Trig G, southern Marlborough, South Island, O32/f8113; ?east-southeast of Trig G, O32/f8117; ?Ngaroma, Conway River, southern Marlborough, O32/f8862; tributary of Mikonui Stream, southern Marlborough, O32/f8788; ?south Of Mikonui Stream, O32/f8774A; Haumuri Bluff, southern Marlborough, O32/f9035, O32/f9504, O32/f9502, O32/f9028; north face of Haumuri Bluff, O32/f9504, O32/f9529; east wing of Haumuri Bluff, southern Marlborough, O32/f9032, O32/f9033, O32/f9027; west wing of Haumuri Bluff, O32/f8025 (type); southeast of Black Grit reef, Haumuri Bluff, O32/f9542; ?north face of Haumuri Bluff, O32/f9544; Waitangi River, Bay of Islands, Northland, P05/f9491; ?near Kekerengu River, Marlborough, P30/f8702; Batley, Kaipara, Northland, Q08/f9023; Bull Point, Kaipara, Q08/f9909; Te Opu, Kaipara, Q08/f9639; Gittos Point, Kaipara, Q09/f9502, Q09/f9503; ?"Ngaiana" Homewood Road, southernmost North Island, T26/f9536; Kaiwhata River, southern North Island, T27/f6729; Mangahouanga Stream, western Hawke's Bay, North Island, ?V19/f26, ?V19/f182, V19/f6909; ?east bank of Te Hoe River, western Hawke's Bay, V19/f184, V19/f185; ?west bank of Te Hoe River, V19/f195; ?lower Mangahouanga Stream, V19/f6508, V19/f6511; ?Hook Stream, western Hawke's Bay, V19/f6645, V19/f6649, V19/f6507; ?Waikokopu Stream, northwestern Hawke's Bay, W18/f26; ?headwaters of Ron Stream, X17/f7674; Clarke Creek, Taurangakautuku River, Raukumara Peninsula, North Island, Z14/f8492; right bank of Matu River, East Cape, North Island, Z15/f6722; ?Waiapu Stream, East Cape, Z15/f7495; east side of Pitt Island, Chatham Islands, CH/f11;

southwestern side of Whenuataru Peninsula, Pitt Island, CH/f257A, CH/f587; west of Flowerpot Bay, Pitt Island, CH/f466.

Stratigraphic range.-Okarahia Sandstone (Piripauan Stage, upper Campanian, Upper Cretaceous); ?Herbert Formation, ?Conway Formation, ?Silverstream Formation, Maungataniwha Sandstone, Kahuitara Tuff, Chaplin Sandstone (unpublished name of Robinson, 1958), other unnamed formations (Piripauan to Haumurian Stages, Upper Cretaceous); Katiki Formation, Selwyn Rapids Beds, unspecified horizon within Unit 4 of Evans (1985), formation unspecified, "Northland Allochthon" (Haumurian Stage, Maastrichtian, uppermost Cretaceous).

Geographic distribution.-Widespread from Northland to Otago and Pitt Island, Chatham Islands.

Discussion.-*Dentalium* (*Laevidentalium*) *morganianum* (Wilckens, 1922) appears to be closely related to *D*. (*L*.) *wilckensi* Medina and del Valle, 1985 (pp. 5-6, Pl. 1, Figs. G-H, L-O) from the Upper Cretaceous Lopez de Bertodano Formation of Seymour Island, Antarctic Peninsula and *D*. *cazadorianum* Wilckens, 1905 (pp. 25-26, Pl. 4, Fig. 9) from the Late Cretaceous of Patagonia. *Dentalium* (*Laevidentalium*) *limatum* Stanton, 1901 (pp. 28-29, Pl. 6, Fig. 9) from the Cretaceous of Patagonia may also be a close relative, but the specimen figured by Stanton is poorly preserved for detailed comparison.

Laevidentalium *morganianum* was recognised from only a handful of localities by Wilckens (1922); the species is now recognised from localities spanning Northland to Otago. *Dentalium* (*Laevidentalium*) *morganianum* may be present as far south in New Zealand as the Taieri Mouth area, southeastern

Otago, South Island (Fleming _in_ Robinson, 1958, p. 18). This species has also come to light in the Kahuitara Tuff of Pitt Island, Chatham Islands (Campbell _et al_., 1993, Tab. 4.3) further extending the geographic range.