

Stratigraphic and geographic distribution of Eocene – Miocene Radiolaria from the southwest Pacific

Barry O'Connor

Department of Geology, Faculty of Agriculture, Utsunomiya University, 321-8505 Utsunomiya, Japan

ABSTRACT: The known stratigraphic and geographic ranges of 50 recently erected species and five recently erected genera of Radiolaria, originally described from the New Zealand area (from the Mahurangi Limestone and Puriri Formation in Northland, and the Oamaru Diatomite in the South Island), are documented. The data is significantly updated from that presented in the original descriptions, and includes information from several DSDP/ODP localities that were not investigated in the original studies. All taxa considered as belonging in the recently erected genera are listed, and full synonymies cover all forms considered as belonging to the recently erected taxa. During the reinvestigation of samples from DSDP Hole 280A three new species were noted and are described herein. The new species are *Dictyoprora nigrinia*, *Plannapus* ? *aitai* (Artostrobiidae), and *Lithomelissa* ? *sakaii* (Plagoniidae).

Problems with some age indicator taxa are discussed, namely the possible diachroneity of the last occurrence of *Lychnocanium amphitrite*, and the extent of the age overlap between *Stichocorys delmontensis* and *Calocyclella* (*Calocyclopsis*) *serrata*.

A distinct biogeographic boundary to Radiolaria exists between the Mahurangi Limestone (Latest Eocene to earliest Miocene), and the Late Eocene to Oligocene sections of the other South Pacific localities investigated. This necessitated the use of two different radiolarian zonal schemes for establishing the age ranges of the new taxa. The boundary seems to be attributable to differing latitudes of deposition and associated water circulation patterns.

INTRODUCTION

In a series of papers detailing radiolarian taxonomy (O'Connor 1994; 1997a, b; 1999) five new genera, 50 new species, and one new combination of Radiolaria from the Late Eocene to Early Miocene of New Zealand were erected (hereafter the new taxa and genera are referred to as recently described or erected). With each successive project information regarding the taxonomy and distribution, both stratigraphic and geographic, of the recently described taxa was constantly updated with the examination of new material, re-evaluation of previously studied samples, and the publication of related studies by other authors (e.g. Hollis et al. 1997).

This paper, which incorporates the new information and is a significant update of data presented in the unpublished PhD thesis of O'Connor (1996b), is intended as an accompaniment and update to the aforementioned studies, and to aid in the use of the recently described taxa in South Pacific biostratigraphy. All taxa considered by the author as belonging in the recently erected genera are listed under the relevant genus, and full synonymies and known stratigraphic and geographic ranges for the five genera, 50 taxa, and one combination are given. A previously unpublished distribution list of Radiolaria from Te Kopua Point is provided in Appendix 2.

Evidence suggests that in the Late Eocene to Oligocene there was a major biogeographic boundary with respect to Radiolaria between the depositional sites represented by the Mahurangi Limestone (text-figs. 1, 3) and the other southwest Pacific sites examined (text-figs. 2, 3). During this time interval radiolarian faunas from the Mahurangi Limestone have distinct low-latitude affinities, while all of the other localities have radiolarian faunas that originated in higher latitudes. Despite an age overlap, and although a significant proportion of the Late Eocene radiolarian taxa from the temperate localities were also

found in the Mahurangi Limestone, very few age index taxa occur on both sides of the biogeographic boundary, and those that do are of little use for dating of one side or the other. This necessitated the use of two radiolarian zonal schemes in establishing the age ranges of the recently described taxa (see Biostratigraphy section, below). The boundary is discussed further below (see Paleobiogeography section, below).

Of the recently erected taxa 11 described from the Oamaru Diatomite, and also found in other southwest Pacific localities investigated, co-occur in the Mahurangi Limestone. Additionally, seven taxa described from the Mahurangi Limestone are found in the temperate localities. These taxa may be the key in linking the South Pacific and tropical radiolarian zonations in the southwest Pacific area.

BIOSTRATIGRAPHY

The location of the southwest Pacific localities discussed in this section is illustrated on the site map, text-figure 3.

Age data

In the papers originally describing the taxa treated herein (O'Connor 1994; 1997a, b; 1999) ages were given as New Zealand stages (defined by foraminifera and calcareous nannofossils), and/or radiolarian zone names (from Bolli et al. 1985 and Haq et al. 1987). Recently, however, new information regarding radiolarian ages and zonations has been forthcoming, necessitating an update of the previously published data. Additionally, New Zealand stages are now being treated as biozones (Chris Hollis pers. comm. 1999), which is in actuality what they represent, and so the informal subdivisions "upper" and "lower" replace the formerly utilized "early" and "late".

Two radiolarian zonation schemes are utilized herein. Sanfilippo and Nigrini's (1998) tropical radiolarian zonation is

used for the Northland localities (Puriri Formation and the Mahurangi Limestone) as age indicator taxa from those samples were tropical species. For the Oamaru Diatomite and other southwest Pacific localities the South Pacific radiolarian zonation of Hollis (1997) is used because of the lack of low-latitude index taxa. Both of these schemes indicate radiolarian zones using code numbers along the lines of the systems used for calcareous nannofossil and foraminiferal zones (see Appendix 1).

Ages are presented herein as New Zealand stages (data from Morgans et al. 1996), and/or the Cenozoic radiolarian zone code numbers of Hollis (1997) or Sanfilippo and Nigrini (1998). Appendix 1 provides charts which correlate New Zealand Cenozoic stages to international age data of Berggren et al. (1995), and to the radiolarian zones of Hollis (1997) and Sanfilippo and Nigrini (1998).

Puriri Formation at Te Kopua Point

The age of the Puriri Formation has been discussed previously (O'Connor 1997b). This age is further elaborated upon and revised herein (see text-fig. 1 for location of the Puriri Formation at Te Kopua Point). Appendix 2 provides a previously unpublished distribution chart of Radiolaria from the samples investigated from Te Kopua Point.

It is difficult to differentiate the earliest Miocene in New Zealand using planktic foraminifera (B.W. Hayward pers. comm. 1998). They indicate that the Puriri Formation and the stratigraphically younger (and physically overlying at Te Kopua Point) Timber Bay Formation are Otaian or older (>18.5 Ma). Those from the Puriri Formation at Puriri Point, investigated by F.J. Brook, gave an upper Waitakian to lower Otaian (c. 24–20.5 Ma) age (B.W. Hayward pers. comm. 1998).

Kadar (1988), using calcareous nannofossils, established an Otaian (22.4–18.5 Ma) age for the Puriri Formation at Te Kopua Point and Puriri Point. This age was based on his understanding that the base of his nannofossil Zone 26a, which he equated to the base of the Otaian, was marked by the first occurrence of the coccolith *Helicosphaera carteri*. However, it has since been demonstrated that *H. carteri* extends well back into the Waitakian in New Zealand, and well below the Oligocene/Miocene boundary overseas (B.W. Hayward pers. comm. 1998, based on A.R. Edwards' data from a refereed manuscript). So it now appears that calcareous nannofossils are unable to be used to differentiate between upper Waitakian and Otaian in New Zealand, and this is the age range they indicate for the Puriri Formation at Te Kopua Point and Puriri Point, i.e. c. 24–18.5 Ma.

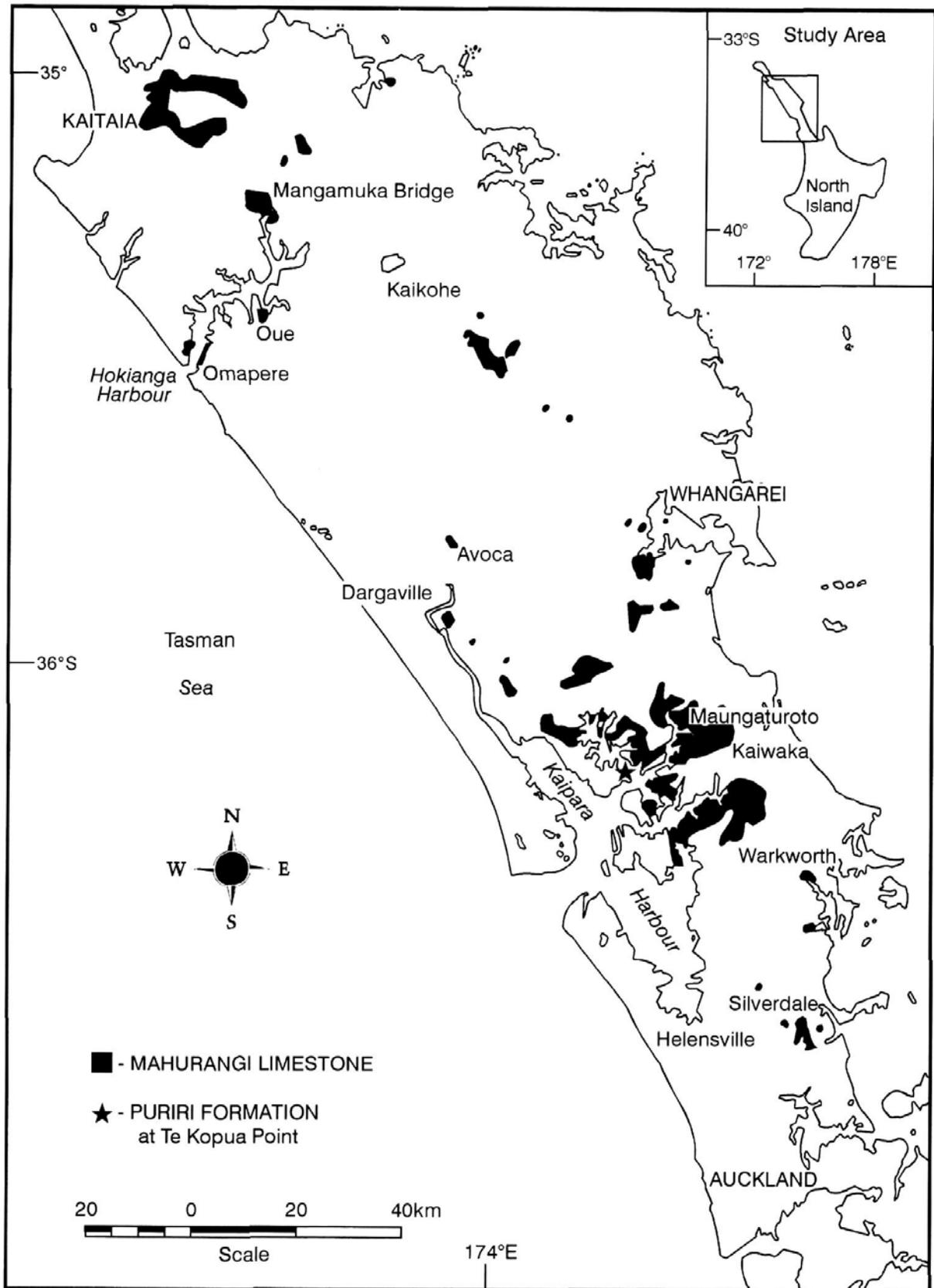
Radiolaria from the Puriri Formation at Te Kopua Point are generally very well preserved, very abundant, and of moderate diversity. The following low-latitude radiolarian index taxa are present in the Puriri Formation at Te Kopua Point: *Calocycletta* (*Calocyclopsis*) *serrata*, *Cyrtocapsa cornuta*, *C. tetrapera*, *Didymocyrtis prismatica*, *Dorcadospyrus ateuchus*, *Lophocyrtis* (*Paralampterium* ?) *galenum*, *Lychnocanium elongatum*, *Pterocanium audax*, and *Stichocorys delmontensis*. The tropical zonation of Sanfilippo and Nigrini (1998) indicates that the age of the Puriri Formation at Te Kopua Point is constrained by the first occurrence of *Stichocorys delmontensis* and the last occurrence of *Dorcadospyrus ateuchus*, i.e. within RN2 (c. 20.5–18 Ma) (see text-fig. 4). When correlated to New Zealand stages this gives a mid-Otaian to lower Altonian age. In conjunction

with ages from foraminifera and calcareous nannofossils, Radiolaria place the Puriri Formation at Te Kopua Point at approximately 20.5 Ma, or mid-Otaian.

The co-occurrence of *Calocycletta* (*Calocyclopsis*) *serrata* and *Stichocorys delmontensis* within the Puriri Formation supports the above age determination. However, these two species are not utilized directly in the dating of the Puriri Formation because there exists some confusion regarding the last occurrence of the former, and first occurrence of the latter. Text-fig. 4 shows *C. (C.) serrata* with a questionable last appearance datum (LAD), and also an uncertain first appearance datum (FAD) for *S. delmontensis*. These uncertainties are due to preservational circumstances making the definite identification of FADs and LADs for these taxa very difficult in key Deep Sea Drilling Project (DSDP) cores (Annika Sanfilippo pers. comm. 1998). Often the delicate distal portions of both taxa are not preserved, making it impossible to be certain of their exact stratigraphic limits, because without these diagnostic parts the two species can be easily confused with similar taxa. In addition, *S. delmontensis* is very rare when it first appears, and evidence seems to suggest that *C. (C.) serrata* is an environmentally sensitive species and thus may have diachronous FADs and/or LADs (Annika Sanfilippo pers. comm. 1998). Both of these taxa co-occur in the Puriri Formation at Te Kopua Point indicating overlap of their age ranges in this region, but the amount of overlap is unknown due to the short stratigraphic range of this formation. Sanfilippo and Nigrini (1998) documented *C. (C.) serrata* as occurring entirely within Zone RN1, and the FAD of *S. delmontensis* as being approximately concurrent with the lower limit of Zone RN2, implying no overlap between the two. Johnson (1978) indicated *C. (C.) serrata* occurring in lowest Zone RN2 in DSDP Hole 369A (eastern tropical Atlantic), with the FAD of *S. delmontensis* slightly higher in the hole, thus no overlap. Data supplied by Annika Sanfilippo (pers. comm. 1998) from her investigations of several DSDP cores showed no overlap of the two ranges in DSDP Site 78 (central Pacific). However, she indicated that in several other cores an overlap did exist (e.g. Sites 70 and 71 - central Pacific; Site 94 - Gulf of Mexico; Site 289 - equatorial Pacific), but the limits were uncertain due to the lack of paleomagnetic and other age control data, hence the dotted and questionable limits of these two taxa in text-fig. 4. Johnson (1976) indicated a slight overlap in DSDP Hole 317B (central Pacific). Steiger (1997, ODP Leg 156) showed *C. (C.) serrata* occurring from Zones RN1–RN4 in Hole 948C (western tropical Atlantic), but indicated that specimens above Zone RN1 were considered to be reworked. Zone RN2 was missing from Hole 948C, so the co-occurrence of *C. (C.) serrata* and *S. delmontensis* there is unknown. However, Zone RN2 was present in Hole 949B (western tropical Atlantic) from the same Leg, and showed *C. (C.) serrata* co-occurring with *S. delmontensis*. The above data demonstrates that an overlap in age between the two taxa can be recognized in many areas. The fact that it is not seen in all instances may be due to the preservational factors mentioned above, as all of the above Sites are in tropical areas thus eliminating climatic variation as a factor. The co-occurrence of both species in the Puriri Formation, however, confirms an overlap, and in doing so supports the mid-Otaian age given above (see text-fig. 4).

Mahurangi Limestone

Ages for Radiolaria from the Mahurangi Limestone (O'Connor 1994, 1997a) were originally based on the tropical radiolarian zonation of Sanfilippo et al. (1985), using the index taxa present. Herein the ages are updated to the scheme of Sanfilippo and



TEXT-FIGURE 1

Map of the Northland area showing areas of outcrop of Mahurangi Limestone, and the location of the Puriri Formation at Te Kopua Point (after O'Connor 1994, 1997a, b, in press).

Nigrini (1998), as detailed in O'Connor (in press) (see text-fig. 1 for location of the Mahurangi Limestone).

Radiolaria within the Mahurangi Limestone are generally well preserved, common to abundant, and the faunas are reasonably diverse. Key radiolarian index taxa used for dating Mahurangi Limestone outcrops are: *Artophormis gracilis*, *Calocyclella* (*Calocyclella*) *parva*, *C. (C.) robusta*, *Centrobotrys petrushevskayae*, *Didymocyrtis prismatica*, *Dorcadospyris ateuchus*, *Lithocyelia angusta*, *Lophocyrtis* (*Paralampterium*) *dumitricai*, *L. (P. ?) longiventer*, *Lychnocanium amphitrite*, *L. elongatum*, *L. trifolium*, *Pterocanium audax*, *Theocyrtis tuberosa*, and *Tristyluspyris triceros*. These species indicate an overall age for the formation of latest Eocene (RP19) to latest Oligocene (RP22) (see text-fig. 5). More detail regarding Radiolaria from the Mahurangi Limestone is provided by O'Connor (in press), including locality information, abundance and preservation data, biostratigraphic information, and the distribution of Radiolaria within the formation.

Although the age index taxa from the Mahurangi Limestone are tropical species, the limestone also contains Radiolaria which are restricted to higher latitudes. This implies that the faunas are not entirely of low-latitude origin, but rather that part of the fauna is tropical, and the other part more temperate, and that the site of deposition was therefore in an intermediate latitude (see Paleobiogeography section, below), as discussed in O'Connor (1993).

Oamaru Diatomite

The age of the Oamaru Diatomite (see text-fig. 2) is well established from diatoms, calcareous nanofossils, and foraminifera. Radiolaria in the Oamaru Diatomite (O'Connor 1999) are generally well preserved, common to abundant, and moderately diverse.

Ages for the recently described radiolarian taxa within the diatomite were determined using data in Edwards (1991, based on the calcareous nanofossil zonation of Edwards, 1971). Additional information was gained from Caulet (1986, 1991), Takemura (1992), Takemura and Ling (1997), and Hollis et al. (1997), including data on the last occurrences of *Lychnocanium amphitrite* and *Zealithapium mitra* in the Late Eocene (or possibly Early Oligocene for *L. amphitrite* - see below), and the first occurrences of *Amphisphaera* aff. *spinulosa*, *Eucyrtidium spinosum*, *Heliodiscus inca*, *Prunopyle fragilis*, *P. polyacantha*, and *Pseudodictyophimus gracilipes* in the Late Eocene (see text-fig. 6). The age of the formation based on the South Pacific radiolarian zonation of Hollis (1997) is lower to upper RP14 (upper Kaiatan to lowest Whaingaroan). This is compatible with the slightly narrower age range of Runangan to lowest Whaingaroan (mid to upper RP14) indicated by calcareous nanofossils, foraminifera, and diatoms.

Although *Lychnocanium amphitrite* is used as an age indicator species for the Oamaru Diatomite, both in O'Connor (1999) and herein, this usage could be problematic as this taxon may have either a later last occurrence (LO) in southern high-latitudes than previously thought, or a diachronous LO. The use of *L. amphitrite* as an indicator for the diatomite was based on data from Caulet (1986, 1991), Takemura (1992), and Hollis et al. (1997). The age of its LO in Hole 592 (Tasman Sea, DSDP Leg 90, Caulet 1986) is uncertain, although Caulet did mention that no radiolarians of Early Oligocene age were rec-

ognized in the hole, thus placing it in the Late Eocene. In Hole 738 (Kerguelen Plateau, ODP Leg 119, Caulet 1991) a last common occurrence (LCO) at approximately the Eocene/Oligocene boundary was indicated, with only a single specimen being found above that point. Data from Holes 748B and 749B (Southern Indian Ocean, ODP Leg 120, Takemura 1992) showed the LCO of *L. amphitrite* to be in the Late Eocene, with sporadic, very rare occurrences up into the Late Oligocene, although most of those in the Late Oligocene were attributed to reworking due to their occurrence as fragments. A Late Eocene LCO was given for Site 277 (southwest Campbell Plateau, DSDP Leg 29, Hollis et al. 1997), with younger occurrences being tentatively attributed to reworking and not being used in the biostratigraphy of the Site. In core catcher samples from ODP Site 1123 (Leg 181) investigated by the author, *L. amphitrite* has a LO in the Late Eocene. However, as most of the Oligocene (from approx. 33Ma and younger) is missing from this hole any possible rare/sporadic late occurrences will not be seen. Sanfilippo and Nigrini (1998) stated that the lower limit of low-latitude Zone RP20, in the Early Oligocene, was approximately synchronous with the LO of *L. amphitrite*, hence the dotted line for its age range in text-fig. 6. Data in O'Connor (in press) from the Mahurangi Limestone (see above) shows a rare occurrence up to this point also. Taking into account all of the above occurrences two scenarios present themselves - 1) *L. amphitrite* has a later LO in low latitudes and areas with tropical affinities (e.g. the Mahurangi Limestone) than in southern high-latitudes, i.e. its LO is diachronous, or 2) Early Oligocene occurrences of *L. amphitrite* in southern high-latitudes are not due to reworking. As *L. amphitrite* is a robust taxon, and therefore a good candidate for reworking, further work on southern ocean localities is required to determine how much reworking really occurs, and thus which scenario is valid. Herein, *L. amphitrite* is used as an age indicator taxon for the South Pacific area, but with caution. In text-fig. 6 its LO is shown for data from both the South Pacific and low-latitude zonations.

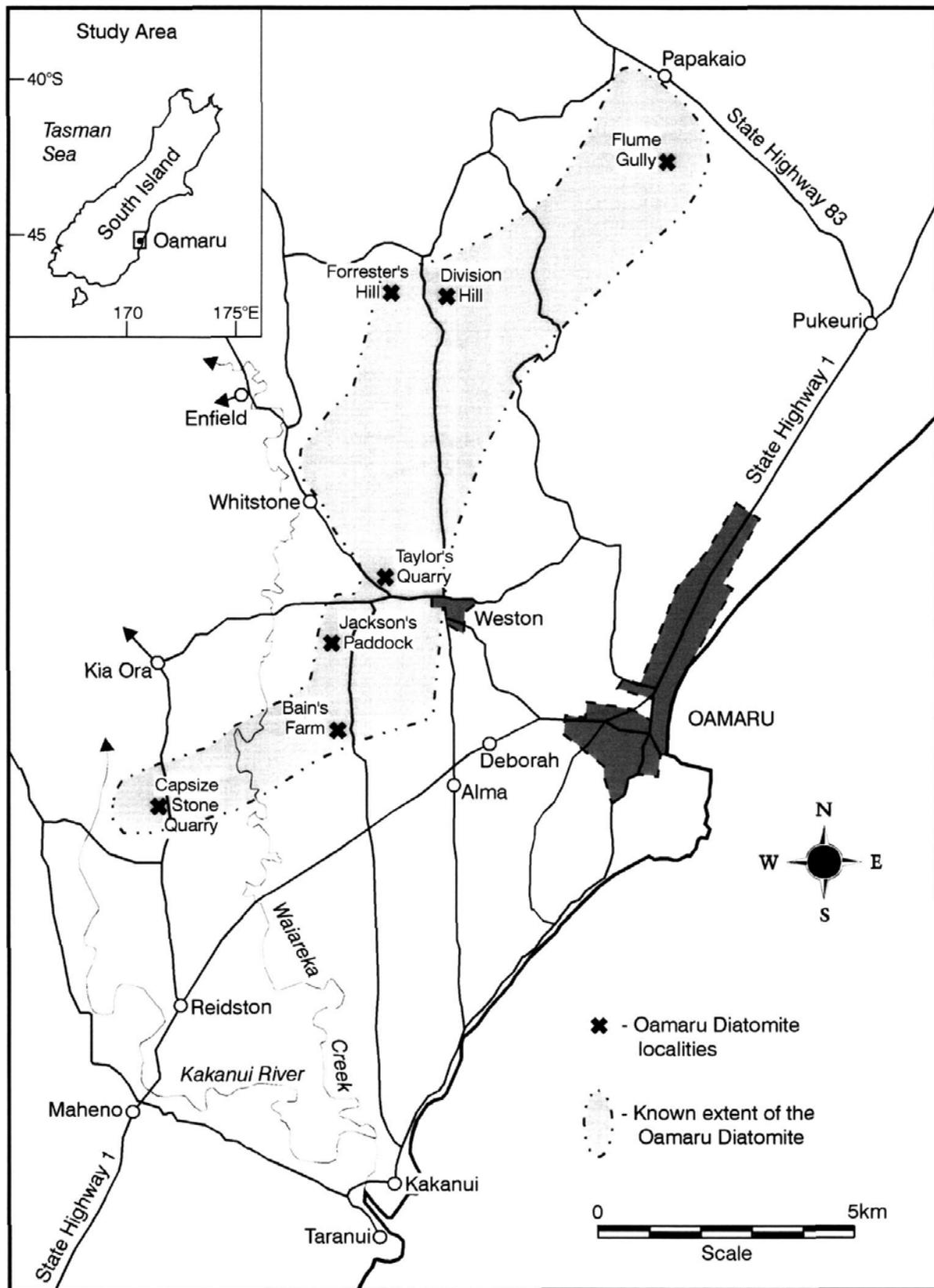
DSDP Leg 29

Petrushevskaya (1975) investigated the Radiolaria from Sites 278, 280, and 281 of DSDP Leg 29. Other sites from this leg have been studied subsequently (see below), and it is surprising that many of the recently described taxa listed below are found in the latter Sites, but very few are found in those documented by Petrushevskaya (1975). All three Sites contained Paleogene Radiolaria, with Site 278 having Oligocene forms, Site 280 containing both Late Eocene and Oligocene Radiolaria (see below, and Crouch and Hollis 1996), and Site 281 having Late Eocene taxa (*ibid.*).

The few taxa from the DSDP Initial Reports of Leg 29 (Petrushevskaya 1975) that are synonymized with recently described taxa below are done so tentatively because of poor illustrations in the Report. Additionally, age data is not available for the synonymized forms, and therefore data from Petrushevskaya (1975) is included mainly for information on geographic distribution.

DSDP Site 277 (Leg 29)

Although Petrushevskaya (1975) did not consider Site 277 in her study of radiolarians from Leg 29, Radiolaria were investigated as part of an integrated biostratigraphic study of the site by Hollis et al. (1997). The study demonstrated how useful Site 277 is for southern high-latitude biostratigraphy, with a good record of Radiolaria, calcareous nanofossils, and foraminifera from Late Paleocene to Oligocene.



TEXT-FIGURE 2

Map of the Oamaru area showing the known extent of the Oamaru Diatomite, and localities from which samples were studied (after Edwards 1991; O'Connor 1999).

For the present paper the radiolarian slides prepared by Chris Hollis for the Site 277 study were re-examined by the author for occurrences of the recently described species treated herein. The material examined ranged from Early Eocene to Early Oligocene, but none of the recently described taxa were found prior to the late Middle Eocene (sample 277-29-1, 97cm). As index taxa from this site were South Pacific species, the radiolarian zonation of Hollis (1997) is applied. The integrated biostratigraphic study of Hollis et al. (1997) was instrumental in correlating this scheme with New Zealand stages, and hence with international epochs. It also made it possible to add, herein, the tropical zonation of Sanfilippo and Nigrini (1998) to these correlations (see Appendix 1).

Site 277 proved very useful for the present study. The sequence extends below the stratigraphic range of the Oamaru Diatomite, and thus allows the probable lower limits of several of the recently described taxa to be established. Age-wise, the sequence also extends up to the lower part of the Mahurangi Limestone, and thus provides insights into which of the recently described species may be useful for correlation between the low-latitude and South Pacific radiolarian zonations.

DSDP Hole 280A (Leg 29)

Hollis, in Crouch and Hollis (1996), examined reference material (from the DSDP/ODP Micropaleontology Reference Centre, Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand) from Sites 280 and 281, and updated Petrushevskaya's (1975) biostratigraphic interpretations using data from Caulet (1991). For the present study strewn slides were prepared from samples previously processed by Chris Hollis from Cores 10 through to 1 of Hole 280A, and examined for the recently described taxa.

Crouch and Hollis (1996) indicated that this Hole represented a Late Eocene to Early Oligocene succession, but lacked well-defined index taxa. They placed the Eocene/Oligocene boundary at the base of Core 6 on the basis of the first common occurrence (FCO) of *Prunopyle monikae*, a species that Caulet (1991, ODP Leg 119) found to occur only in the Early Oligocene. However, during the present study that species is also found to be reasonably common in the sample from Core 7 (280A-7-3, 40cm), and so the boundary is herein considered to lie between that sample and 280A-8-1, 70cm. As *P. monikae* occurred in all samples from Core 7 through to Core 2 these are all considered to be Early Oligocene in age. Moreover, Hollis et al. (1997) used the first occurrence (FO) of *Axoprimum ? irregularis* as a marker of the base of upper Zone RP15. In the Hole 280A samples investigated herein the FO of this species is in sample 280A-7-3, 40cm, putting it and the overlying samples in upper RP15 or younger. The co-occurrence of the above two taxa in samples 280A-7-3, 40cm through to 280A-2-3, 50cm places this succession in the Early Oligocene part of upper Zone RP15. Additionally, the presence of the index taxon *Stichocorys peregrina* in the slide from Core 1 (280A-1-3, 65cm, pers. obs.) indicates an age of Late Miocene or younger for this sample and implies a long hiatus, the underlying sample (280A-2-3, 50cm) being of Early Oligocene age. The Late Eocene to Oligocene radiolarian faunas at this Hole have high-latitude affinities. Similar faunas were reported from the Antarctic (Chen 1975), Kerguelen Plateau (Caulet 1991), and the Southern Indian Ocean (Takemura 1992).

During the investigation of the Hole 280A samples three new taxa were noted. These are described below.

DSDP Site 283 (Leg 29)

Radiolaria from Site 283 were not investigated in the Initial Reports of Leg 29 (Petrushevskaya 1975), although their presence was mentioned in the Site report (Kennett et al. 1975). Crouch et al. (unpublished manuscript) initiated an integrated biostratigraphic study of this site, including the Radiolaria. Six samples were examined by Chris Hollis from cores 8 to 2 for Radiolaria (all available core splits from the site stored in the DSDP/ODP Micropaleontology Reference Centre, Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand) and they were found to be abundant in all samples.

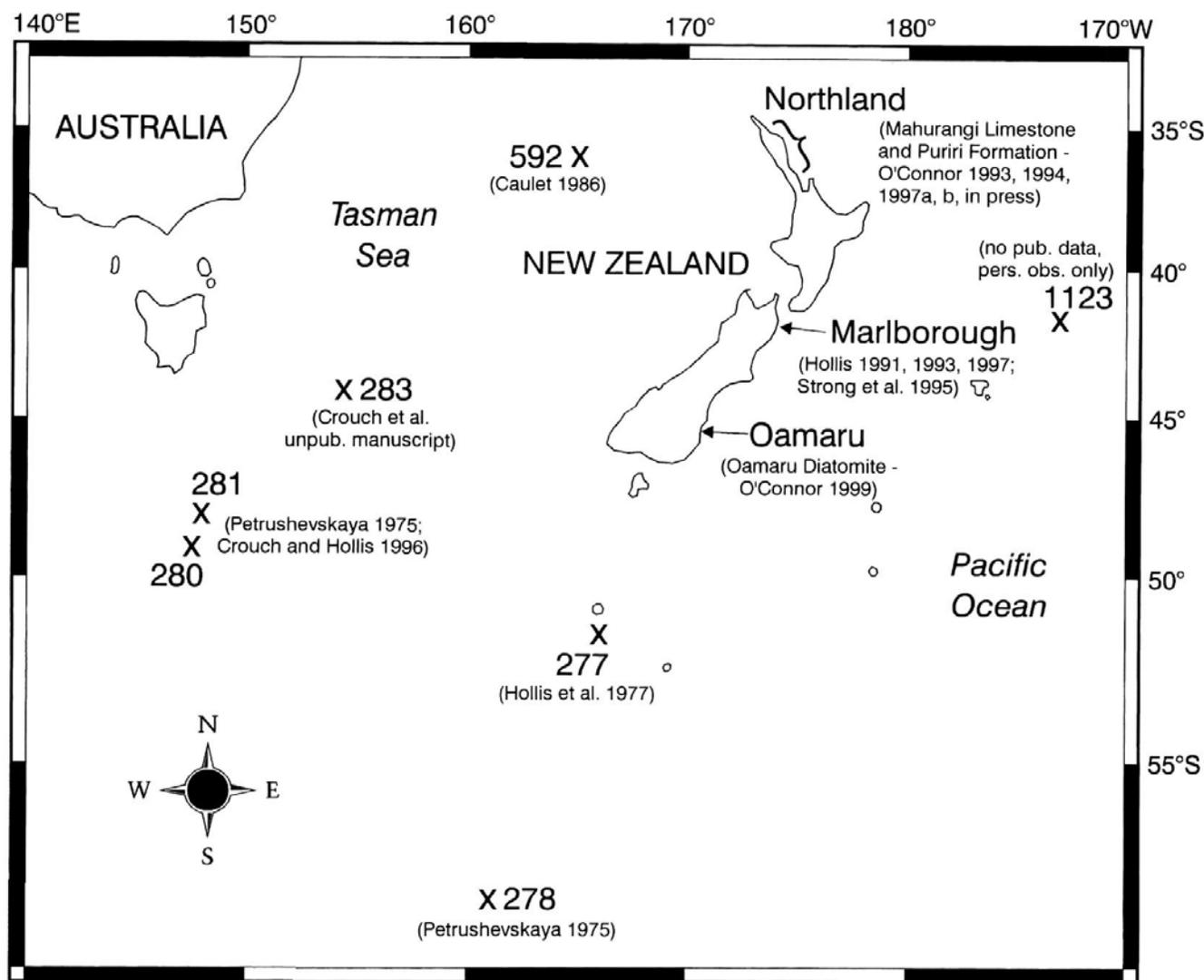
Chris Hollis's slides were re-examined for the present study. The six samples ranged from late Middle to Late Eocene, and many of the recently described taxa listed below were present. As for Site 277, the South Pacific radiolarian zonation of Hollis (1997) was applied, again because of the lack of low-latitude index taxa. The lower part of the range of the Oamaru Diatomite appears to be covered by the Site 283 samples.

This site proved useful for estimating the lower age limits for several of the recently described taxa. The age of the oldest sample (283-8-2, 25cm, late Middle Eocene) is comparable to that of the oldest sample in which recently described species were found in Site 277 (277-29-1, 97cm).

DSDP Site 592 (Leg 90)

Caulet (1986) found Radiolaria of Paleogene age in Site 592 of site DSDP Leg 90, and while noting that the faunas were "...not very different from tropical faunas..." (*ibid.*, p. 840), he also pointed out that typical tropical morphotypes were absent, and that other taxa with tropical affinities appeared to differ from their tropical counterparts (*ibid.*, p. 841). Two taxa he specifically mentioned as differing from tropical morphotypes were *Thyrsoyrtis bromia* and *Cyclampterium ? milowi* (now *Lophocyrtis (Cyclampterium) milowi*). He noted that the forms of *T. bromia* were somewhat different from those found in the tropics, and that the tests of *C. ? milowi* were narrower than normal. It is likely that these two species may in fact be *Thyrsoyrtis (T. ?) pinguiscoides* and *Lophocyrtis (Paralampterium ?) longiventer*. Investigations by the author show that *T. (T. ?) pinguiscoides* appears to be restricted to the Late Eocene of southern high-latitudes (O'Connor 1999; see Systematic Paleontology section, below), and Sanfilippo (1990) noted that *L. (P. ?) longiventer* is moderately abundant in mid to high-latitude assemblages in the late Middle Eocene to Early Oligocene. It is also possible that the taxon Caulet listed as *Cryptoprora ornata* (now *Cryptocarpium ornatum*) may be *Carpocanistrum ballisticum*, a species superficially similar to *C. ornatum*. Moreover, most of the Eocene taxa documented from this Site are also found in other southwest Pacific localities investigated, namely the Oamaru Diatomite, DSDP Sites 277 and 283, and ODP Site 1123. Site 592 faunas differ from those of latest Eocene age in the Mahurangi Limestone by lacking the tropical index taxon *Theocyrtis tuberosa*, which is also absent from all other localities investigated herein, and by the presence of useful South Pacific age indicator species such as *Heliodiscus inca* and *Zealithapium mitra*. These factors indicate that rather than representing tropical faunas, the Site 592 assemblages are of more temperate origins.

Because Caulet compared the Site 592 radiolarian assemblages to tropical faunas he utilized the tropical zonation of Riedel and Sanfilippo (1978), and placed them in the late Eocene. However, he gave no basis for this age determination in terms of spe-



TEXT-FIGURE 3
Map of southwest Pacific showing localities, and relevant publications mentioned in the text. "X" denotes DSDP/ODP Site, other localities onland.

cific taxa. As he identified *T. bromia* in the Site 592 faunas it seems likely that this taxon was used as part his age determination, as it was thought to be restricted to the Late Eocene at the time (*ibid.* text-fig. 1). Nowadays however, this species is known to range from the late Middle to late Eocene (RP16-RP19, Sanfilippo and Nigrini 1998). If, as seems likely from Caulet's comments, the taxon he identified as *Thyrsoyrtis bromia* is in fact *T. (T. ?) pinguisoides*, then the Late Eocene age determination appears correct due to the apparently restricted range of this species in the southwest Pacific area. Other temperate index taxa identified by Caulet which can provide age data for the Site are *Lychnocanium amphitrite* and *Zealithapium mitra*, with upper limits of Late Eocene, and *Heliodiscus inca* and *Pseudodictyophimus gracilipes*, with lower limits of Late Eocene (see Oamaru Diatomite, above).

Site 592 adds to the geographic distribution data for a few of the recently described taxa. More importantly however, it helps establish that the position of the biogeographic boundary, discussed in detail below, lay to the north of this locality in the Late Eocene.

ODP Site 1123 (Leg 181)

Ocean Drilling Program (ODP) Site 1123, comprising a sequence from Late Eocene to Pleistocene, was one of two localities drilled on the Chatham Rise, off the east coast of New Zealand, during ODP Leg 181 (see Carter et al. 1999). Unfortunately, due to a hiatus of approximately 12 million years, most of the Oligocene and earliest Miocene are missing. Even so, the site proved very useful due to good age control from both calcareous nannofossils and paleomagnetic data, and many of the recently described taxa listed below were present in the radiolarian faunas. Radiolarian preservation is excellent, and faunas are diverse and abundant.

It was necessary to utilize both of the radiolarian zonation schemes mentioned above for this Site. The Late Eocene-lowest Oligocene section is zoned according to the South Pacific radiolarian zonation of Hollis (1997), and the low-latitude radiolarian zonal scheme of Sanfilippo and Nigrini (1998) is applied to the Miocene section. This was due to a change from temperate to tropical radiolarian index taxa between these two time intervals (see Paleobiogeography section, below).

PALEOBIOGEOGRAPHY

Recognition of a biogeographic boundary

The necessity of having to use two separate zonal schemes to date the radiolarian faunas discussed above suggests that there was a major biogeographic boundary with respect to Radiolaria between the Mahurangi Limestone and the Eocene to Oligocene sections of the other localities investigated. Low-latitude index taxa, and other taxa with tropical affinities, are present in the Mahurangi Limestone throughout the stratigraphic range of its deposition (latest Eocene to latest Oligocene). However, despite an age overlap, low-latitude index taxa are either absent from the Eocene to Oligocene of the Oamaru Diatomite (latest Eocene to earliest Oligocene), DSDP Site 277 (Late Paleocene to Early Oligocene), DSDP Site 278 (Lower Oligocene to Pleistocene), DSDP Hole 280A (Eocene to Miocene), and ODP Site 1123 (Late Eocene to Pleistocene), or the rare ones that do occur are of no use in dating the localities. For example, the last occurrence (LO) of *Tristylospyris tricerus* is an important marker in the Mahurangi Limestone, but its presence in the Oamaru Diatomite is of little stratigraphic value as its age range more than spans that of the diatomite. Although there is no age overlap between the Mahurangi Limestone and DSDP Sites 281, 283, and probably 592, a similar situation exists at these localities. Similarly, the occurrences of taxa utilized for dating high-latitude localities, such as *Prunopyle fragilis*, *P. polyacantha*, and *Pseudodictyophimus gracilipes*, in the Mahurangi Limestone are of little use as these taxa have age ranges that span the deposition of the limestone. It was the dearth of common index taxa that dictated the use of separate zonal schemes for the Eocene to Oligocene time span, and that indicated the presence of a biogeographic boundary during this time.

Cause of the biogeographic boundary

The biogeographic boundary may be attributed to latitudinal differences during deposition, and associated prevailing water circulation patterns. The Mahurangi Limestone is a part of the Northland Allochthon, a large sheet of sediments originally deposited to the northeast of the New Zealand landmass, and thought to have moved onto the Northland area in the Late Oligocene or Early Miocene (Balance and Spörli 1979; Hayward et al. 1989; Hayward 1993). This would have placed the site of its deposition within the influence of an anticyclonic gyre bringing warmer water, and associated radiolarians, southwards from lower latitudes. The anticyclonic gyre would have opposed a cyclonic gyre such as that shown in Kennett (1982, fig. 19-10, lower left part of diagram), and Lazarus and Caulet (1993, figs. 19, 20).

Although low-latitude index taxa were utilized for dating the Mahurangi Limestone, around half of the taxa found in the Oamaru Diatomite and associated southwest Pacific localities were also identified in the limestone. Of the 127 species of Radiolaria documented from the Oamaru Diatomite (O'Connor 1999), approximately 44% are also found in the Mahurangi Limestone, including 11 of the recently described taxa described from the diatomite. In addition seven of the recently described species described from the Mahurangi Limestone occur in the Oamaru Diatomite. Similar patterns were noted between the Mahurangi Limestone and Sites 277 and 283, with 43% of the documented fauna from Site 277, and 50% from Site 283 occurring in the Mahurangi Limestone. Only a small number of Eocene taxa were documented from Site 592 (Caulet 1986), but of these approximately 40% occur in the Mahurangi Limestone.

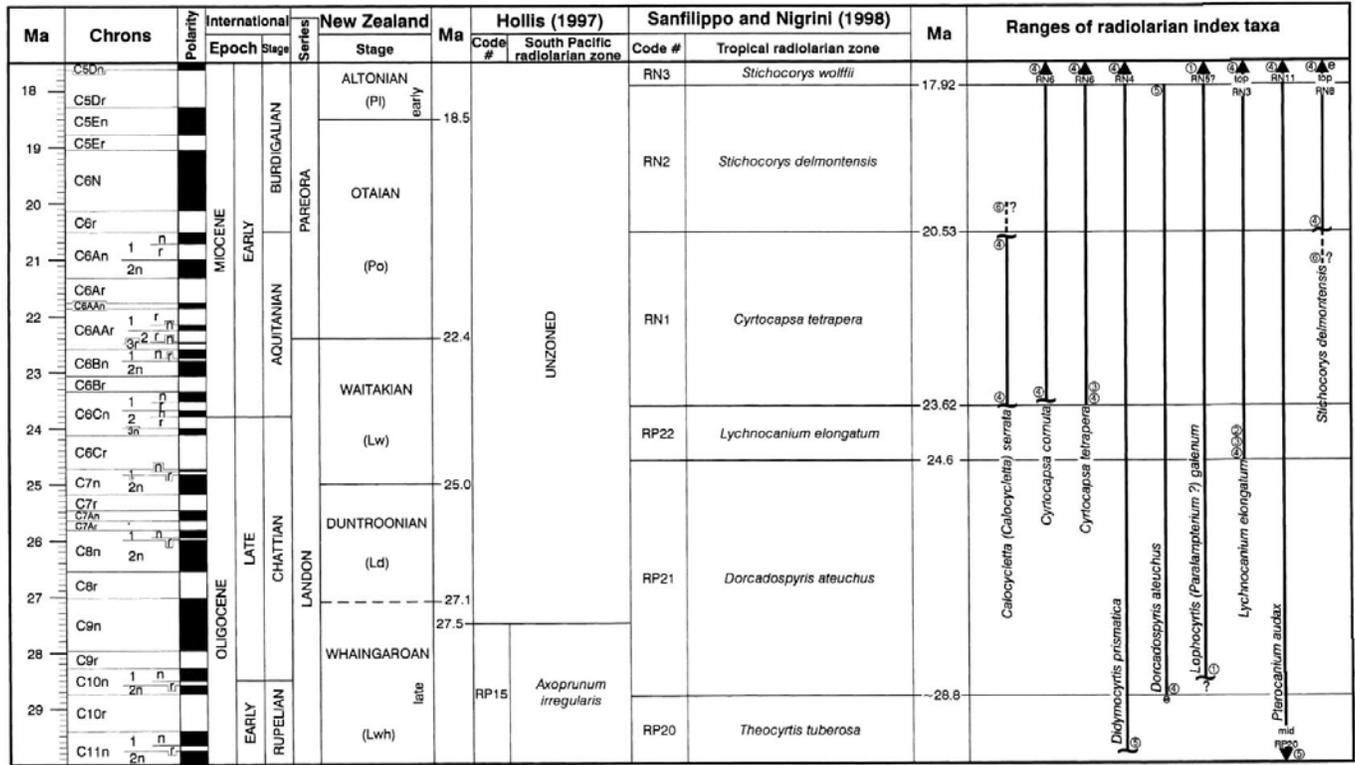
The mix of tropical and temperate taxa within the Mahurangi Limestone implies that the radiolarian faunas are not solely of a low-latitude origin, and this in turn may indicate that although the depositional site of the limestone was influenced by warmer waters from the north, there was also some impact exerted by cooler southern waters. The mixing of the low latitude and temperate faunas created a "transitional fauna", as postulated in O'Connor (1993). This is a radiolarian fauna containing taxa with low-latitude affinities, along with those from higher latitudes, plus a group of species endemic to the area. As cool water taxa are more likely to adapt to warm conditions than visa versa (Sancetta 1979), it seems likely that the cool water species "wandered" into the area of limestone deposition from the cool waters of the cyclonic gyre (see below), thus the influence of the gyre need not have been felt by the tropical taxa.

Site 592 (Late Eocene, Caulet 1986) in the Tasman sea, the northernmost of the non-Northland localities discussed (see text-fig. 3), lacks useful low-latitude radiolarian index taxa (see Biostratigraphy section, above). This indicates that the influence of the warming waters from the anticyclonic gyre appears not to have extended as far as 50°S, the approximate position of Site 592 during the Late Eocene (Lawver et al. 1992, fig. 13). This Site, along with the other DSDP/ODP Sites investigated, appears to have been influenced by a cyclonic gyre which maintained the temperate aspect of the Tasman Sea and waters to the south and east of New Zealand by transporting cooler Antarctic waters northward (see Kennett 1982, fig. 19-10; Lazarus and Caulet 1993, figs. 19, 20). This would explain their lack of low-latitude radiolarian index taxa, and marked temperate signature. Moreover, radiolarian faunas from the Late Eocene to Early Oligocene of Hole 280A, which at approximately 68°S (Lawver et al. 1992, figs. 13, 14) was the southernmost of the investigated localities during that interval, have much in common with high-latitude faunas documented in Chen (1975), Caulet (1991), and Takemura (1992).

The above observations suggest that there was a biogeographic boundary to Radiolaria during the Late Eocene - Early Oligocene. However, due to large gaps in the relevant cores covering the critical interval, i.e. Late Oligocene - Early Miocene, it is not known what happened to the boundary after this time.

CONCLUSION

The fact that there are no complete Late Eocene to Pliocene sections from the southwest Pacific area means that the geographic extent of the biogeographic boundary through time is not able to be determined due to insufficient data. Until more and complete sections covering the time interval in question are uncovered/recovered in the South Pacific area we can only speculate on the chances of rectifying the differences between the two radiolarian zonations used herein, and of deducing the geographic extent of the boundary. However, it seems likely that the key to correlation between the two zonal schemes lies with some of the recently described taxa documented below. Several of the recently described species are found in both the low-latitude affinity faunas of the Mahurangi Limestone, and the more temperate faunas of the other southwest Pacific localities, and with further work it is likely that they will be utilized as linking taxa, joining the two zonal schemes in the South Pacific area.



TEXT-FIGURE 4

Chart showing age ranges of radiolarian index taxa from the Puriri Formation. Numbers at either end of ranges signify source of age data: 1 = Sanfilippo (1990), 2 = Sanfilippo and Nigrini (1995), 3 = Sanfilippo and Nigrini (1996), 4 = Sanfilippo and Nigrini (1998), 5 = Annika Sanfilippo, unpublished data (pers. comm. July 2nd 1998, data is not correlated to the geomagnetic timescale), 6 = Annika Sanfilippo, unpublished data (pers. comm. July 13th 1998), “~” = approximate limit, “e” = evolutionary limit, “?” = uncertain limit, arrows signify that range continues off chart (end of range shown - zones indicated are those of Sanfilippo and Nigrini 1998). Age ranges correlate to the Tropical radiolarian zonation of Sanfilippo and Nigrini (1998). Magnetostratigraphic and international stage data from Berggren et al. (1995), New Zealand stage data from Morgans et al. (1996).

SYSTEMATIC PALEONTOLOGY

A systematic list of taxa not treated as either new or recently described species in the following section is given in Appendix 3.

New species

During the reinvestigation of samples from DSDP Hole 280A three new species were noted, and these are described below (see Biostratigraphy section, above, for stratigraphic information on Hole 280A).

Materials and methods

Strewn slides and SEM stubs were prepared as outlined in O'Connor (1994, 1997a) from material which had already been processed by Chris Hollis for a previous investigation. A total of 10 samples from the following core locations were examined, and the number of Radiolaria per slide (radiolarian density) was approximated from counts of one to four lengthwise traverses (in parentheses): 280A-10-5, 87cm (~2000), 280A-9-1, 85cm (~1200), 280A-8-1, 70cm (~2000), 280A-7-3, 40cm (~2200), 280A-6-2, 60cm (~3200), 280A-5-1, 104cm (~2000), 280A-4-4, 40cm (~4200), 280A-3-4, 40cm (~2600), 280A-2-3, 50cm (~2000), and 280A-1-3, 65cm (~900).

Preservation of radiolarians on all slides was good to excellent (see O'Connor 1994 for description of preservation grades). Abundances of the new species were determined from full counts of one slide from each sample and are as follows: very rare (<5), rare (6-10), common (11-20), abundant (21-50), very abundant (>50). Terminology applied to the various skeletal elements is that of O'Connor (1997a). All type material, samples and slides will be lodged with the Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand. Plates were prepared as outlined in O'Connor (1999), except that transmitted light images were taken using a Fujix Digital Camera (HC-300/OL), and thus were captured via computer and not scanned from photographic negatives. For investigation of internal skeletal structure under the SEM specimens were all broken manually using a sharp scalpel blade.

In the following descriptions and the plate captions specimens are referred to by slide or SEM stub number as follows: for a specimen on a strewn slide - 1123C-26x, CC A, E21/0, denotes a specimen from ODP Site 1123, Hole 1123C, Core 26x, core catcher sample, slide A, England finder coordinates E21/0; for a specimen on an SEM stub - 280A-6-2, 20cm, 02-01-01, denotes a specimen from DSDP Site 280, Hole 280A, Core 6, Section 2, 20cm, SEM stub 2, row 1, specimen 1 in the row.

Description of new species

Order NASSELLARIA Ehrenberg 1875

Suborder CYRTIDA Haeckel 1862, emend. Petrushevskaya 1971a

Family Artostrobiidae Riedel 1967a, emend. O'Connor 1997a

Comments: Although in O'Connor (1997a) it was mentioned that appendages on post-cephalic segments are rare and only seen on two-segmented members of this family, it has since been noted that some species with more than two segments also possess appendages, e.g. *Dictyoprora physothorax* Caulet, and the new species, *D. nigrinae*, described below.

Genus *Dictyoprora* Haeckel, emend. Nigrini 1977

Dictyoprora Haeckel 1881, p. 430. Type species: *Dictyocephalus amphora* Haeckel 1887, p. 1305, pl. 62, fig. 4 (S.D. Campbell 1954).

Dictyoprora nigrinae O'Connor n. sp.

Plate 2, figures 1a-8b; plate 3, figures 1a-8

Description: Shell of three segments, small, hyaline.

Cephalis externally hemispheroidal, internally ovoid; two distinct, external furrows visible on posterior part running either side of vertical tube to collar stricture, external expression of arches **Li-Vbl** and **Lr-Vbr** (pl. 3, figs. 1a, b, 2, 5, 6); surface generally roughened by raised pores, and often low, irregular, wavy ridges; apical horn usually very short, most often in the form of a low bump with a pore on either side (pl. 3, fig. 1b), but very rare specimens have long, conical apical horn (pl. 2, figs. 7a, b); pores very small, circular to subcircular, irregularly distributed, raised above surface in the form of small, hollow, conical protuberances; well developed vertical tube extends steeply upwards from posterior near base of cephalis at an angle greater than 50° from horizontal, externally conical, generally internally cylindrical; collar stricture generally externally indistinct but may be visible as slight contour change.

Thorax inflated truncate-conical, maximum width attained before lumbar stricture; surface roughened by wavy ridges, generally longitudinally directed but meandering on some specimens (pl. 3, fig. 5); pores small, circular to subcircular, irregularly arranged in vague transverse rows, often downwardly directed with a protruding hood over upper part (pl. 3, figs. 1a, 3, 4, 6); many specimens have one to four short, pointed, downwardly directed wings corresponding to **D**, **Li**, **Lr**, and **Vbd** (pl. 2, figs. 1a-5b, 7a-8b; pl. 3, figs. 1a, 2, 4); lumbar stricture externally expressed as rounded, concave constriction, internally as thickened ledge.

Abdomen often irregular, but generally cylindroid, may have shallow, rounded constrictions; surface roughened by same ridges as thorax, although ridges become less distinct distally; pores small, circular to ovate, irregular in size distribution although distal pores may be slightly larger, arranged in irregular, irregularly-spaced transverse rows, on many specimens one or more transverse pore rows are incomplete around the circumference (pl. 3, figs. 3, 6); peristome generally smooth; aperture slightly constricted; termination smooth to slightly undulating.

Internal skeletal structure typical of three-or-more-segmented artostrobiids (see O'Connor 1997a, b); elements consist of bars **M**, **D**, **V**, **A**, **Li**, **Lr**, **Il**, **Ir**, **Vbl**, **Vbr**, **Vbd**, spines **Vs**, **Ax**, and arches **A-Vbl**, **A-Vbr**, **Vbl-Vbd**, **Vbr-Vbd**, **Li-Vbl**, **Lr-Vbr**,

Il-Li, **Ir-Lr**, **D-Il**, **D-Ir** (text-fig. 7; pl. 3, fig. 7); **M** angled steeply downwards towards posterior; **A** extends freely upward from anterior end of **M** to top of cephalis, may protrude as apical horn (see above); small antecephalic lobe anterior to **A**; **D** extends downwards at a slight angle from anterior end of **M** to collar stricture, becomes incorporated in thoracic wall, may protrude outside as small dorsal wing on thorax (see above); **V** extends upward at a steep angle from posterior end of **M**, branches to form **Vbl**, **Vbr** and **Vbd**; **Vbl** and **Vbr** extend laterally to join cephalic wall at either side of vertical tube; **Vbd** extends downward at an angle to join cephalic wall at lower base of vertical tube, may protrude outside as small wing on thorax (see above); remaining bars (excluding **M**) extend to arches; **Li** and **Lr** become incorporated in thoracic wall, may protrude outside as small lateral wings on thorax (see above); **Vs** continues from **V** extending freely into vertical tube; cluster of long **Ax**, extend downward through thorax into abdomen, generally one from junction of **V** and **M**, two each from bars **M**, **Li** and **Lr** near their junction with each other, although some may branch at base; arches **A-Vbl** and **A-Vbr** mostly incorporated in cephalic wall so internally indistinct, curve downward from point where **A** joins cephalic wall to join **Vbl** and **Vbr** at cephalic wall, define lateral lobes but not externally expressed; arches **Vbl-Vbd** and **Vbr-Vbd** form partial ring at lower part of base of vertical tube and together with rest of arches form ring at base of cephalis; arches **Li-Vbl** and **Lr-Vbr** externally expressed as furrows (see above).

Dimensions: Range of 41 specimens (Holotype measurements given in parentheses): length of apical horn: 2-12µm (4µm); length of cephalis: 19-25µm (22µm); maximum width of cephalis excluding vertical tube: 28-41µm (37µm); length of thorax: 25-38µm (29µm); maximum width of thorax excluding wings: 46-57µm (55µm); number of transverse pore rows on thorax: 2-4 (3); maximum number of pores on half equator of thorax: 4-10 (6); length of abdomen: 48-97µm (79µm); maximum width of abdomen: 49-73µm (61µm); number of transverse pore rows on abdomen: 1-6 (5); maximum number of pores on half equator of abdomen: 7-17 (11).

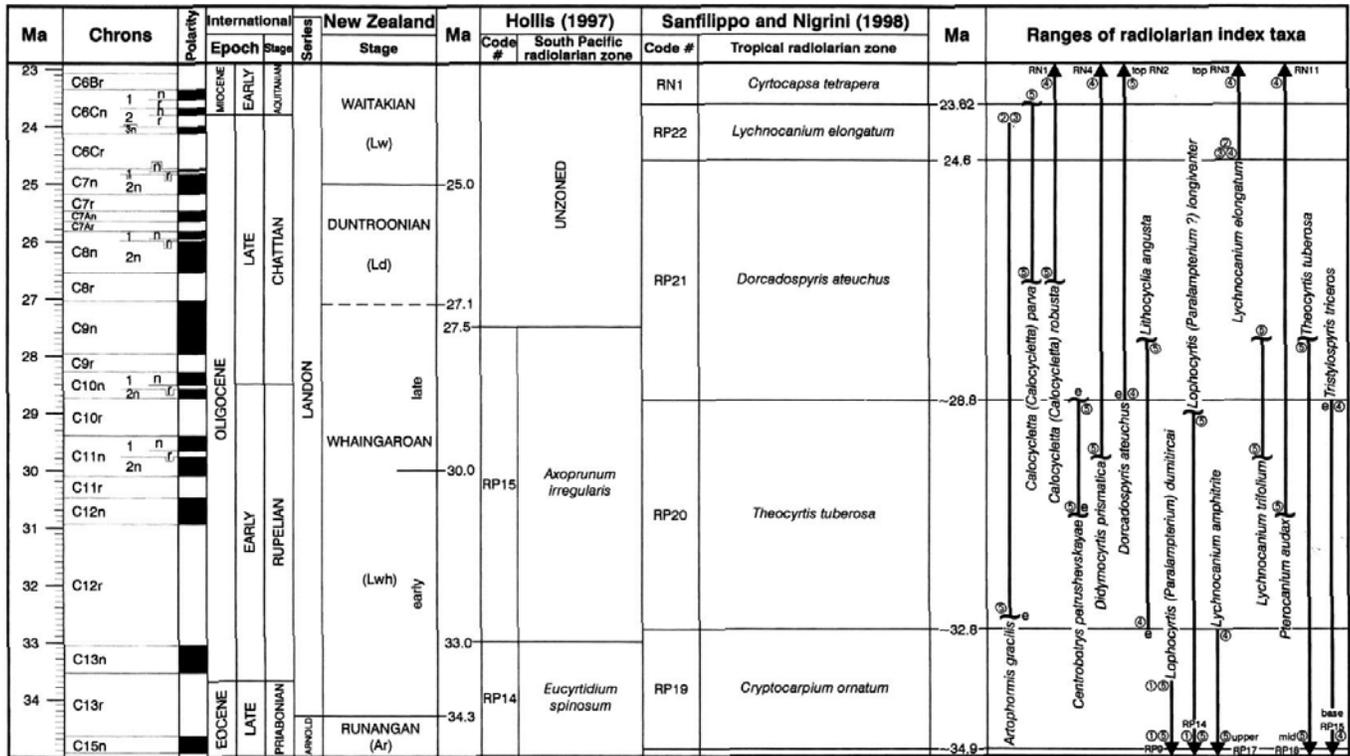
Etymology: In honour of Catherine Nigrini for her major contributions to the field of Cenozoic radiolarian micropaleontology, and in particular to the family Artostrobiidae.

Holotype and type locality: 280A-7-3, 40cm A, E37/2; DSDP Site 280, Hole 280A.

Occurrence: Late Eocene - Early Oligocene, upper RP14-RP15 (280A-9-1, 85cm - 280A-4-4, 40cm).

Abundance: 280A-9-1, 85cm, very rare; 280A-8-1, 70cm, very rare; 280A-7-3, 40cm, very abundant; 280A-6-2, 60cm, common; 280A-5-1, 104cm, rare; 280A-4-4, 40cm, rare.

Discussion: *Dictyoprora nigrinae* differs from other members of the genus as follows: from *D. pirum* and *D. gibsoni* primarily by not having a laterally compressed abdomen; from *D. amphora*, *D. armadillo*, *D. ovata*, and *D. mongolferi* primarily by having many fewer transverse pore rows on the abdomen, and by those transverse rows being irregular and irregularly-spaced; from *D. urceolus* by having a much more steeply upwardly-directed vertical tube, an irregularly-shaped abdomen, and transverse abdominal pore rows which are irregular and irregularly-spaced; from *D. physothorax* by possessing an apical horn, and a vertical tube that is much more steeply up-



TEXT-FIGURE 5
Chart showing age ranges of radiolarian index taxa from the Mahurangi Limestone (modified from O'Connor in press). See text-fig. 4 for details.

wardly-directed, and in the irregularity of the shape of the abdomen and arrangement of abdominal pores.

Genus *Plannapus* O'Connor

Plannapus O'Connor 1997a, p. 69. Type species: *Dicolocapsa microcephala* Haeckel 1887, p. 1312, pl. 57, fig. 1, sensu O'Connor 1997a (O.D.).

Plannapus ? aitai O'Connor n. sp.

Plate 2, figures 16a-21b; plate 3, figures 9-18

Description: Shell spindle-shaped, of two segments, very small.

Cephalis externally hemispheroidal, internally spheroidal to ovoid, relatively thick-walled, poreless; apical horn shorter than cephalis, generally thin, conical; surface roughened by numerous small, irregularly distributed nodes or tubercles; steeply upwardly-directed vertical pore at base of cephalis, a rim or lip surrounding the external lower half of pore gives it the form of a sort of tube (pl. 3, fig. 11b); collar stricture generally externally indistinct, but may be visible as very slight contour change.

Thorax slightly inflated-cylindrical, thick-walled but thinning distally, tapering distally, greatest width generally at or slightly above half length; surface roughened by nodes similar to those on cephalis, nodes become smaller and less prominent distally so last 1/4 to 1/5 may be smooth; pores small, circular to subcircular, arranged in transverse rows, both pore and row spacing generally regular but regularity often decreases distally, pores often divided by lattice of fine bars (pl. 3, fig. 11c); many specimens have one to three short, triangular wings on upper-

most part of thorax coincident with **D**, **Ll** and **Lr** (pl. 3, figs. 12-15); termination generally ragged; aperture constricted.

Internal cephalic elements consist of at least bars **A**, **M**, **D**, **V**, **Ll**, **Lr**, **ll**, **lr**, **Vbr**, **Vbl**, spines **Vs**, **Ax**, and arches **A-Vbl**, **A-Vbr**, **Vbl-Vbr**, **Ll-Vbl**, **Lr-Vbr**, **ll-Ll**, **lr-Lr**, **D-ll**, **D-lr** (text-fig. 8; pl. 3, figs. 17, 18); **M** angled steeply downwards towards posterior; **A** incorporated in cephalic wall, extends outside as apical horn; **V** extends upwards at an angle from posterior end of **M** to vertical pore, then branches into short, thick, laterally directed **Vbl** and **Vbr**; **Ll** and **Lr** extend laterally from posterior end of **M** to arches, become incorporated in thoracic wall, may extend outside as short lateral wings (see above); **D**, **ll** and **lr** incorporated in cephalic wall as pore bars, as are arches **D-ll** and **D-lr**, **D** may extend outside as dorsal wing (see above); **Vs** extends from junction of **V**, **Vbl** and **Vbr** freely into vertical pore and then outside; cluster of long, thick, conical **Ax** extends downwards from bars **M**, **V**, **Ll** and **Lr** to at least half way down inside of thorax, generally one from junction of **V** and **M**, two each from bars **M**, **Ll** and **Lr** near their junction with each other; arches **A-Vbl** and **A-Vbr** incorporated in cephalic wall, visible as low ridges on inside wall of cephalis, curve downwards from point where **A** exits as apical horn and join **Vbl** and **Vbr** at either side of vertical pore; arch **Vbl-Vbr** forms rim of lower half of vertical pore and with other arches forms ring at base of cephalis.

Dimensions: Range of 39 specimens (Holotype measurements given in parentheses): length of apical horn: 3-10µm (7µm); length of cephalis: 12-16µm (13µm); maximum width of cephalis excluding vertical tube: 16-23µm (17µm); length of

thorax: 93–140µm (110µm); maximum width of thorax excluding wings: 40–48µm (48µm); number of transverse pore rows on thorax: 9–18 (11); maximum number of pores on half equator of thorax: 6–9 (7).

Etymology: In honour of Yoshiaki Aita of Utsunomiya University for his contributions to both Mesozoic and Cenozoic radiolarian micropaleontology, and for his kindness and support during my stay in Japan.

Holotype and type locality: 280A-7-3, 40cm B, N49/1; DSDP Site 280, Hole 280A.

Occurrence: Late Eocene - Early Oligocene, upper RP14-RP15 (280A-10-5, 87cm - 280A-4-4, 40cm).

Abundance: 280A-10-5, 87cm, very rare; 280A-9-1, 85cm, very abundant; 280A-8-1, 70cm, abundant; 280A-7-7, 40cm, common; 280A-6-2, 60cm, common; 280A-4-4, 40cm, very rare.

Discussion: *Plannapus ? aitai* is only tentatively placed in *Plannapus* because it possesses a long, cylindroid, rather than inflated, thorax, and has transverse thoracic pore alignment, a vertical pore, rather than a tube, and a cluster of long, thick **Ax**. The internal skeletal structure is also slightly different from that originally described for the genus, with bars **A**, **D**, **II** and **Ir**, and arches **D-II** and **D-Lr** being incorporated in the cephalic wall, all except **A** as pore bars. Additionally, the possession of a cluster of **Ax** is not normal for the genus. Overall, it does not appear similar to other members so far ascribed to *Plannapus* (see List of genera section, below). However, it does have only two segments, and it resembles the other taxon tentatively included in *Plannapus*, *P. ? stathmepora*, from which it differs by having transverse pore alignment on the thorax, an upwardly-directed vertical pore, rather than a downwardly-directed vertical tube, and the same differences in internal skeletal structure mentioned above. Although their generic assignments are uncertain, both *P. ? aitai* and *P. ? stathmepora* belong to the Artostrobiidae due to their possession of a cluster of **Ax**, a feature which seems to be unique to some members of the family.

Plannapus ? aitai differs from morphologically similar forms as follows; from *Cyrtocalpis compacta* by having a poreless cephalis, an apical horn, a distinct vertical pore, a cluster of **Ax**, smaller and more regularly arranged thoracic pores, and by being cylindroid, rather than ovate; from the species listed as *Artostobus pusillum* in Petrushevskaya (1975 - *A. pusillum* was originally described as a three-segmented species) by having a vertical pore, smaller and more regularly arranged thoracic pores, a cluster of **Ax**, and a thicker-walled thorax.

Family PLAGONIIDAE Haeckel 1881, emend. Riedel 1967b

Genus *Lithomelissa* Ehrenberg, emend. O'Connor 1997a

Lithomelissa Ehrenberg 1847, p. 54. Type species: *L. microptera* Ehrenberg 1854, pl. 36, fig. 2, 1873, p. 241, 1875, pl.3, fig. 13, (by subsequent monotypy, *vide* Foreman and Riedel 1972).

Lithomelissa ? sakaii O'Connor n. sp.

Plate 2, figures 9a-15

Description: Shell of two segments, large with three prominent, fenestrated wings.

Cephalis truncate-spheroidal, large; apical horn long, sturdy, three-bladed, blades aligned with **D**, **LI** and **Lr** (and, consequently, with **A₁**, and the proximal parts of **A-LI** and **A-Lr**), blades smooth-edged, each blade fenestrated from base upwards to at least half length by a single longitudinal pore row, pores on blades circular to ovate and decreasing in size distally; surface rough due to spines at pore bar junctions and raised pore bars; pores small, circular to ovate, irregularly distributed; collar stricture externally defined as a contour change.

Thorax generally cylindroid but may bulge where wings emerge; surface smooth to irregular due to irregular nature of pore bars; pores circular to polygonal, generally irregular in size and distribution but some specimens have rough longitudinal pore alignment while others have an irregular, lattice-like structure; three long, sturdy, three-bladed wings extend outwards and downwards from uppermost part of thorax, external expression of **D**, **II** and **Lr**, blades smooth-edged, each blade fenestrated from base outwards to at least half length by a single longitudinal pore row, pores on blades circular to ovate and decreasing in size distally, wings often buttressed near base (pl. 2, fig. 9a); termination ragged.

Internal cephalic elements consist of at least bars **A**, **M**, **D**, **V**, **LI**, **Lr**, **A₁** spines **Vs**, **Ax**, and arches **A-LI**, **A-Lr**, **D-II**, **D-Lr**, **V-LI**, **V-Lr** (text-fig. 9; pl. 2, figs. 13-15); **M** short; **A** extends freely upwards from anterior end of **M** to top of cephalis, extends outside as apical horn (see above); **V** extends upwards at an angle from posterior end of **M** to arches, continues as short **Vs**; **D** extends downwards at an angle from anterior end of **M** to arches, then continues downwards to thoracic wall where it extends outside as dorsal wing (see above); **LI** and **Lr** extend laterally from posterior end of **M** to arches then continue obliquely downwards to thoracic wall where they extend outside as lateral wings (see above); **Ax** short, projects straight downwards from junction of **M** and **V**; **A₁** extends upwards at a slight angle from approximately 2/3 up length of **A** to cephalic wall; at point where **A₁** branches from **A** arches **A-LI** and **A-Lr** curve downwards freely at first then join to cephalic wall before finally joining with **LI** and **Lr**; rest of arches form ring at base of cephalis joined to cephalic wall by thin bars extending laterally from arches.

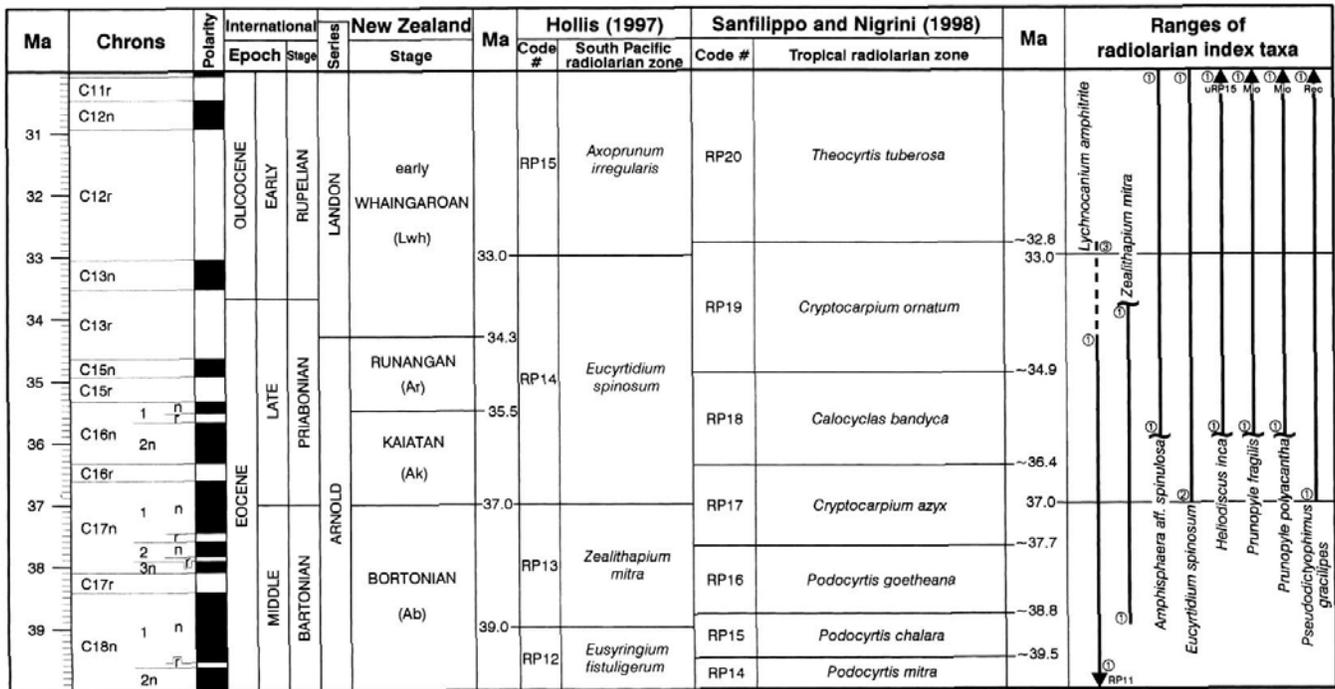
Dimensions: Range of 27 specimens (*Holotype* measurements given in parentheses): length of apical horn: 72–95µm (80µm); length of cephalis: 65–82µm (73µm); maximum width of cephalis: 79–110µm (109µm); length of thorax: 61–106µm (101µm); maximum width of thorax excluding wings: 92–119µm (108µm); length of wings: 107–172µm (137µm).

Etymology: In honour of Toyosaburo Sakai of Utsunomiya University for his contributions to geology, and radiolarian micropaleontology in particular, and for his kindness and support during my stay in Japan.

Holotype and type locality: 280A-5-1, 104cm B, L56/0; DSDP Site 280, Hole 280A.

Occurrence: Late Eocene - Early Oligocene, upper RP14-RP15 (280A-8-1, 70cm - 280A-3-4, 40cm).

Abundance: 280A-8-1, 70cm, very rare; 280A-7-3, 40cm, rare; 280A-6-2, 60cm, common; 280A-5-1, 104cm, common; 280A-4-4, 40cm, rare; 280A-3-4, 40cm, very rare.



TEXT-FIGURE 6

Chart showing age ranges of radiolarian index taxa from the Oamaru Diatomite. Numbers at either end of ranges signify source of age data: 1 = Hollis *et al.* (1997), 2 = Takemura and Ling (1997), 3 = Sanfilippo and Nigrini (1998), “~” = approximate limit, arrows signify that range continues off chart (ends of ranges shown - zones indicated are those of Hollis 1997). Age ranges correlate to the South Pacific radiolarian zonation of Hollis (1997). Magnetostratigraphic and international stage data from Berggren *et al.* (1995), New Zealand stage data from Morgans *et al.* (1996).

Discussion: Lithomelissa ? sakaii is only tentatively included in *Lithomelissa* because it does not possess bars II and Ir (see O’Connor 1997a). However, it does possess a large, spheroidal cephalis, and bar A is free inside the cephalis, both characteristic features of the genus. It differs from morphologically similar forms by possessing fenestrated apical horn and thoracic wings.

LISTS OF RECENTLY DESCRIBED GENERA AND SPECIES

Format, occurrence data, materials and methods

The following lists are in strict alphabetical order. Age ranges may be extended with future work. For each recently described genus and species the original reference is quoted, along with any synonymies providing additional references that the author accepts as illustrating and/or describing the genus or species. For information on taxa referred to but not detailed in this list see Appendix 3.

The format of age ranges cited for the recently described taxa is dependent upon their geographic distribution. For those taxa whose geographic distribution extends, or is thought to extend, outside the southwest Pacific area the known global range is given first, using the international epochs in Berggren *et al.* (1995). The known southwest Pacific age range is quoted for all of the recently described taxa, and is presented as both international epochs and radiolarian zonal code numbers. However, the radiolarian zonal scheme used is dependent on the distribution of the taxon. For taxa from the Northland area, i.e. Mahurangi Limestone and Puriri Formation, and/or the Miocene and younger of ODP Site 1123, the low-latitude zonation of Sanfilippo and Nigrini (1998) is used. Southwest Pacific

ranges established from the Oamaru Diatomite, Marlborough, DSDP Leg 29, DSDP Sites 277, 280, 283 and 592, and ODP Site 1123 are given using the South Pacific radiolarian zonation of Hollis (1977). If a taxon is distributed throughout both areas two separate southwest Pacific ranges are quoted, i.e. its low-latitude and South Pacific zone ranges. This separation is necessary due to the differing index taxa present in these localities. Appendix 1 correlates the two radiolarian zonal schemes to New Zealand stages and international epochs.

Illustrated specimens are referred to in the plate captions by a slide number as described above (see Description of new species section, above). Samples and slides containing the illustrated specimens are lodged with the following institutions: Karakanui Peninsula - Department of Geology, University of Auckland, New Zealand; DSDP Sites 280A and 283 - Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand; ODP Site 1123 - Department of Geology, Faculty of Agriculture, Utsunomiya University, Japan.

A “?” preceding a taxon indicates that the inclusion of that species in the synonymy is uncertain. A “?” following a generic or specific name indicates uncertain placement. A “?” preceding occurrence and/or age data indicates either uncertain inclusion (accompanied by uncertain inclusion in the synonymy), uncertain presence due to preservation making certain identification of the taxon impossible, uncertain presence due to unclear illustration in a data source, or uncertain age due to lack of (or unclear) age data in a data source. The following prefixes are added to some ages - “l” = lower, “m” = middle, “u” = upper. Sources for occurrence data are:

Occurrence: Northland (Mahurangi Limestone and Puriri Formation, Early Oligocene - Early Miocene); Oamaru (Late Eocene); Western Tropical Pacific (Recent); Central Pacific (Late Pliocene); East Coast of Australia (Recent); Antarctic (? Recent); Mediterranean (Recent); Indian Ocean (Recent); California (Late Cretaceous) - Marca Shale, Moreno Gulch, Moreno Formation; Leg 7 (Middle Miocene - Quaternary); Leg 14 (Miocene); Leg 22 (Early Oligocene); Leg 29 (Miocene - ? Middle Pleistocene); Leg 31 (Late Eocene - Middle Miocene); Leg 38 (Early - Middle Miocene); Leg 72 (Late Oligocene - Middle Miocene); Leg 114 (Late Eocene - Early Oligocene); Leg 120 (Early Oligocene); Site 277 (Late Eocene - Early Oligocene); Hole 280A (Late Eocene - Early Oligocene); Site 283 (late Middle - Late Eocene); Site 1123 (Late Eocene - Middle Miocene).

Comments: At present the only two-segmented artostrobid genus. Transverse pore alignment on one segment is not necessary for inclusion in this genus, as it is in all others within the Artostrobiidae.

Global Range: Late Cretaceous (Upper Maestrichtian) - Recent.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone, Puriri Formation: latest Eocene - Early Miocene, uRP19-RN2.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Leg 29, Sites 277, 283, 1123, Hole 280A: late Middle Eocene - ? Middle Pleistocene, RP13-?Middle Pleistocene.

Genus *Tricorporisphaera* O'Connor 1999, pl. 1, figs. 1a-2, pl. 5, figs. 1a-3

Type species: *Tricorporisphaera bibula* O'Connor 1999, pl. 1, figs. 1a-2, pl. 5, figs. 1a-3 (by monotypy).

Species included: *Tricorporisphaera bibula* O'Connor.

Occurrence: Oamaru (Late Eocene); ? Hole 280A (Late Eocene).

Southwest Pacific Range, South Pacific Zonation: Late Eocene, m-uRP14.

Genus *Valkyria* O'Connor 1997a, p. 72, text-fig. 7, pl. 2, figs. 15, 16, pl. 3, figs. 1, 2, pl. 7, figs. 11, 12, pl. 8, figs. 1, 2

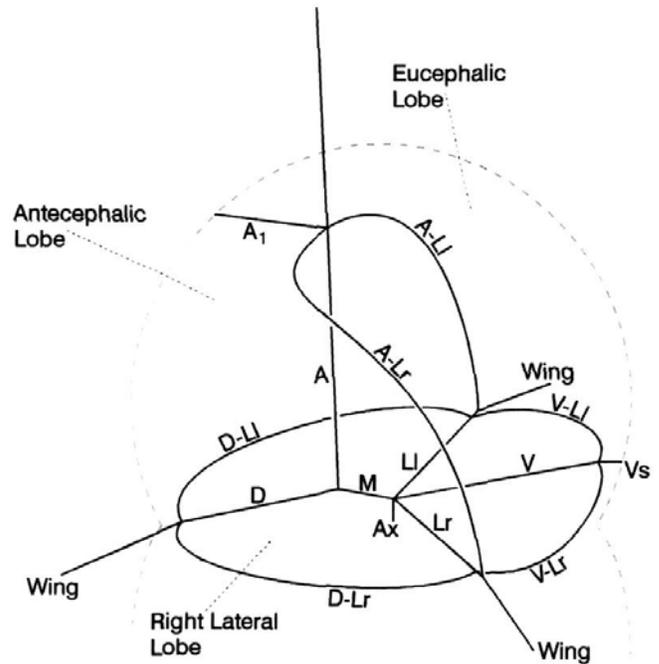
Type species: *Valkyria pukapuka* O'Connor 1997a, p. 72, text-fig. 7, pl. 2, figs. 15, 16, pl. 3, figs. 1, 2, pl. 7, figs. 11, 12, pl. 8, figs. 1, 2 (O.D.).

Species included: *Valkyria pukapuka* O'Connor, *Thyrsocyrtis ? annikae* Nishimura, *Pterocanium ? gigas* Nishimura, *P. ? procerum* Nishimura.

Occurrence: Northland (Mahurangi Limestone and Puriri Formation, Early Oligocene - Early Miocene); Site 384 (Late Paleocene); Site 1123 (Early Miocene).

Global Range: Late Paleocene - Early Miocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone, Puriri Formation, Site 1123: Early Oligocene - Early Miocene, IRP20-RN2.



TEXT-FIGURE 9
Schematic illustration of the internal skeleton of *Lithomelissa ? aitai* (oblique lateral view, not to scale).

Genus *Verutotholus* O'Connor 1999, text-fig. 6, pl. 2, figs. 12a-22b, pl. 6, figs. 1a-10b

Type species: *Verutotholus doigi* O'Connor 1999, text-fig. 6, pl. 2, figs. 12a-16, pl. 6, figs. 1a-4 (O.D.).

Species included: *Verutotholus doigi* O'Connor, *V. edwardsi* O'Connor, *V. mackayi* O'Connor, ? *Clathrocyclus ? dicerus* Foreman, ? *C. ? hyronia* Foreman.

Occurrence: Oamaru (Late Eocene); Northland (Mahurangi Limestone, Early - Late Oligocene); ? California (Late Cretaceous) - Marca Shale, Moreno Gulch, Moreno Formation, Cima Hill, 'Moreno Grande' Formation, Uhalde Formation; ? Leg 29 (no age data for illustrated specimen); Site 277 (Late Eocene - Early Oligocene); ? Hole 280A (Early Oligocene); Site 283 (late Middle - Late Eocene); Site 1123 (Late Eocene).

Global Range: ? Late Cretaceous - Late Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Early - Late Oligocene, uRP19-mRP21.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 1123, ? Hole 280A: late Middle Eocene - Early Oligocene, RP13-mRP15.

Genus *Zealithapium* O'Connor 1999, pl. 2, figs. 6-11, pl. 5, figs. 29a-32, pl. 9, fig. 47

Type species: *Zealithapium oamaru* O'Connor 1999, pl. 2, figs. 6-11, pl. 5, figs. 29a-32 (O.D.).

Species included: *Zealithapium oamaru* O'Connor, *Lithapium plegmacantha* Riedel and Sanfilippo, *L. anoectum* Riedel and Sanfilippo, *L. mitra* (Ehrenberg).

Occurrence: Oamaru (Late Eocene); Marlborough (Middle Eocene); Barbados (Eocene); Leg 4 (? Middle Eocene); Leg 10 (late Early - Late Eocene); Leg 14 (Late Eocene); Leg 16 (Middle - Late Eocene); Leg 48 (Middle - ? Late Eocene); Leg 119 (Middle Eocene); Leg 120 (Middle Eocene); Site 277 (Late Eocene); Site 592 (Late Eocene); Site 1123 (Late Eocene).

Comments: Erected to include the phylogenetic lineage of *Lithapium plegmacantha*, *L. anoectum* and *L. mitra*, and the obviously related *Zealithapium oamaru*.

Global Range: late Early - Late Eocene.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Marlborough, Sites 277, 592, 1123: Middle - Late Eocene, RP11-uRP14.

LIST OF SPECIES

Anthocyrtidium marieae O'Connor 1997b, p. 109, text-fig. 6, pl. 2, figs. 5-8, pl. 5, figs. 9-13

Anthocyrtidium sp. Riedel and Sanfilippo 1977, pl. 15, fig. 16; Sanfilippo and Riedel 1992, pl. 4, fig. 4.

Occurrence: Northland (Puriri Formation, Early Miocene); Site 289 (Late Oligocene/Early Miocene); Site 1123 (Early Miocene).

Comments: In the Late Oligocene part of the Mahurangi Limestone a form which differs slightly from *A. marieae*, primarily by having a series of short subterminal "teeth", is observed in O'Connor (1997b) as *A. aff. pliocenica*, but it lacks the terminal "teeth", having a smooth termination instead. It appears possible that this undescribed form is ancestral to *A. marieae*, which in turn may be ancestral to *A. aff. pliocenica*, which could ultimately have lead to *A. pliocenica*. Alternatively, *A. marieae* may be a short-lived offshoot of this possible lineage, as it is the only form without subterminal "teeth".

Global Range: Late Oligocene - Early Miocene.

Southwest Pacific Range, Low-Latitude Zonation: Puriri Formation, Site 1123: Early Miocene, IRN2.

Anthocyrtidium odontatum O'Connor 1994, p. 342, pl. 2, figs. 5-8, pl. 4, figs. 1-4

Anthocyrtidium n. sp. O'Connor 1993, p. 65, pl. 7, figs. 5-9, pl. 11, figs. 15-18.

Occurrence: Northland (Mahurangi Limestone, latest Eocene - latest Oligocene); ? Site 277 (Early Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - latest Oligocene, uRP19-RP22.

Southwest Pacific Range, South Pacific Zonation: ? Site 277: ? Early Oligocene, ?mRP15.

Artophormis fluminafauces O'Connor 1999, text-fig. 10, pl. 3, figs. 12-16b, pl. 6, figs. 24a-27

Occurrence: Oamaru (Late Eocene); ? Site 1123 (Early Oligocene).

Southwest Pacific Range, South Pacific Zonation: Late Eocene, mRP14-?IRP15.

Botryocella pauciperforata O'Connor 1999, text-fig. 4, pl. 1, figs. 21a-24, pl. 5, figs. 20a-24

Botryocella sp. O Petrushevskaya 1971b, figs. 82.V, VI. *Botryopyle dictyocephalus* Haeckel group, Riedel and Sanfilippo 1971, p. 1602, pl. 3F, figs. 9, 12 (*partim*); O'Connor 1993, p. 56, pl. 10, fig. 15. *Botryocella* aff. *cribrosa* group, Petrushevskaya and Kozlova 1972, pl. 39, fig. 4 (*partim*). *Botryocella* sp. Riedel and Sanfilippo 1977, pl. 15, fig. 9.

Occurrence: Oamaru (Late Eocene); Northland (Mahurangi Limestone, Early Oligocene); Leg 7 (Late Oligocene); Leg 14 (Early Oligocene); Site 277 (Late Eocene); ? Hole 280A (Early Oligocene); Site 283 (Late Eocene).

Global Range: Late Eocene - Late Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Early Oligocene, RP20/RP21 boundary.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, ? Hole 280A: Late Eocene - ? Early Oligocene, IRP14-?RP15.

Botryostrobos hollisi O'Connor 1997b, p. 105, text-fig. 3, pl. 1, figs. 9-12, pl. 5, figs. 1-4

Occurrence: Northland (Puriri Formation, Early Miocene); Site 1123 (Early Miocene).

Southwest Pacific Range, Low-Latitude Zonation: Early Miocene, IRN2.

Carpocanium rubyae O'Connor 1997b, p. 107, text-fig. 5, pl. 2, figs. 1-4, pl. 5, figs. 5-8

Carpocanistrum sp. C Ling 1975, p. 730, pl. 12, fig. 5.

Occurrence: Northland (Puriri Formation, Early Miocene); Leg 31 (Early - Late Miocene); Site 1123 (Early - Late Miocene).

Comments: In the Early Miocene (lower RN2) of Site 1123 this species is preceded by a very similar taxon differing only in the form of the peristome, which has a flat or slightly undulating termination, i.e. lacks the shovel-shaped feet (pl. 1, figs. 2a, b).

In the mid-Late Miocene (uppermost RN6) of Site 1123 this species appears to evolve into a taxon with more, longer, and narrower feet, and which is wider with respect to its length, has more and smaller pores, and lacks longitudinal ridges between longitudinal pore rows (pl. 1, figs. 3a, b).

Global Range: Early - Late Miocene.

Southwest Pacific Range, Low-Latitude Zonation: Puriri Formation, Site 1123: Early - Late Miocene, RN2-uRN6.

Carpocanopsis ballisticum O'Connor 1999, text-fig. 5 pl. 2, figs. 1-5, pl. 5, figs. 25a-28

? *Cryptoprora* cf. *ornata* Ehrenberg, Johnson 1974, pl. 2, figs. 18-20. *Cryptoprora ornata* Ehrenberg, Caulet 1986, p. 852.

Cryptocarpium ornatum (Ehrenberg), Hollis et al. 1997, p. 66, pl. 6, figs. 23-25 (*partim*).

Occurrence: ? Northland (Mahurangi Limestone, Early - Late Oligocene); Oamaru (Late Eocene); ? Leg 22 (? early Middle Eocene); Site 277 (Late Eocene); Site 283 (late Middle - Late Eocene); ? Site 592 (Late Eocene); ? Site 1123 (Late Eocene - Early Oligocene).

Global Range: ? early Middle Eocene - ? Late Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: ? Mahurangi Limestone: ? late Early - ? early Late Oligocene, ?uRP20-?mRP21.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, ? 592, ? 1123: late Middle Eocene - ? Early Oligocene, RP13-?IRP15.

Cyrtocapsa osculum O'Connor 1997a, p. 73, text-fig. 8, pl. 1, figs. 15-17, pl. 2, figs. 1, 2, pl. 8, figs. 3-10

Theocorys aff. *Theocorys* ? *spongoconus* Kling, Foreman 1973, p. 440, pl. 11, fig. 14. *Theocorys* ? sp. A O'Connor 1993, p. 79, pl. 9, figs. 16-20. *Theocorys* ? sp. Caulet 1986, pl. 6, fig. 3.

Occurrence: Northland (Mahurangi Limestone, Late Eocene - Late Oligocene); Leg 10 (Early Oligocene); ? Site 277 (Early Oligocene); Site 592 (Late Eocene); Site 1123 (Late Eocene - Early Oligocene).

Comments: Possibly ancestral to other Cenozoic *Cyrtocapsa* species. Early forms (Late Eocene) tend to have a slightly larger basal pore than originally described (pl. 1, figs. 4a-5b).

Global Range: Late Eocene - Late Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Late Oligocene, RP19-mRP21.

Southwest Pacific Range, South Pacific Zonation: ? Sites 277, 592, 1123: Late Eocene - Early Oligocene, mRP14-mRP15.

Dictyoprora gibsoni O'Connor 1994, p. 338, pl. 1, figs. 5, 6, 8, pl. 3, figs. 4-7

Dictyoprora n.sp. O'Connor 1993, p. 49, pl. 4, figs. 16-18, pl. 11, figs. 12-14. *Theocampe gibsoni* (O'Connor), O'Connor 1997a, pl. 11, fig. 1, 1997b, p. 118.

Occurrence: Northland (Mahurangi Limestone and Puriri Formation, Early Oligocene - Early Miocene); ? Site 277 (Late Eocene).

Comments: Possibly a descendant of either *D. pirum* (Ehrenberg) or *D. urceolus* (Haeckel), this taxon is the youngest known dictyoprurid. Hollis (1991) established *Theocampe* as the senior synonym of *Dictyoprora*, but apparently missed a spelling correction in the errata section of Haeckel's (1887) monograph, which meant that *Dictyoprora* retained its status as the senior synonym. The practice of using *Theocampe* for Mesozoic forms and *Dictyoprora* for Cenozoic forms does not appear to be valid.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone, Puriri Formation: Early Oligocene - Early Miocene, RP20-RN2.

South Pacific Range, South Pacific Zonation: ? Site 277: Late Eocene, 1-?mRP14.

Dorcadospyris mahurangi O'Connor 1994, p. 338, pl. 1, figs. 1-4, pl. 3, figs. 1-3

Dorcadospyris n.sp. O'Connor 1993, p. 44, pl. 3, figs. 14-16, pl. 11, figs. 8-11.

Occurrence: Northland (Mahurangi Limestone, Oligocene); Site 1123 (Early Miocene).

Comments: Appears to be a morphological offshoot of *Tristylospyris tricerus* (Ehrenberg).

Southwest Pacific Range, Low-Latitude Zonation: Oligocene - Early Miocene, RP20- IRN2.

Eucyrtidium ventriosum O'Connor 1999, text-fig. 11, pl. 3, figs. 17-21b, pl. 6, figs. 28a-31

Eucyrtidium sp. A. Ling 1975, p. 731, pl. 12, fig. 20. *Eucyrtidium* sp. B. group O'Connor 1993, p. 73, pl. 8, fig. 11 (*partim*). *Eucyrtidium montiparum* Ehrenberg, Hollis et al. 1997, p. 61, pl. 5, figs. 25-27 (*partim*).

Occurrence: Northland (Mahurangi Limestone, latest Eocene - Early Oligocene); Oamaru (Late Eocene); Leg 31 (Late Eocene); Site 277 (Late Eocene - Early Oligocene); ? Hole 280A (Early Oligocene); Site 283 (late Middle - Late Eocene); Site 1123 (Late Eocene - Early Oligocene).

Global Range: late Middle Eocene - Early Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Early Oligocene, RP19-RP20/21 boundary.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 1123, ? Hole 280A: late Middle Eocene - Early Oligocene, RP13-mRP15.

Eurystomoskevos cauleti O'Connor 1999, text-fig. 12, pl. 3, figs. 22-26, pl. 7, figs. 1a-3

? *Artostrobos* ? cf. *pretabulatus* Petrushevskaya, Takemura 1992, p. 745, pl. 5, fig. 12. *Eurystomoskevos "cauleti"* O'Connor, Hollis et al. 1997, p. 61, pl. 5, figs. 4, 5 (*nom. nud.*). *Eurystomoskevos cauleti* O'Connor, Crouch et al. unpublished manuscript, Table 4 (*nom. nud.*).

Occurrence: Oamaru (Late Eocene); ? Leg 120 (Late Eocene); Site 277 (Late Eocene); Hole 280A (Early Oligocene); Site 283 (late Middle Eocene).

Global Range: late Middle - Late Eocene.

Southwest Pacific Range, South Pacific Zonation: late Middle - Early Oligocene, RP13-RP15.

Heliodiscus tunicatus O'Connor 1997a, p. 65, pl. 1, figs. 1-5, pl. 5, figs. 1-5

Phacodiscidae gen. et sp. indet. O'Connor 1993, p. 39, pl. 2, figs. 8, 9. *Heliodiscus tunicatus* O'Connor, O'Connor 1996a, p. 397, pl. 1, figs. 8-10, pl. 2, figs. 23-37 (*nom. nud.*).

Occurrence: Northland (Mahurangi Limestone, latest Eocene - early Late Oligocene); Site 280A (Early Oligocene).

Comments: This species has also been found in early Late Oligocene samples of Mahurangi Limestone from Karakanui Peninsula, Northland (pers. obs.).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - early Late Oligocene, RP19-IRP21.

Southwest Pacific Range, South Pacific Zonation: Site 280A: Early Oligocene, RP15.

Lamprocyclus matakohe O'Connor 1994, p. 344, pl. 2, figs. 9, 10, 14, 15, pl. 4, figs. 6-11

Lamprocyclus n.sp O'Connor 1993, p. 67, pl. 7, figs. 10-14, pl. 12, figs. 1-4. **Lamprocyclus matakohe** O'Connor, Hollis et al. 1997, p. 66, pl. 7, figs. 1-7; Takemura and Ling 1997, p. 113, pl. 1, fig. 7.

Occurrence: Northland (Mahurangi Limestone, Oligocene); Leg 114 (Early - Late Oligocene); Site 277 (Early Oligocene); Site 1123 (Early Miocene).

Comments: Although this species was reported from Site 283 by Hollis in Crouch et al. (unpublished manuscript, Table 4), it was not identified in the Site 283 samples investigated by the author.

Global Range: Oligocene - Early Miocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone, Site 1123: Oligocene - Early Miocene, RP19/20 boundary-IRN2.

Southwest Pacific Range, South Pacific Zonation: Site 277: Early Oligocene, IRP15.

Lamprocyclus particollis O'Connor 1999, text-fig. 9, pl. 3, figs. 5-11, pl. 6, figs. 19a-23

? **Lamprocyclus** sp. Sanfilippo and Riedel 1992, pl. 1, fig. 10. **Lamprocyclus "particollis"** O'Connor, Hollis et al. 1997, p. 66, pl. 7, figs. 1-7 (*nom. nud.*). **Lamprocyclus "particollis"** (sic) O'Connor, Crouch et al. unpublished manuscript, Table 4 (*nom. nud.*).

Occurrence: Oamaru (Late Eocene); Leg 95 (Late Eocene); Site 277 (Late Eocene - Early Oligocene); Hole 280A (Early Oligocene); Site 283 (Late Eocene); Site 1123 (Late Eocene - Early Oligocene).

Comments: Many specimens from Hole 280A have smaller (and hence slightly more) pores on the thorax and abdomen (approx. 20 on half-equator cf. 13-18 in O'Connor, 1999) than originally described (pl. 1, figs. 6a, b). These may be higher-latitude morphotypes.

Global Range: Late Eocene - Early Oligocene.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 1123, Hole 280A: Late Eocene - Early Oligocene, IRP14-IRP15.

Lithomelissa gelasinus O'Connor 1997a, p. 69, text-fig. 4, pl. 2, figs. 3-6, pl. 6, figs. 6-9

Lithomelissa aff. **sphaerocephalis** Chen, O'Connor 1993, p. 60, pl. 6, fig. 1. **Lithomelissa** cf. **gelasinus** O'Connor 1999, pl. 9, fig. 22.

Occurrence: Northland (Mahurangi Limestone, latest Eocene - latest Oligocene); Oamaru (Late Eocene); Site 277 (Late Eocene - Early Oligocene); Hole 280A (Late Eocene - Early Oligocene); Site 283 (late Middle - Late Eocene); ? Site 1123 (Early Oligocene).

Comments: Early forms may have a pored, rather than spongy, thorax, and some also have a longer apical horn than originally described (pl. 1, figs. 7a, b; O'Connor 1999, pl. 9, fig. 22). Rare specimens in Hole 280A material have the aperture covered by a "sieve plate", i.e. a closed termination (pl. 1, figs. 8a, b).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - latest Oligocene, RP19-RP22.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, ? 1123, Hole 280A: late Middle Eocene - Early Oligocene, RP13-IRP15.

Lithomelissa lautouri O'Connor 1999, text-fig. 7, pl. 2, figs. 23-27, pl. 6, figs. 11a-15

? **Lamptonium sanfilippoae** Foreman, Ling 1975, p. 729, pl. 9, fig. 23 (*partim*). ? **Lithomelissa** sp. Caulet 1986, pl. 2, fig. 6.

Occurrence: Oamaru (Late Eocene); ? Leg 31 (Late Eocene); Site 283 (? late Middle - Late Eocene); ? Site 592 (Late Eocene); Site 1123 (Late Eocene).

Global Range: Late Eocene.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 283, 592, 1123: ? late Middle - latest Eocene, ?RP13-uRP14.

Lithomelissa maureenae O'Connor 1997a, p. 70, text-fig. 5, pl. 2, figs. 7-10, pl. 6, figs. 10, 11, pl. 7, figs. 1-6

Lithomelissa sp. A O'Connor 1993, p. 60, pl. 6, figs. 2, 3. **Lithomelissa** sp. B O'Connor 1993, p. 61, pl. 6, figs. 4, 5.

Occurrence: Northland (Mahurangi Limestone, Early Oligocene); Hole 280A (Early Oligocene).

Comments: This species was found to co-occur with *L. tricornis* in Hole 280A material. However, it differed from that species in the ways described in O'Connor (1994). *L. tricornis* was not seen to occur in Northland material.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Early Oligocene, IRP20-RP20/21 boundary.

Southwest Pacific Range, South Pacific Zonation: Hole 280A: Early Oligocene, uRP14-RP15.

Lophocyrtis (Lophocyrtis) haywardi O'Connor 1999, text-fig. 13, pl. 3, figs. 27-31, pl. 7, figs. 4a-7

Lophocyrtis (Cyclampterium) hadra Riedel and Sanfilippo, Sanfilippo 1990, p. 304, pl. 1, fig. 12 (*partim*); O'Connor 1993, p. 74, pl. 8, fig. 17; Hollis et al. 1997, p. 62, pl. 6, fig. 18. **Lophocyrtis (Lophocyrtis) cf. jacchia** (Ehrenberg), Strong et al. 1995, p. 208, fig. 11Q (*partim*). **Lophocyrtis hadra** Riedel and Sanfilippo, Crouch et al. unpublished manuscript, Table 4 (*nom. nud.*).

Occurrence: Oamaru (Late Eocene); Northland (Mahurangi Limestone, Late Eocene - Early Oligocene); Marlborough

(Middle Eocene); Leg 48 (late Middle Eocene); Site 277 (Late Eocene); Site 283 (Late Eocene); Site 1123 (latest Eocene).

Global Range: Middle Eocene - Early Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Early Oligocene, RP19.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Marlborough, Sites 277, 283, 1123: Middle - latest Eocene, uRP11-uRP14.

Lophocyrtis (Paralampterium ?) inaequalis O'Connor 1997a, p. 74, text-fig. 9, pl. 3, figs. 3-6, pl. 8, figs. 11, 12, pl. 9, figs. 1-5

Lophocyrtis (Paralampterium ?) galenum Sanfilippo, O'Connor 1993, p. 75, pl. 8, figs. 23-28; *Lophocyrtis (Cyclampterium) millowi* (sic.) Riedel and Sanfilippo, Hollis et al. 1997, p. 62, pl. 6, fig. 21.

Occurrence: Northland (Mahurangi Limestone, Late Eocene - Late Oligocene); Site 277 (Early - Late Oligocene).

Comments: Possible ancestor of *Lophocyrtis (Paralampterium ?) galenum* Sanfilippo.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Late Oligocene, RP19-RP21.

Southwest Pacific Range, South Pacific Zonation: Site 277: late Early - early Late Oligocene, uRP15

Lophophaena tekopua O'Connor 1997a, p. 71, text-fig. 6, pl. 2, figs. 11-14, pl. 7, figs. 7-10

Pseudodictyophimus sp. B O'Connor 1993, p. 62, pl. 6, figs. 14, 15.

Occurrence: Northland (Mahurangi Limestone and Puriri Formation, Late Eocene - Early Miocene); Hole 280A (Early Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone, Puriri Formation: latest Eocene - Early Miocene, RP19-RN2.

Southwest Pacific Range, South Pacific Zonation: Hole 280A: Early Oligocene, uRP15.

Lychnocanium alma O'Connor 1999, pl. 4, figs. 1-5, pl. 7, figs. 8a-11

Occurrence: Oamaru (Late Eocene); ? Site 277 (Late Eocene); Site 1123 (latest Eocene).

Southwest Pacific Range, South Pacific Zonation: Late Eocene, m-uRP14.

Lychnocanium neptunei O'Connor 1997a, p. 76, pl. 3, figs. 7-10, pl. 9, figs. 7-12

Lychnocanium aff. *grande* Campbell and Clark, Chen 1975, p. 462, pl. 1, figs. 6, 7. *Lychnocanoma* sp. O'Connor 1993, p. 77, pl. 9, figs. 1-3. *Lychnocanoma* aff. *grande* (Campbell and Clark), Strong et al. 1995, p. 209, fig. 11f-h. *Lychnocanium "neptunei"* O'Connor, Hollis et al. 1997, p. 64 (*nom. nud.*).

Occurrence: Northland (Mahurangi Limestone, Late Eocene - Oligocene); Marlborough (Middle Eocene); Leg 28 (Middle -

Late Eocene); Site 277 (? Middle Eocene - ? Late Eocene); ? Site 283 (Late Eocene).

Global Range: Middle Eocene - Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Oligocene, RP19-?RP22.

Southwest Pacific Range, South Pacific Zonation: Marlborough, Sites 277, 283: early Middle - Late Eocene, uRP10-?mRP14.

Lychnocanium waiareka O'Connor 1999, pl. 4, figs. 6-11, pl. 7, figs. 12a-15

Lychnocanium tripodium Ehrenberg, Hollis et al. 1997, p. 64, pl. 5, figs. 36, 37 (*partim*).

Occurrence: Oamaru (Late Eocene); Site 277 (Late Eocene); Site 283 (late Middle - Late Eocene); Site 1123 (Late Eocene).

Southwest Pacific Range, South Pacific Zonation: late Middle - Late Eocene, RP13-uRP14.

Lychnocanium waitaki O'Connor 1999, pl. 4, figs. 12-15, pl. 7, figs. 16a-19

Occurrence: Oamaru (Late Eocene); ? Site 277 (Late Eocene); Site 283 (late Middle Eocene); Site 1123 (Late Eocene).

Southwest Pacific Range, South Pacific Zonation: late Middle - Late Eocene, RP13-uRP14.

Phormocyrtis alexandrae O'Connor 1997b, p. 110, text-fig. 7, pl. 2, figs. 9-12, pl. 6, figs. 1-4, 6

Eucyrtidium sp. B Sakai 1980, p. 710, pl. 7, figs. 7a, b. *Eucyrtidium* sp. Sugiyama and Furutani 1992, p. 209, pl. 14, fig. 2.

Occurrence: Northland (Puriri Formation, Early Miocene); Oidawara Formation (Middle Miocene); Site 436 (Middle Miocene); Site 1123 (Early - Middle Miocene).

Comments: A possible descendant of the Oligocene form *Phormocyrtis* cf. *alexandrae*.

Global Range: Early - Middle Miocene.

Southwest Pacific Range, Low-Latitude Zonation: Puriri Formation, Site 1123: Early - Middle Miocene, IRN2-IRN5.

Phormocyrtis vasculum O'Connor 1994, p. 346, pl. 2, figs. 11-13, pl. 4, figs. 12-16

Podocyrtis (Podocyrtis) ? n.sp. O'Connor 1993, p. 69, pl. 7, figs. 16-20, pl. 12, figs. 5-9.

Occurrence: Northland (Mahurangi Limestone, Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: Oligocene, ?uRP20-?RP22.

Plannapus hornibrooki O'Connor 1999, text-fig. 2, pl. 1, figs. 7a-10, pl. 5, figs. 8a-11

Occurrence: Northland (Mahurangi Limestone, latest Eocene - Early Oligocene); Oamaru (Late Eocene); Site 277 (Late Eocene - ? Early Oligocene); Hole 280A (Early Oligocene); Site

283 (late Middle - Late Eocene); Site 1123 (Late Eocene - Early Oligocene).

Comments: Some forms have a slightly larger apical horn than originally described (pl. 1, figs. 10a-11b).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Early Oligocene, RP19.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 1123, Hole 280A: late Middle Eocene - Early Oligocene, RP13-RP15.

Plannapus mauricei O'Connor 1999, pl. 1, figs. 11-14, pl. 5, figs. 12a-15

Occurrence: Northland (Mahurangi Limestone, latest Eocene - Early Oligocene); Oamaru (Late Eocene); Site 277 (Late Eocene - Early Oligocene); Hole 280A (Early Oligocene); Site 283 (late Middle - Late Eocene); Site 1123 (Late Eocene - Early Oligocene).

Comments: Some late Middle - early Late Eocene specimens have a longer apical horn than originally described (pl. 1, figs. 12a-13b).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Early Oligocene, RP19.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 1123, Hole 280A: late Middle Eocene - Early Oligocene, RP13-RP15.

Plectodiscus runanganus O'Connor 1999, pl. 1, figs. 3a-6, pl. 5, figs. 4a-7

Occurrence: Oamaru (Late Eocene); Site 277 (Late Eocene); Site 283 (late Middle - Late Eocene); Site 1123 (Late Eocene).

Southwest Pacific Range, South Pacific Zonation: late Middle - Late Eocene, RP13-URP14.

Pterosyringium hamata O'Connor 1999, text-fig. 14, pl. 4, figs. 16-21b, pl. 7, figs. 20a-23

Theoperid, gen. et sp. indet. Johnson 1974, pl. 2, figs. 14-17, pl. 6, fig. 11. ? Theoperid, gen. et sp. indet. Johnson 1974, pl. 5, fig. 17. ? *Pterocyrtidium* sp. Ling 1975, p. 729, pl. 10, figs. 18, 19.

Occurrence: Northland (Mahurangi Limestone, Late Eocene - Oligocene); Oamaru (Late Eocene); Leg 22 (early Middle Eocene); ? Leg 22 (Late Eocene); ? Leg 31 (Late Eocene); Site 277 (Late Eocene - Early Oligocene); Site 283 (? late Middle Eocene); Site 1123 (latest Eocene - early Oligocene).

Global Range: early Middle Eocene - Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: latest Eocene - Oligocene, RP19-?RP22.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 1123: ? late Middle Eocene - Early Oligocene, ?RP13-IRP15.

Rhopalastrum tritelum O'Connor 1997a, p. 66, pl. 1, figs. 6-9, pl. 5, figs. 6-9

Rhopalastrum aff. *profunda* (Ehrenberg), O'Connor 1993, p. 41, pl. 2, figs. 22, 23. *Rhopalastrum tritelum* O'Connor, O'Connor 1996a, p. 397, pl. 1, figs. 6, 7 (*nom. nud.*).

Occurrence: Northland (Mahurangi Limestone, Early Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: Early Oligocene, RP20/21 boundary.

Sethochytris cavipodis O'Connor 1999, text-fig. 15, pl. 4, figs. 22-27, pl. 7, figs. 24a-27

? Gen. et sp. indet., Riedel and Sanfilippo 1970, pl. 8, fig. 10. ? *Lithochytris* (*Lithochytrodes*) *turgidulum* (sic) (Ehrenberg), Petrushevskaya and Kozlova 1972, p. 552, pl. 27, figs. 8, 9.

Occurrence: Oamaru (Late Eocene); ? Leg 4 (Middle Eocene); ? Leg 14 (late Middle Eocene); Site 277 (latest Eocene - Early Oligocene); Site 283 (? late Middle - Late Eocene); Site 1123 (Late Eocene - ? Early Oligocene).

Global Range: ? Middle Eocene - Early Oligocene.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 1123: ? late Middle Eocene - Early Oligocene, ?RP13-?IRP15.

Siphocampe grantmackiei O'Connor 1997b, p. 106, text-fig. 4, pl. 1, figs. 5-8, pl. 4, figs. 7-12

? *Lithomitra lineata* (Ehrenberg) group, Riedel and Sanfilippo 1971, p. 1600, pl. 11, figs. 4, 9, pl. 21, fig. 14 (*partim*). ? *Lithomitra imbricata* (Ehrenberg) group, Petrushevskaya and Kozlova 1972, p. 539, pl. 24, figs. 2-4 (*partim*). *Siphocampe grantmackiei* O'Connor, O'Connor 1996a, p. 398, pl. 2, figs. 7, 8 (*nom. nud.*).

Occurrence: Northland (Puriri Formation, Early Miocene); ? Leg 7 (late Early Miocene - Early Pliocene); ? Leg 14 (Early Oligocene - late Early Miocene).

Global Range: ? Early Oligocene - ? Pliocene.

Southwest Pacific Range, Low-Latitude Zonation: Puriri Formation: Early Miocene, RN2.

Siphocampe missilis O'Connor 1994, p. 340, pl. 1, figs. 7, 9-12, pl. 3, figs. 8-12

Siphocampe n.sp. O'Connor 1993, p. 52, pl. 4, figs. 25-28, pl. 12, figs. 10-14. *Siphocampe acephala* (Ehrenberg) group, Hollis et al. 1997, p. 54, pl. 4, fig. 14 (*partim*).

Occurrence: Northland (Mahurangi Limestone, ? latest Eocene - Oligocene); Site 277 (? late Middle Eocene - Early Oligocene); ? Hole 280A (Late Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: ? latest Eocene - Oligocene, ?RP19-?RP22.

Southwest Pacific Range, South Pacific Zonation: Site 277, ? Hole 280A: ? late Middle Eocene - Early Oligocene, ?RP13-RP15.

Spirocyrtis greeni O'Connor 1999, text-fig. 3, pl. 1, figs. 15-20b, pl. 5, figs. 16a-19

? *Eucyrtidium acuminatum* (Ehrenberg), Bury 1862, pl. 1, fig. 1. *Spirocyrtis* ? sp. O'Connor 1993, p. 56, pl. 5, fig. 7, pl. 10, fig. 13

Occurrence: Northland (Mahurangi Limestone, Oligocene); Oamaru (Late Eocene); ? Barbados (Eocene, no specific age data available); Site 277 (? late Middle Eocene - Early Oligocene); Hole 280A (Early Oligocene); Site 283 (Late Eocene).

Comments: Earliest recorded *Spirocyrtis* taxon. Possibly the basal stock of the genus.

Global Range: Eocene - Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Oligocene, RP20/21 boundary-?RP22.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, Hole 280A: ? late Middle Eocene - Early Oligocene, ?RP13-RP15.

Spirocyrtis proboscis O'Connor 1994, p. 341, pl. 2, figs. 1-4, pl. 3, figs. 13-16

Spirocyrtis n.sp. O'Connor 1993, p. 54, pl. 5, figs. 2-6, pl. 12, figs. 15-17.

Occurrence: Northland (Mahurangi Limestone, Early Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: Early Oligocene, uRP20-RP20/RP21 boundary.

Spongotrochus antoniae O'Connor 1997b, p. 103, text-fig. 2, pl. 1, figs. 1-4, pl. 4, figs. 1-6

Spongotrochus antoniae O'Connor, O'Connor 1996a, p. 397, pl. 1, figs. 22-24 (*nom. nud.*).

Occurrence: Northland (Puriri Formation, Early Miocene).

Southwest Pacific Range, Low-Latitude Zonation: Early Miocene, RN2.

Stichocorys negripontensis O'Connor 1997a, p. 78, pl. 3, figs. 11-14, pl. 9, figs. 13-16, pl. 11, fig. 4

Stichocorys cf. *delmontensis* (Campbell and Clark), O'Connor 1993, p. 78, pl. 11, fig. 7.

Occurrence: Northland (Mahurangi Limestone, Oligocene).

Comments: Earliest recorded member of *Stichocorys*. Possibly the first member of the *Stichocorys* lineage.

Southwest Pacific Range, Low-Latitude Zonation: Oligocene, uRP20-RP22.

Theocorys bianulus O'Connor 1997a, p. 82, pl. 4, figs. 1-4, pl. 10, figs. 1-4, pl. 11, fig. 5

Eucyrtidium aff. *Eucyrtidium "rocket"* Petrushevskaya, O'Connor 1993, p. 73, pl. 8, figs. 4, 5.

Occurrence: Northland (Mahurangi Limestone, latest Eocene - Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: latest Eocene - Oligocene, RP19-?RP22.

Theocorys perforalvus O'Connor 1997a, p. 84, text-fig. 10, pl. 4, figs. 9-12, pl. 10, figs. 9-14, pl. 11, fig. 6

Theocorys aff. *spongoconus* Kling, O'Connor 1993, p. 79, pl. 9, figs. 11, 12.

Occurrence: Northland (Mahurangi Limestone, Early - Late Oligocene); Site 283 (late Middle - Late Eocene).

Comments: Early forms appear to have larger abdominal pores than originally described (pl. 1, figs. 14a-15b), and rare specimens also have a larger apical horn (pl. 1, figs. 14a, b).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Early - Late Oligocene, uRP20-uRP21.

Southwest Pacific Range, South Pacific Zonation: Site 283: late Middle - Late Eocene, RP13-RP14.

Theocorys puriri O'Connor 1997a, p. 86, pl. 4, figs. 5-8, pl. 10, figs. 5-8, pl. 11, fig. 7

Theocorys aff. *redondoensis* (Campbell and Clark), O'Connor 1993, p. 79, pl. 9, figs. 13-15. *Theocorys spongoconus* Kling, Sanfilippo and Nigrini 1995, p. 282, pl. 1, fig. 15 (*partim*).

Occurrence: Northland (Mahurangi Limestone and Puriri Formation, Early Oligocene - Early Miocene); Hole 574c (Late Oligocene).

Global Range: Early Oligocene - Early Miocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone, Puriri Formation: Early Oligocene - Early Miocene, RP20-RN2.

Thyrsocyrtis (Thyrsocyrtis ?) pinguisoides O'Connor 1999, text-fig. 16 pl. 4, figs. 28-32, pl. 7, figs. 28a-31

? *Thyrsocyrtis* sp. Dinkelman 1973, p. 788, pl. 3, figs. 7, 8. ? *Thyrsocyrtis bromia* Ehrenberg, Caulet 1986, p. 854. *Theocotyle "pinguisoides"* O'Connor, Hollis et al. 1997, p. 65, pl. 6, figs. 10-12 (*nom. nud.*). *Theocotyle pinguisoides* O'Connor, Crouch et al. unpublished manuscript, Table 4 (*nom. nud.*).

Occurrence: Oamaru (Late Eocene); ? Leg 16 (Late Eocene); Site 277 (Late Eocene); Site 283 (Late Eocene); ? Site 592 (Late Eocene); Site 1123 (latest Eocene).

Comments: The short stratigraphic range of this species may make it a useful age index taxon in future studies of the south Pacific area. At Site 1123 *T. (T. ?) pinguisoides* is immediately preceded by a similar form that differs by having a smaller thorax in proportion to the abdomen, and a wider peristome that often has three short, broad feet (pl. 1, figs. 16a-17b). This form differs from *T. (T.) bromia* primarily by having more thoracic and abdominal pores, smaller abdominal pores, and a longer and stouter apical horn.

Global Range: Late Eocene.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 592, 1123: Late Eocene, 1-uRP14.

Tricorporisphaera bibula O'Connor 1999, pl. 1, figs. 1a-2, pl. 5, figs. 1a-3

Occurrence: Oamaru (Late Eocene); ? Hole 280A (Early Oligocene).

Southwest Pacific Range, South Pacific Zonation: Late Eocene - ? Early Oligocene, mRP14-?uRP15.

Valkyria pukapuka O'Connor 1997a, p. 72, text-fig. 7, pl. 2, figs. 15, 16, pl. 3, figs. 1, 2, pl. 7, figs. 11, 12, pl. 8, figs. 1, 2

Occurrence: Northland (Mahurangi Limestone and Puriri Formation, Early Oligocene - Early Miocene); Site 1123 (Early Miocene).

Southwest Pacific Range, Low-Latitude Zonation: Early Oligocene - Early Miocene, RP20-IRN2.

Velicucullus fragilis O'Connor 1999, text-fig. 8, pl. 3, figs. 1a-4b, pl. 6, figs. 16a-18

Occurrence: Oamaru (Late Eocene); Site 277 (Late Eocene); Site 283 (Late Eocene).

Southwest Pacific Range, South Pacific Zonation: Late Eocene, l-mRP14.

Verutotholus doigi O'Connor 1999, text-fig. 6, pl. 2, figs. 12a-16, pl. 6, figs. 1a-4

? *Clathrocyclas universa* ? Clark and Campbell, Petrushevskaya 1975, pl. 42, fig. 5. ? *Clathrocyclas* sp. Caulet 1986, pl. 6, fig. 1. *Clathrocyclas universa* Clark and Campbell, Hollis et al. 1997, p. 59, pl. 5, figs. 17-20; Crouch et al. unpublished manuscript, Table 4.

Occurrence: Northland (Mahurangi Limestone, Early - Late Oligocene); Oamaru (Late Eocene); ? Leg 29 (no age data for illustrated specimen); Site 277 (Late Eocene - Early Oligocene); Site 283 (late Middle - Late Eocene); ? Site 592 (Late Eocene); Site 1123 (Late Eocene).

Comments: In O'Connor (1999), *Pterocodon* ? *ampla* was tentatively synonymized with *V. doigi* on the basis of the presence of a vertical pore at the collar stricture. That synonymy is not applied here, although it appears likely that *P. ? ampla* sensu Foreman (1973) belongs in *Verutotholus* because of its overall morphology and possession of a vertical pore/tube. The specimen illustrated and described as *Verutotholus* cf. *doigi* in O'Connor (1996b, 1999) appears similar to *P. ? ampla* sensu Foreman.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Early - Late Oligocene, RP19-RP21.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Sites 277, 283, 592, 1123: late Middle Eocene - Early Oligocene, RP13-?IRP15.

Verutotholus edwardsi O'Connor 1999, pl. 2, figs. 17a-20, pl. 6, figs. 5a-8

? *Anthocyrta* sp. Ling 1975, p. 728, pl.8, fig. 19

Occurrence: Northland (Mahurangi Limestone, Late Oligocene); Oamaru (Late Eocene); ? Leg 31 (Late Eocene); Site 1123 (latest Eocene).

Global Range: Late Eocene - Late Oligocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Late Oligocene, RP21.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Site 1123: Late Eocene, m-uRP14.

Verutotholus mackayi O'Connor 1999, pl. 2, figs. 21a-22b, pl. 6, figs. 91-10b

Occurrence: Northland (Mahurangi Limestone, Early Oligocene); Oamaru (Late Eocene); ? Hole 280A (Early Oligocene).

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone: Early Oligocene, RP20/21 boundary.

Southwest Pacific Range, South Pacific Zonation: Oamaru, Hole ? 280A: Late Eocene - ? Early Oligocene, mRP14-?RP15.

Zealithapium oamaru O'Connor 1999, pl. 2, figs. 6-11, pl. 5, figs. 29a-32

Occurrence: Oamaru (Late Eocene); Site 1123 (latest Eocene).

Southwest Pacific Range, South Pacific Zonation: Late Eocene, m-uRP14.

Combination

Plannapus microcephalus (Haeckel), O'Connor 1997a, p. 70, pl. 1, figs. 10-14, pl. 5, figs. 10-12, pl. 6, figs. 1-5

Dicolocapsa microcephala Haeckel 1887, p. 1312, pl. 57, fig. 1; Sanfilippo and Riedel 1970, pl. 1, fig. 7; Petrushevskaya and Kozlova 1972, p. 541, pl. 22, fig. 32; Ling 1975, pl. 13, fig. 9; Riedel and Sanfilippo 1977, pl. 15, fig. 18; Johnson 1983, pl. 1, fig. 10. *Dicolocapsa* aff. *microcephala* Haeckel, O'Connor 1993, p. 71, pl. 7, figs. 26, 27. *Dictyocephalus microcephalus* (Haeckel), Nishimura 1990, p. 163, fig. 35-5.

Occurrence: Northland (Mahurangi Limestone and Puriri Formation, latest Eocene - Early Miocene); Leg 14 (Early Miocene); Leg 31 (Late Eocene - Middle Miocene); Leg 72 (Late Oligocene - Middle Miocene); Kinugasa Formation (Early Miocene); Site 1123 (Middle Miocene).

Global Range: Late Eocene - Middle Miocene.

Southwest Pacific Range, Low-Latitude Zonation: Mahurangi Limestone, Puriri Formation, Site 1123: latest Eocene - Middle Miocene, RP19-uRN5.

ACKNOWLEDGMENTS

I gratefully acknowledge the support, logistical and otherwise, of Yoshiaki Aita and Toyosaburo Sakai at Utsunomiya University during the course of this project. A huge thanks to Chris Hollis for providing slides and samples, for constant reviews and advice, for support throughout the course of my radiolarian work, but most of all for prodding me in the right direction when I have strayed slightly, and for pointing out the obvious when I was blind to the evidence. I am indebted to Jack Grant-Mackie for constant help and advice throughout the duration of the work that formed the basis of this project. A big thanks to Annika Sanfilippo for reviewing the early draft, for providing me with very useful unpublished data, and for taking the time to re-examine DSDP slides to help try to sort out the *serrata* /

delmontensis problem. Thanks to Stanley Kling for reviewing the final draft. Thanks also to Bruce Hayward for digging out his old foram data for me to use. And a big thanks to ODP for supplying the Site 1123 samples from ODP Leg 181. I am appreciative for all of the help I have received, acknowledged or otherwise. The work included in this paper has received support from various grants over the years, all gratefully received and acknowledged with thanks: R.N. Brothers Memorial Award, University of Auckland Doctoral Scholarship, McKee Trust Postgraduate Scholarship, and Japan Society for the Promotion of Science Postdoctoral Fellowship.

REFERENCES

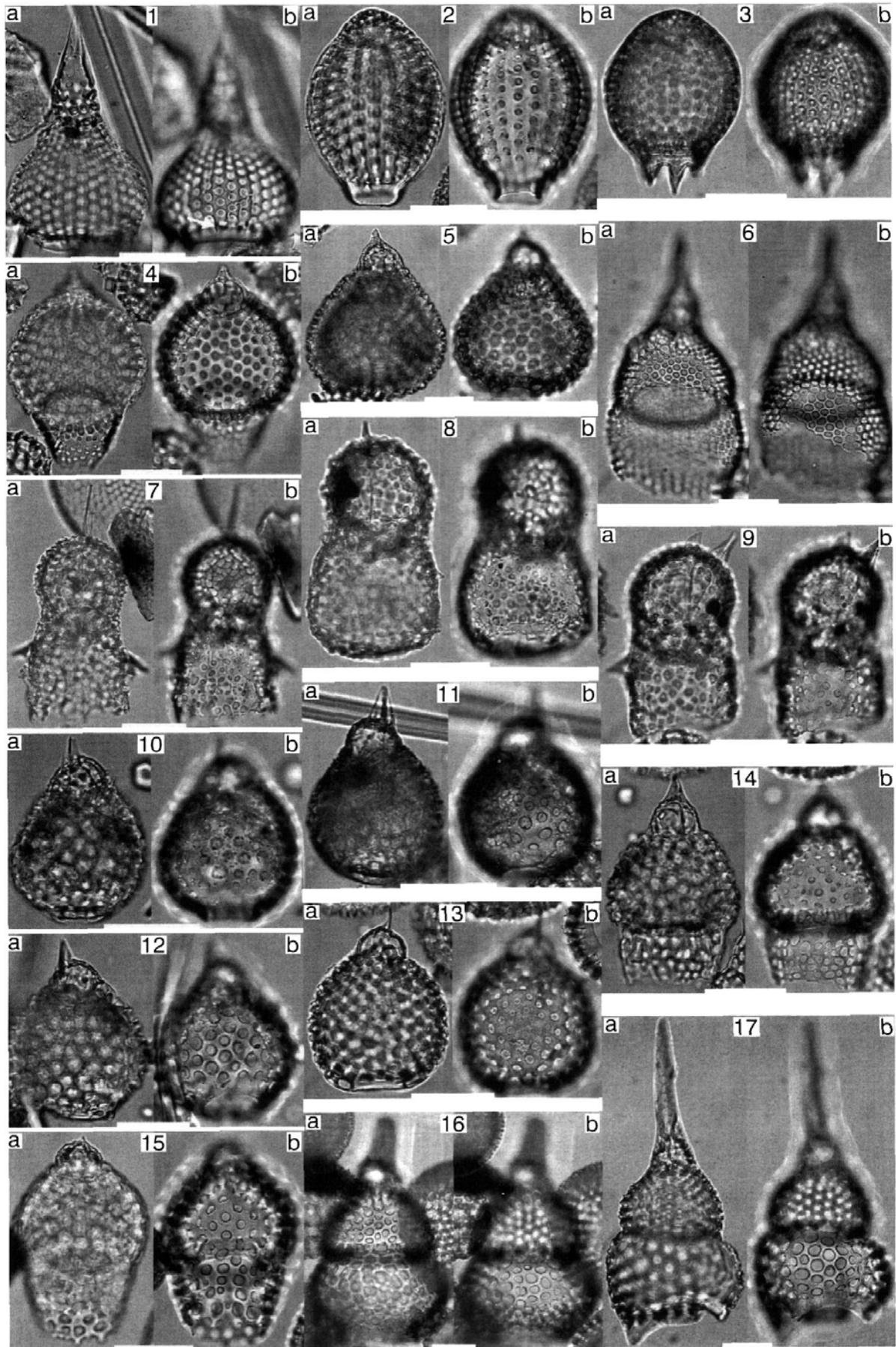
- BAILEY, J. W., 1856. Notice of microscopic forms found in the soundings of the Sea of Kamtschatka - with a plate. *The American Journal of Science and Arts* (2nd Series), 22:1-6, pl. 1.
- BALLANCE, P. F. and SPÖRLI, K. B., 1979. Northland Allochthon. *Journal of the Royal Society of New Zealand*, 9:259-275.
- BERGGREN, W. A., KENT, D. V., SWISHER, C. C. III. and AUBRY, M-P. 1995. A revised Cenozoic geochronology and chronostratigraphy. In: Berggren, W.A., Kent, D.V., Aubry, M-P., and Hardenbol, J., Eds., *Geochronology Time Scales and Global Stratigraphic Correlation*. SEPM Special Publication, 54:129-212.
- BJØRKLUND, K. R., 1976. Radiolaria from the Norwegian Sea, Leg 38 of the Deep Sea Drilling Project. In: Talwini, M. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 38:1101-1168. Washington, DC: US Government Printing Office.
- BLUEFORD, J. R., 1988. Radiolarian biostratigraphy of siliceous Eocene deposits in central California. *Micropaleontology*, 34:236-258.
- BOLLI, H. M., SAUNDERS, J. B. and PERCH-NIELSEN, K., 1985. Comparison of zonal schemes for different microfossil groups. In: Bolli, H. M., Saunders, J. B. and Perch-Nielsen, K., Eds., *Plankton stratigraphy*. Cambridge University Press. pp.3-10.
- BURY, Mrs., 1862. Figures of remarkable forms of polycystins, or allied organisms, in the Barbados chalk deposit. 4pp., 26pls. London.
- CAMPBELL, A. S., 1954. Radiolaria. In: Moore, R. C., Ed., *Treatise on Invertebrate Paleontology*. Part D, Protista 3. Protozoa (chiefly Radiolaria and Tintinnia). Geological Society of America and University of Kansas Press. pp.11-163.
- CAMPBELL, A. S. and CLARK, B. L., 1944. Miocene radiolarian faunas from southern California. *Special Paper of the Geological Society of America*, 51:1-76.
- CARTER, R. M., MCCAIVE, I. N., RICHTER, C., CARTER, L., et al., 1999. *Proceedings of the Ocean Drilling Program, Initial Reports*, Volume 181 [CD-ROM]. College Station, Texas.
- CAULET, J.-P., 1986. Radiolarians from the Southwest Pacific. In: Kennett, J.P. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 90:835-861. Washington, DC: US Government Printing Office.
- , 1991. Radiolarians from the Kerguelen Plateau, Leg 119. In: Barron, J. et al. *Proceedings of the Ocean Drilling Program, Scientific Results*, Volume 119:513-546. College Station, Texas.
- CHEN, Pei-Hsin, 1975. Antarctic Radiolaria. In: Hayes, D.E. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 28:437-513. Washington, DC: US Government Printing Office.
- CLARK, B. L. and CAMPBELL, A. S., 1942. Eocene radiolarian faunas from the Mt. Diablo area, California. *Special Paper of the Geological Society of America*, 39:1-112.
- CROUCH, E. M. and HOLLIS, C. J., 1996. Paleocene palynomorph and radiolarian biostratigraphy of DSDP Leg 29, sites 280 and 281, South Tasman Rise. *Institute of Geological and Nuclear Sciences, Science Report 96/19*. Lower Hutt. 46pp.
- CROUCH, E. M., HOLLIS, C. J., RAINE, J. I., STRONG, C. P., WAGHORN, D. B. and WILSON, G. J., unpublished manuscript. Integrated biostratigraphy of DSDP Site 283 (Leg 29), central Tasman Sea: palynomorphs, radiolarians, foraminifera, calcareous nannofossils.
- DINKELMAN, M.G., 1973. Radiolarian stratigraphy: Leg 16, Deep Sea Drilling Project. In: van Andel, T.H. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 16:747-813. Washington, DC: US Government Printing Office.
- DUMITRICA, P., 1973. Paleocene Radiolaria, DSDP Leg 21. In: Burns, R.E. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 21:787-817. Washington, DC: US Government Printing Office.
- EDWARDS, A. R., 1971. A calcareous nannoplankton zonation of the New Zealand Paleogene. In: Farinacci, A. (ed). *Proceedings of the II Planktonic Conference, Roma 1970*. Edizioni Tecnoscienza, Roma. pp.381-419.
- , 1991. The Oamaru Diatomite. *New Zealand Geological Survey Paleontological Bulletin*, 64. 260pp.
- EHRENBERG, C. G., 1847. Über die mikroskopischen kieselschaligen Polycystinen als mächtige Gebirgsmasse von Barbados und über das Verhältniss der aus mehr als 300 neuen Arten bestehenden ganz eigenthümlichen Formengruppe jener Felsmasse zu den jetzt lebenden Thieren und zur Kreidebildung. Eine neue Anregung zur Erforschung des Erdlebens. *Königlich Preussische Akademie der Wissenschaften zu Berlin, Bericht, Jahre 1847*, pp.40-60, table opposite p.54, 1 pl.
- , 1854. *Mikrogeologie. Das Erden und Felsen schaffende Wirken des unsichtbar kleinen selbständigen Lebens auf der Erde*. Voss, Leipzig. 374pp., Atlas 31pp., 41pls. Fortsetzung (1856) 88pp.
- , 1872a. *Mikrogeologische Studien als Zusammenfassung seiner Beobachtungen des kleinsten Lebens der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss*. Königlich Preussische Akademie der Wissenschaften zu Berlin, Monatsbericht, Jahre 1872, pp.265-322.
- , 1872b. *Mikrogeologischen Studien über das kleinste Leben der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss*. Königlich Preussische Akademie der Wissenschaften zu Berlin, Abhandlungen, Jahre 1872, pp.131-399, pls.1-12.
- , 1873. *Grössere Felsproben des Polycystinen-Mergels von Barbados mit weiteren Erläuterungen*. Königlich Preussische Akademie der Wissenschaften zu Berlin, Monatsbericht, Jahre 1873, pp.213-263.
- , 1875. *Fortsetzung der mikrogeologischen Studien als Gesamt-Übersicht der mikroskopischen Paläontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rücksicht auf den Polycystinen-Mergel von Barbados*. Königlich Preussische Akademie der Wissenschaften zu Berlin, Abhandlungen, Jahre 1875, pp.1-226, pls.1-30.
- FOREMAN, H. P., 1968. Upper Maestrichtian Radiolaria of California. *Special Papers in Palaeontology*, 3. The Palaeontological Association, London. 82 pp., 8 pls.

- , 1973. Radiolaria of Leg 10 with systematics and ranges for the families Amphipyndacidae, Artostrobiidae and Theoperidae. In: Worzel, J.L. et al. Initial Reports of the Deep Sea Drilling Project, Volume 10:407-474. Washington, DC: US Government Printing Office.
- FOREMAN, H. P. and RIEDEL, W. R., 1972. Catalogue of Polycystine Radiolaria, Series 1 (1834-1900), Volume 1 (Meyen, 1834 - Bury, 1862). Special Publication of the American Museum of Natural History, New York.
- FRIZZELL, D. L. and MIDDOUR, E. S., 1951. Paleocene Radiolaria from Southeastern Missouri. University of Missouri School of Mines and Metallurgy Bulletin, Technical Series, No.77.
- HAECKEL, E., 1862. Die Radiolarien (Rhizopoda Radiaria): Eine Monographie. Reimer, Berlin. xiv + 572pp., Atlas iv, 35 pls.
- , 1881. Entwurf eines Radiolarien-Systems auf Grund von Studien der Challenger-Radiolarien. Jenaische Zeitschrift für Naturwissenschaft, 15, new series, vol.8, pt.3:418-472.
- , 1887. Report on the Radiolaria collected by *H.M.S. Challenger* during the years 1873-76. Report on the scientific results of the voyage of the *H.M.S. Challenger*, Zoology 18. Two parts, clxxxviii + 1803pp., 140 pls., 1 map.
- HAQ, B. U., HARDENBOL, J., VAIL, P. R., WRIGHT, R. C., STOVER, L. E., BAUM, G., LOUITT, T., GOMBOS, A., DAVIES, T., PFLUM, C., ROMINE, K., POSAMENTIER, R., JAN DU CHENE, R., COLIN, J. P., IOANNIDES, N., SARG, J. F. and MORGAN, B. E., 1987. Mesozoic-Cenozoic Cycle Chart, Version 3.1A. In: Hastings, B.J. et al., 1988. Sea level changes: an integrated approach. Society of Economic Paleontologists and Mineralogists Special Publication, 42. 407pp.
- HAYS, J.D., 1965. Radiolaria and Late Tertiary and Quaternary history of Antarctic seas. Biology of the Antarctic Seas, II. American Geophysical Union Antarctic Research Series, 5:125-184.
- , 1970. Stratigraphy and evolutionary trends of Radiolaria in North Pacific deep-sea sediments. Geological Society of America Memoir, 126:185-218.
- HAYWARD, B. W., 1993. The Tempestuous 10 Million Year Life of a Double Arc and Intra-Arc Basin - New Zealand's Northland Basin in the Early Miocene. In: Ballance, P.F. (ed). South Pacific Sedimentary

PLATE 1

All illustrations are transmitted light photomicrographs. Specimen 1 is from Karakanui Point, Northland; specimens 2-5, 16, and 17 are from ODP Leg 181, Site 1123; specimens 6-9 are from DSDP Leg 29, Site 280; specimens 10-15 are from DSDP Leg 29, Site 283. All scale bars are 50µm.

- | | | | |
|------|--|-------|---|
| 1a,b | <i>Anthocyrtidium</i> aff. <i>marieae</i> O'Connor, Late Oligocene, Karak 23 B, L32/4. White arrow indicates subterminal tooth. | 9a,b | <i>Lithomelissa gelasinus</i> O'Connor, specimen with two apical horns and pored thorax, Early Oligocene, 280A-5-1, 104cm B, H33/2. |
| 2a,b | <i>Carpocanium</i> sp., form immediately preceding <i>Carpocanium rubyae</i> O'Connor, Early Miocene, 1123C-26x, CC A, E21/0. | 10a,b | <i>Plannapus hornibrooki</i> O'Connor, specimen with large apical horn, Late Eocene, 283-5-2, 25cm B, H31/0. |
| 3a,b | <i>Carpocanium</i> sp., form seen to succeed <i>Carpocanium rubyae</i> O'Connor, Late Miocene, 1123B-34x, CC A, K30/0. | 11a,b | <i>Plannapus hornibrooki</i> O'Connor, specimen with large apical horn, Late Eocene, 283-5-2, 25cm B, T32/0. |
| 4a,b | <i>Cyrtocapsa osculum</i> O'Connor, specimen with large basal pore, latest Eocene, 1123C-32x, CC A, M32/1. | 12a,b | <i>Plannapus mauricei</i> O'Connor, specimen with large apical horn, Late Eocene, 283-8-1, 40cm A, Z35/2. |
| 5a,b | <i>Cyrtocapsa osculum</i> O'Connor, specimen with large basal pore, Late Eocene, 1123C-33x, CC coarse A, D51/1. | 13a,b | <i>Plannapus mauricei</i> O'Connor, specimen with large apical horn, Late Eocene, 283-8-2, 25cm A, J47/0. |
| 6a,b | <i>Lamprocyclus particollis</i> O'Connor, specimen with more and smaller thoracic and abdominal pores, Early Oligocene, 280A-6-2, 60cm A, P49/4. | 14a,b | <i>Theocorys perforalvus</i> O'Connor, specimen with large pores on abdomen, Late Eocene, 283-8-1, 40cm A, V55/1. |
| 7a,b | <i>Lithomelissa gelasinus</i> O'Connor, specimen with pored thorax, and long apical horn, Early Oligocene, 280A-7-3, 40cm A, R36/2. | 15a,b | <i>Theocorys perforalvus</i> O'Connor, specimen with large pores on abdomen, Late Eocene, 283-8-2, 25cm A, X52/2. |
| 8a,b | <i>Lithomelissa gelasinus</i> O'Connor, specimen with closed and pored thorax, Early Oligocene, 280A-5-1, 104cm B, R29/1. | 16a,b | <i>Thyrsoyrtis</i> (<i>Thyrsoyrtis</i> ?) sp., form immediately preceding <i>T. (T. ?) pinguisoides</i> O'Connor, Late Eocene, 1123C-33x, CC A, X30/1. |
| | | 17a,b | <i>Thyrsoyrtis</i> (<i>Thyrsoyrtis</i> ?) sp., form immediately preceding <i>T. (T. ?) pinguisoides</i> O'Connor, Late Eocene, 1123C-33x, CC A, X41/2. |

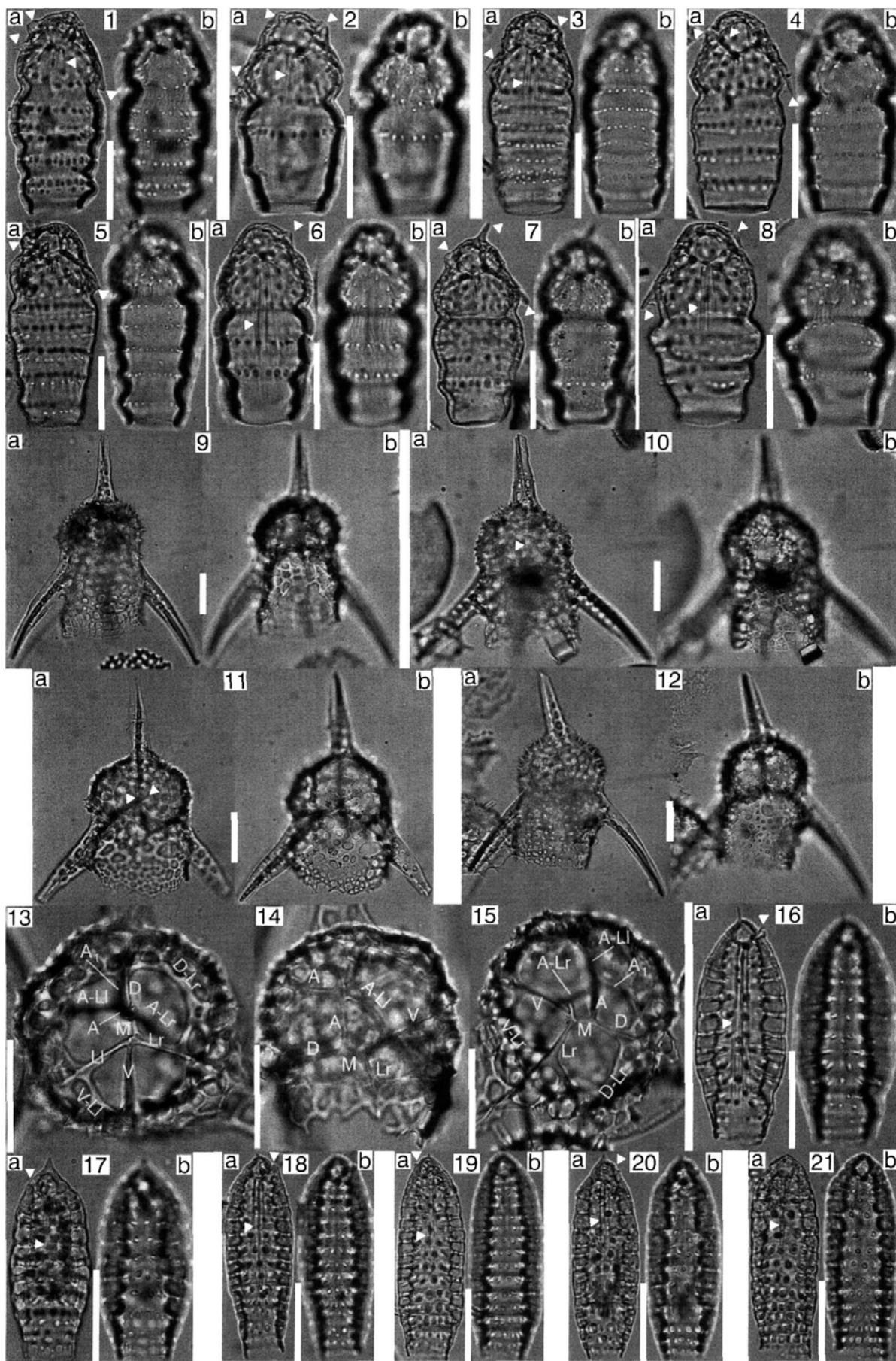


- Basins. Sedimentary Basins of the World, 2 (series editor: K.J. Hsü). Elsevier Science Publishers B.V., Amsterdam. pp.113-142.
- HAYWARD, B. W., BROOK, F. J. and ISAAC, M. J., 1989. Cretaceous to middle Tertiary stratigraphy, paleogeography and tectonic history of Northland, New Zealand. In: Spörlri, K.B. and Kear, D. (eds). Geology of Northland: accretion, allochthons and arcs at the edge of the New Zealand micro-continent. The Royal Society of New Zealand Bulletin, 26:47-64.
- HOLDSWORTH, B. K., 1975. Cenozoic Radiolaria biostratigraphy: Leg 30: tropical and equatorial Pacific. In: Andrews, J.E. et al. Initial Reports of the Deep Sea Drilling Project, Volume 30:499-537. Washington, DC: US Government Printing Office.
- HOLLIS, C. J., 1991. Latest Cretaceous to Late Paleocene Radiolaria from Marlborough (New Zealand) and DSDP Site 208. Unpublished PhD. thesis, Department of Geology, University of Auckland. 309pp.
- , 1993. Latest Cretaceous to Late Paleocene radiolarian biostratigraphy: A new zonation from the New Zealand region. Marine Micropaleontology, 21:295-327.

PLATE 2

All illustrations are transmitted light photomicrographs. All specimens are from DSDP Leg 29, Site 280. All scale bars are 50µm.

- 1a,b *Dictyoprora nigrinia* O'Connor, n.sp., Holotype, Early Oligocene, 280A-7-3, 40cm A, E37/2. White arrows indicate, from left to right, wing from **Vbd**, vertical tube, **Ax**, and wing from **D**.
- 2a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-7-3, 40cm A, E45/0. White arrows indicate, from left to right, wing from **D**, apical horn, **Ax**, and vertical tube.
- 3a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-7-3, 40cm B, J34/2. White arrows indicate, from left to right, wing from **D**, **Ax**, and vertical tube.
- 4a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-7-3, 40cm B, Q21/4. White arrows indicate, from left to right, vertical tube, **A-Vbl**, and wing from **D**.
- 5a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-7-3, 40cm B, U42/0. White arrows indicate, from left to right, vertical tube, and wing from **D**.
- 6a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm A, V47/2. White arrows indicate, from left to right, **Ax**, and vertical tube.
- 7a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-7-3, 40cm B, U37/0. White arrows indicate, from left to right, vertical tube, apical horn, and wing from **D**.
- 8a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-7-3, 40cm B, T33/4. White arrows indicate, from left to right, wing from **D**, **Ax**, and vertical tube.
- 9a,b *Lithomelissa ? sakaii* O'Connor, n. sp., Holotype, Early Oligocene, 280A-5-1, 104cm B, L56/0.
- 10a,b *Lithomelissa ? sakaii* O'Connor, n. sp., Paratype, Early Oligocene, 280A-5-1, 104cm B, J44/2. White arrow indicates **A**.
- 11a,b *Lithomelissa ? sakaii* O'Connor, n. sp., Paratype, Early Oligocene, 280A-5-1, 104cm B, P21/1. White arrows indicate, from left to right, **A**, and **A-Ll**.
- 12a,b *Lithomelissa ? sakaii* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm B, J28/4
- 13 *Lithomelissa ? sakaii* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm B, O24/0. Basal view showing internal skeletal structure.
- 14 *Lithomelissa ? sakaii* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm A, S33/0. Oblique right-lateral view showing internal skeletal structure.
- 15 *Lithomelissa ? sakaii* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm A, M23/1. Basal view showing internal skeletal structure.
- 16a,b *Plannapus ? aitai* O'Connor, n. sp., Holotype, Early Oligocene, 280A-7-3, 40cm B, N49/1. White arrows indicate, from left to right, **Ax**, and vertical tube.
- 17a,b *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-7-3, 40cm A, H44/1. White arrows indicate, from left to right, vertical tube, and **Ax**.
- 18a,b *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-7-3, 40cm A, P40/2. White arrows indicate, from left to right, **Ax**, and vertical tube.
- 19a,b *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-7-3, 40cm B, Q34/1. White arrows indicate, from left to right, vertical tube, and **Ax**.
- 20a,b *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-7-3, 40cm A, K41/3. White arrows indicate, from left to right, **Ax**, and vertical tube.
- 21a,b *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-7-3, 40cm B, J33/0. White arrow indicates **Ax**.

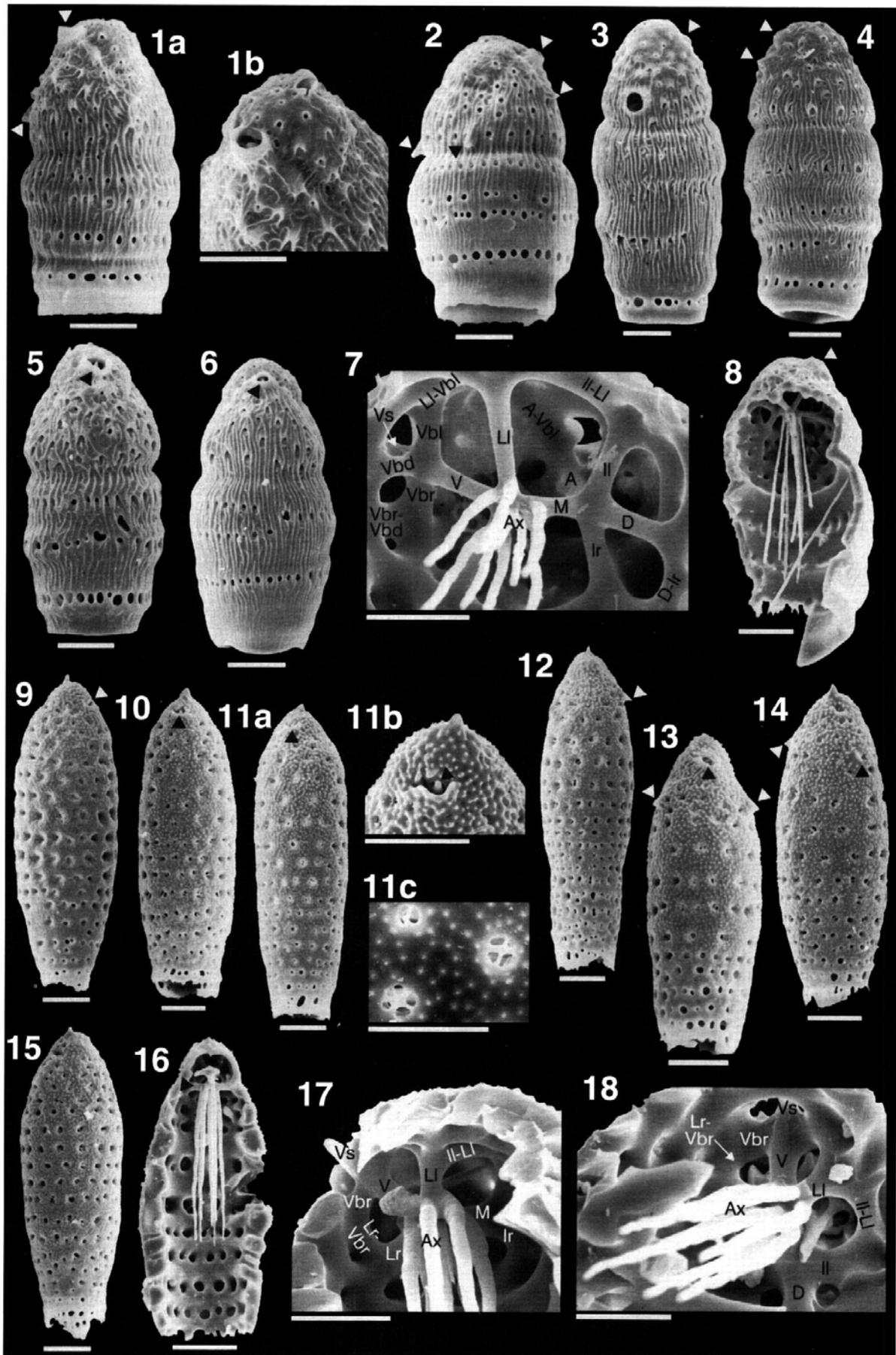


- , 1997. Cretaceous-Paleocene Radiolaria from eastern Marlborough, New Zealand. Institute of Geological and Nuclear Sciences monograph 17. 152pp.
- HOLLIS, C. J., WAGHORN, D. B., STRONG, C. P. and CROUCH, E. M., 1997. Integrated Paleogene biostratigraphy of DSDP site 277 (Leg29): foraminifera, calcareous nannofossils, Radiolaria, and palynomorphs. Institute of Geological and Nuclear Sciences science report 97/07. 87pp.
- IWATA, K. and TAJIKA, J., 1986. Late Cretaceous radiolarians of the Yubetsu Group, Tokoro Belt, northeast Hokkaido. Journal of the Faculty of Science, Hokkaido University, Series 4: Geology and Mineralogy, 21:619-644.
- JOHNSON, D. A., 1974. Radiolaria from the eastern Indian Ocean, DSDP Leg 22. In: von der Borch, C.C. et al. Initial Reports of the Deep Sea Drilling Project, Volume 22:521-575. Washington, DC: US Government Printing Office.
- , 1976. Cenozoic radiolarians from the Central Pacific, DSDP Leg 33. In: Schlanger, S.O. et al. Initial Reports of the Deep Sea Drilling Project, Volume 33:425-437. Washington, DC: US Government Printing Office.

PLATE 3

All illustrations are scanning electron microphotographs. All specimens are from DSDP Leg 29, Site 280. Scale bars for specimens 1-6, 8-11b, and 12-16 are 20µm; scale bars for specimens 7, 11c, 17, and 18 are 10µm.

- 1a,b *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-03-10.
- 1a White arrows indicate, from left to right, wing from **Lr**, and vertical tube.
- 1b Close-up of cephalis showing vertical tube and very short apical horn with lateral pore.
- 2 *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-03-08. White arrows indicate, from left to right, wing from **D**, vertical tube, and wing from **Vbd**. Black arrow indicates wing from **Lr**.
- 3 *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-03-01. White arrow indicates vertical tube.
- 4 *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-02-01. White arrows indicate, from left to right, wing from **Vbd**, and vertical tube.
- 5 *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-02-03. Black arrow indicates vertical tube.
- 6 *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-02-04. Black arrow indicates vertical tube.
- 7 *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-01-07. Basal view of cephalis showing internal skeletal structure.
- 8 *Dictyoprora nigrinia* O'Connor, n.sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-01-06. Broken specimen showing long **Ax**. White arrow indicates vertical tube.
- 9 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-01-01. White arrow indicates vertical tube.
- 10 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-01-02. Black arrow indicates vertical tube.
- 11a-c *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-01-03.
- 11a Black arrow indicates vertical tube.
- 11b Close-up of cephalis showing roughened surface, and vertical tube.
- 11c Close-up of thorax showing divided pores, and small nodes on surface.
- 12 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-02-04. White arrow indicates wing from **D**.
- 13 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 02-02-05. White arrows indicate, from left to right, wing from **Lr**, and wing from **Ll**. Black arrow indicates vertical tube.
- 14 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-04-01. White arrow indicates wing from **Ll**. Black arrow indicates wing from **D**.
- 15 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-04-03. White arrow indicates wing from **D**.
- 16 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-03-08. Broken specimen showing long **Ax**. Black arrow indicates **Ll**.
- 17 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-03-07. Basal view of cephalis showing internal skeletal structure.
- 18 *Plannapus ? aitai* O'Connor, n. sp., Paratype, Early Oligocene, 280A-6-2, 60cm, 03-03-02. Basal view of cephalis showing internal skeletal structure.



APPENDIX 1
Cenozoic timescale.

Ma	Chron	Polarity	International		New Zealand	Ma	Hollis (1997)		Sanfilippo and Nigrini (1998)	
			Epoch	Stage			Code #	South Pacific radiolarian zone	Code #	Tropical radiolarian zone
0.5	C1n		PLEISTOCENE	LATE	HAWERAN (Wq)	0.4	UNZONED	RN17	<i>Buccinosphaera invaginata</i>	0.18
		MIDDLE		CASTLECLIFFIAN	RN16			<i>Collosphaera tuberosa</i>	0.42	
		EARLY	(Wc)	RN15	<i>Stylatractus universus</i>	0.61				
1	C1r	1r	EARLY CALABRIAN			RN14		<i>Amphirhopalum ypsilon</i>	-1.1	
1.5		2r				RN13		<i>Anthocytidium angulare</i>	1.74	
2	C2n	1r	LATE WANGANUI	GELASIAN	NUKUMARUAN (Wn)	2.6		RN12b	<i>Pterocanium prismatium</i>	2.4
		2r						RN12a		2.78
2.5	C2r	1n	LATE PIOCENE	PIACENZIAN	MANGAPANIAN (Wm)	3.2		RN11b	<i>Pterocanium audax</i>	3.42
3	C2An	2r			WAIPAPIAN (Wp)			RN11a		3.87
3.5		3n								
4	C2Ar	1n	EARLY ZANGLIAN	ZANGLIAN	OPOITIAN (Wo)	5.2	RN10	<i>Phormostichoartus doliolum</i>	4.19	
4.5		2r								
5	C3n	3r	LATE TARRANTIAN	TARRANTIAN	KAPITEAN (Tk) early	5.5	UNZONED	RN9	<i>Stichocorys peregrina</i>	6.71
6		4n								
6.5	C3r	1n	LATE TARRANTIAN	TARRANTIAN	KAPITEAN (Tk) late	6.6	UNZONED	RN8	<i>Didymocyrtis penultima</i>	7.7
7		2r								
7.5	C3An	1r	LATE TARRANTIAN	TARRANTIAN	TONGAPORUTUAN late	10.1	UNZONED	RN7	<i>Didymocyrtis antepenultima</i>	8.77
8		2n								
8.5	C3Ar	3r	LATE TARRANTIAN	TARRANTIAN	(Tt)	11.3	UNZONED	RN6	<i>Diartus petterssoni</i>	11.95
9		2r								
9.5	C3Br	1r	LATE TARRANTIAN	TARRANTIAN	WAIUAN (Sw)	13.0	UNZONED	RN5	<i>Dorcadospyris alata</i>	15.68
10		2n								
10.5	C4n	1r	MIDDLE SERRAVALLIAN	SERRAVALLIAN	LILLBURNIAN (Sl)	15.1	UNZONED	RN4	<i>Calocycletta costata</i>	17.03
11		2r								
11.5	C4Ar	1r	MIDDLE SERRAVALLIAN	SERRAVALLIAN	CLIFDENIAN (Sc)	16.3	UNZONED	RN3	<i>Stichocorys wolffii</i>	17.92
12		2n								
12.5	C4An	1r	MIDDLE SERRAVALLIAN	SERRAVALLIAN	ALTONIAN (Pl) middle	16.7	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
13		2r								
13.5	C4Ar	3r	MIDDLE SERRAVALLIAN	SERRAVALLIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
14		2n								
14.5	C5n	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
15		2r								
15.5	C5r	1n	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
16		2r								
16.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
17		2n								
17.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
18		2r								
18.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
19		2n								
19.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
20		2r								
20.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
21		2n								
21.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
22		2r								
22.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
23		2n								
23.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
24		2r								
24.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
25		2n								
25.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
26		2r								
26.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
27		2n								
27.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
28		2r								
28.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
29		2n								
29.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
30		2r								
30.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
31		2n								
31.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
32		2r								
32.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
33		2n								
33.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
34		2r								
34.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
35		2n								
35.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
36		2r								
36.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
37		2n								
37.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
38		2r								
38.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
39		2n								
39.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
40		2r								
40.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
41		2n								
41.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
42		2r								
42.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
43		2n								
43.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
44		2r								
44.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
45		2n								
45.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
46		2r								
46.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
47		2n								
47.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
48		2r								
48.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
49		2n								
49.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
50		2r								
50.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
51		2n								
51.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
52		2r								
52.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
53		2n								
53.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
54		2r								
54.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
55		2n								
55.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
56		2r								
56.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
57		2n								
57.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
58		2r								
58.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
59		2n								
59.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
60		2r								
60.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
61		2n								
61.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
62		2r								
62.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
63		2n								
63.5	C5Ar	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	18.5
64		2r								
64.5	C5An	1r	EARLY LANGHIAN	LANGHIAN	ALTONIAN (Pl) early	18.5	UNZONED			

APPENDIX 1
Continued.

Ma	Chrons	Polarity	International			New Zealand	Ma	Hollis (1997)		Sanfilippo and Nigrini (1998)		
			Epoch	Stage	Series			Code #	South Pacific radiolarian zone	Code #	Tropical radiolarian zone	Ma
42	C19r C19n		Eocene	MIDDLE	LUTETIAN	ARNOLD	BORTONIAN (Ab)	RP12	<i>Eusyringium fistuligerum</i>	RP14	<i>Podocyrtis mitra</i>	
43	C20n						PORANGAN					RP13
44	C20r						(Dp)	RP11	<i>Eusyringium lagena</i>		~44.5	
46	C21n						HERETANGAN			RP12	<i>Thyrsocyrtis triacantha</i>	
47	C21r						(Dh)			RP11	<i>Dictyoprora mongolfieri</i>	~47.5
48	C22n							RP10	<i>Cycladophora ? auriculaleporis</i>	RP10	<i>Theocotyle cryptocephala</i>	~48.5
49	C22r									RP9	<i>Phormocyrtis striata striata</i>	~49.0
50	C23n	1 n 2n	Eocene	EARLY	YPRESIAN	DANNEVIRKE	MANGAORAPAN					~50.3
51	C23r						(Dm)	RP9	<i>Bekoma divaricata - Dictyoprora mongolfieri</i>	RP8	<i>Buryella clinata</i>	
52	C24n	1 n 2 n 3 n					WAIPAWAN					~52.85
53	C24r						(Dw)	RP8	<i>Bekoma divaricata</i>	RP7	<i>Bekoma bidartensis</i>	
54	C25n							RP7	<i>Bekoma campechensis - Bekoma bidartensis</i>			
55	C25r							RP6	<i>Bekoma campechensis</i>			~56.9
56	C26n						late			RP 6c	<i>Spongodiscus nitidus - Pterocodon ? poculum</i>	~57.6
57	C26r						TEURIAN			RP 6b	<i>Orbula discipulus</i>	
58	C27n									RP 6a	<i>Peritviator ? dumitricai</i>	~59.2
59	C27r											~60.2
60	C28n											
61	C28r											
62	C29n						early					
63	C29r						(Dt)	RP4	<i>Buryella foremanae</i>			
64	C27n											
65	C27r											
66	C28n											
67	C28r											
68	C29n											
69	C29r											
70												
71												
72												
73												
74												
75												
76												
77												
78												
79												
80												
81												
82												
83												
84												
85												
86												
87												
88												
89												
90												
91												
92												
93												
94												
95												
96												
97												
98												
99												
100												

APPENDIX 1
Continued.

Ma	Chron	Polarity	International		Series	New Zealand		Ma	Hollis (1997)		Sanfilippo and Nigrini (1998)																																
			Epoch	Stage		Stage	Code #		South Pacific radiolarian zone	Code #	Tropical radiolarian zone	Ma																															
19	C5Dr		MIOCENE	EARLY	BURDIGALIAN	ALTONIAN (Pi) early	18.5	UNZONED	RN2	<i>Stichocorys delmontensis</i>	20.53																																
	C5En					OTAIAIAN																																					
	C5Er																																										
20	C6N																																										
21	C6r					MIOCENE	EARLY					AQUITANIAN	(Po)	22.4	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62																									
	C6An	1 n 2 n																																									
22	C6Ar												MIOCENE						EARLY	AQUITANIAN	WAITAKIAN	22.4	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62																	
	C6AAr	1 r 2 r 3 r																																									
23	C6Bn	1 n 2 n																			MIOCENE						EARLY	AQUITANIAN	(Lw)	22.4	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62									
	C6Br	1 n 2 n																																									
24	C6Cn	1 n 2 n 3 n	MIOCENE	EARLY	AQUITANIAN			DUNTRONIAN	22.4	UNZONED	RN1																		<i>Cyrtocapsa tetrapera</i>						23.62								
	C6Cr	1 n 2 n																																									
25	C7n	1 n 2 n						MIOCENE																												LATE	CHATTIAN	(Ld)	22.4	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62
	C7r	1 n 2 n																																									
26	C7An	1 n 2 n				MIOCENE	LATE					CHATTIAN		(Ld)	22.4	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>																				23.62					
	C7Ar	1 n 2 n																																									
27	C8n	1 n 2 n											MIOCENE	LATE					CHATTIAN	DUNTRONIAN		22.4	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62																	
	C8r	1 n 2 n																																									
28	C9n	1 n 2 n																		OLIGOCENE	EARLY						LONDON	late		27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62									
	C9r	1 n 2 n																																									
29	C10n	1 n 2 n	OLIGOCENE	EARLY	LONDON				WHAINGAROAN	27.5	UNZONED																	RN1	<i>Cyrtocapsa tetrapera</i>						23.62								
	C10r	1 n 2 n																																									
30	C11n	1 n 2 n						OLIGOCENE	EARLY																											LONDON	WHAINGAROAN		27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62
	C11r	1 n 2 n																																									
31	C12n	1 n 2 n				OLIGOCENE	EARLY					LONDON			WHAINGAROAN	27.5	UNZONED	RN1																			<i>Cyrtocapsa tetrapera</i>	23.62					
	C12r	1 n 2 n																																									
32	C13n	1 n 2 n											OLIGOCENE	EARLY	LONDON				WHAINGAROAN			27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62																	
	C13r	1 n 2 n																																									
33	C15n	1 n 2 n																	OLIGOCENE	EARLY	LONDON						WHAINGAROAN			27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62									
	C15r	1 n 2 n																																									
34	C16n	1 n 2 n	OLIGOCENE	EARLY	LONDON					WHAINGAROAN	27.5																UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>						23.62								
	C16r	1 n 2 n																																									
35	C17n	1 n 2 n 3 n						OLIGOCENE	EARLY	LONDON																										WHAINGAROAN			27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62
	C17r	1 n 2 n 3 n																																									
36	C18n	1 n 2 n				OLIGOCENE	EARLY					LONDON				WHAINGAROAN	27.5	UNZONED																		RN1	<i>Cyrtocapsa tetrapera</i>	23.62					
	C18r	1 n 2 n																																									
37	C19n	1 n 2 n											OLIGOCENE	EARLY	LONDON	WHAINGAROAN						27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62																	
	C19r	1 n 2 n																																									
38	C20n	1 n 2 n														OLIGOCENE			EARLY	LONDON	WHAINGAROAN									27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62									
	C20r	1 n 2 n																																									
39	C21n	1 n 2 n	OLIGOCENE	EARLY	LONDON						WHAINGAROAN										27.5						UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>						23.62								
	C21r	1 n 2 n																																									
40	C22n	1 n 2 n						OLIGOCENE	EARLY	LONDON	WHAINGAROAN																												27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62
	C22r	1 n 2 n																																									
41	C23n	1 n 2 n				OLIGOCENE	EARLY				LONDON	WHAINGAROAN					27.5	UNZONED																		RN1	<i>Cyrtocapsa tetrapera</i>	23.62					
	C23r	1 n 2 n																																									
42	C24n	1 n 2 n										OLIGOCENE	EARLY	LONDON	WHAINGAROAN							27.5	UNZONED	RN1	<i>Cyrtocapsa tetrapera</i>	23.62																	
	C24r	1 n 2 n																																									

- , 1978. Cenozoic Radiolaria from the eastern tropical Atlantic, DSDP Leg 41. In: Lancelot, Y. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 41:763-789. Washington, DC: US Government Printing Office.
- , 1983. Cenozoic radiolarians from the Brazil Basin and Rio Grande Rise. In: Barker, P.F. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 72:783-791. Washington, DC: US Government Printing Office.
- KADAR, A. P., 1988. Upper Cretaceous to Lower Miocene calcareous nanofossils from Northland, New Zealand. Unpublished PhD. thesis, Department of Geology, University of Auckland. 405pp.
- KENNETT, J. P., 1982. *Marine Geology*. Prentice-Hall, London. 813pp.
- KENNETT, J. P., HOUTZ, R. E., et. al., 1975. *Initial Reports of the Deep Sea Drilling Project*, Volume 29. U.S. Government Printing Office, Washington. 1197pp.
- KNOLL, A.H. and JOHNSON, D.A., 1975. Late Pleistocene evolution of the collosphaerid *Buccinosphaera invaginata* Haeckel. *Micropaleontology*, 21:60-68.
- KOZLOVA, G. E., 1983. Radiolyariyevye komplekсы borealnogo nishneve paleotsena (Radiolarian complexes of boreal regions in the lower Paleocene). In: Lyubimova, P.S. and Myatlyuk, E. V., Eds., *Rol Mikrofauny v izuchenii osadochnykh tolshch kontinentov i morei (sbornik nauchnykh trudov)* (The use of microfauna in the study of sediments from the continents and oceans (miscellaneous scientific reports)). Leningrad, USSR, *Trudy vsesoyuznogo neftyanogo nauchno-issledovatel'skogo geolograzvedochnogo instituta (VNIGRI)* (Proceedings of the All Union Petroleum Scientific Research Institute for Geological Survey (VNIGRI)). pp. 84-112.
- , 1984. Zonalnoe podrazdelenie borealogo paleogena po radiolyariyam (Zonal subdivision of the Boreal Paleogene by radiolarians). In: Petrushevskaya, M.G. and Stepanjants, S.D., Eds., *Morfologiya. Ekologiya i evolutsiya Radiolyarii. Materialy IV simpoziuma evropeiskikh radiolyaristov EURORAD IV (Morphology, Ecology and Evolution of Radiolarians. Materials of the IV Symposium of European Radiolarists, Eurorad IV)*. Leningrad, USSR, *Akademiya Nauk SSSR, Zoological Institute*. pp.196-210, pls.10-12.
- LAWVER, L. A., GAHAGAN, L. M. and COFFIN, M. F., 1992. The development of paleoseaways around Antarctica. In: Kennett, J.P. and Warnke, D.A. (eds). *The Antarctic Paleoenvironment: A Perspective on Global Change*. Antarctic Research Series, 56: 7-30. American Geophysical Union, Washington, D.C.
- LAZARUS, D. and CAULET, J.-P., 1993. Cenozoic Southern Ocean reconstructions from sedimentologic, radiolarian, and other microfossil data. In: Kennett, J.P. and Warnke, D.A., Eds., *The Antarctic Paleoenvironment: A Perspective on Global Change*. Antarctic Research Series, 60: 145-174. American Geophysical Union, Washington, D.C.
- LAZARUS, D., SCHERER, R. P. and PROTHERO, D. R., 1985. Evolution of the radiolarian species-complex *Pterocanium*: a preliminary survey. *Journal of Paleontology*, 59:183-220.
- LING, H., 1975. Radiolaria: Leg 31 of the Deep Sea Drilling Project. In: Karig, D.E. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 31:703-761. Washington, DC: US Government Printing Office.
- MATO, C. Y. and THEYER, F., 1980. *Lychnocanoma bandyca* n.sp., a new stratigraphically important late Eocene radiolarian. In: Sliter, W. V., Ed., *Studies in Marine Micropaleontology and Paleoecology*; a memorial volume to Orville L. Bandy. Special Publication of the Cushman Laboratory, 19:225-229.
- MOORE, T. C. jr., 1971. Radiolaria. In: Tracey, J.I. jr et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 8:727-775. Washington, DC: US Government Printing Office.
- , 1972. Mid-Tertiary evolution of the radiolarian genus *Calocyclus*. *Micropaleontology*, 18:144-152.
- MORGANS, H. E. G., SCOTT, G. H., BEU, A. G., GRAHAM, I. J., MUMME, T. C., ST. GEORGE, W. and STRONG, C. P., 1996. New Zealand Cenozoic time scale (1996). Institute of Geological and Nuclear Sciences science report 96/38.
- NIGRINI, C., 1967. Radiolaria in pelagic sediments from the Indian and Pacific Oceans. *Bulletin of the Scripps Institution of Oceanography*, Volume 11. 125pp.
- , 1971. Radiolarian zones in the Quaternary of the equatorial Pacific Ocean. In: Funnell, B.M. and Riedel, W. R., Eds., *The Micropaleontology of Oceans*. Cambridge University Press, London, pp.443-461.
- , 1977. Tropical Cenozoic Artostrobiidae (Radiolaria). *Micropaleontology*, 23:241-269.
- NISHIMURA, A., 1992. Paleocene radiolarian biostratigraphy in the northwest Atlantic at Site 384, Leg 43, of the Deep Sea Drilling Project. *Micropaleontology*, 38:317-362.
- NISHIMURA, H., 1990. Taxonomic study on Cenozoic Nassellaria (Radiolaria). *Science Reports of the Institute of Geoscience, University of Tsukuba, Section B*, Volume 11:69-172.
- O'CONNOR, B. M., 1993. Radiolaria from the Mahurangi Limestone, Northland, New Zealand. Unpublished M.Sc. thesis, Department of Geology, University of Auckland. 135pp.
- , 1994. Seven new radiolarian species from the Oligocene of New Zealand. *Micropaleontology*, 40:337-350.
- , 1996a. Confocal Laser Scanning Microscopy: a new technique for investigating and illustrating fossil Radiolaria. *Micropaleontology*, 42:395-402.
- , 1996b. *Studies in New Zealand Late Paleogene - Early Neogene Radiolaria*. Unpublished PhD. thesis, Department of Geology, University of Auckland. 299pp.
- , 1997a. New Radiolaria from the Oligocene and Early Miocene of New Zealand. *Micropaleontology*, 43(1):63-100.
- , 1997b. Lower Miocene Radiolaria from Te Kopua Point, Kaipara Harbour, New Zealand. *Micropaleontology*, 43(2):101-128.
- , 1999. Radiolaria from the Late Eocene Oamaru Diatomite, South Island, New Zealand. *Micropaleontology*, 45(1):1-55.
- , in press. Distribution and biostratigraphy of latest Eocene to latest Oligocene Radiolaria from the Mahurangi Limestone, Northland, New Zealand. *New Zealand Journal of Geology and Geophysics*, 42 (4).
- PALMER, A. A., 1987. Cenozoic Radiolaria from DSDP sites 612 and 613 (Leg 95, New Jersey Transect) and Atlantic Slope Project site ASP 15. In: Poag, C.W. et al. *Initial Reports of the Deep Sea Drilling Project*, Volume 95:339-357. Washington, DC: US Government Printing Office.
- PETRUSHEVSKAYA, M. G., 1969. Spumellarian and Nassellarian radiolarians in bottom sediments as indicators of hydrological conditions. In: *Basic Problems of Micropaleontology and of the Accumulation of Organogenic Sediments in Oceans and Seas* (reprint). Academy of Sciences Oceanographical Commission. pp.127-150.

- , 1971a. On the natural system of Polycystine Radiolaria (Class Sarcodina). In: Farinacci, A., Ed., Proceedings of the II Planktonic Conference, Roma 1970. Edizioni Tecnoscienza, Roma. pp.981-991.
- , 1971b. Radiolyarii Nassellaria v planktone Mirovogo Okeana (Nassellarian radiolarians in the plankton of the World Ocean). Issledovaniya Fauny Morei (Explorations of the Fauna of the Seas), 9(17):5-294 + 398-420 (index and contents).
- , 1975. Cenozoic radiolarians of the Antarctic, Leg 29, DSDP. In: Kennett, J.P. et al. Initial Reports of the Deep Sea Drilling Project, Volume 29:541-675. Washington, DC: US Government Printing Office.
- , 1977. Novye vidy radiolyarii otryada Nassellaria (New radiolarian species from the order Nassellaria). In: Issledovaniya fauny morei - Novye vidy i rody morskikh bespozvonochnykh. Sbornik nauchnykh rabot (Explanation of the Fauna of the Seas - New Species and Genera of Marine Invertebrates). Zoologicheskii Zhurnal, Akademia Nauk SSSR (Academy of Sciences of the USSR, Zoological Institute), Leningrad, USSR, 21 (29), pp.10-19.
- PETRUSHEVSKAYA, M. G. and KOZLOVA, G. E., 1972. Radiolaria: Leg 14, Deep Sea Drilling Project. In: Hayes, D.E. et al. Initial reports of the Deep Sea Drilling Project, Volume 14:495-648. Washington, DC: US Government Printing Office.
- RIEDEL, W. R., 1953. Mesozoic and late Tertiary Radiolaria of Rott. Journal of Paleontology, 27:805-813.
- , 1957. Radiolaria: a preliminary stratigraphy. In: Pettersson, H., Ed., Reports of the Swedish Deep-Sea Expedition 1947-1948, Volume 6(3):59-96. Göteborg, Sweden: Elanders Boktryckeri Aktiebolag.
- , 1958. Radiolaria in Antarctic sediments. B.A.N.Z. Antarctic Research Expedition Reports, Series B, Volume 6, Part 10:217-255.
- , 1959. Oligocene and Lower Miocene Radiolaria in tropical Pacific sediments. Micropaleontology, 5:285-302.
- , 1967a. Some new families of Radiolaria. Proceedings of the Geological Society of London, 1640:148-149.
- , 1967b. Subclass Radiolaria. In: Harland, W. B., ed., The Fossil Record. Geological Society of London, London. pp.291-298.
- RIEDEL, W. R. and FUNNELL, B. M., 1964. Tertiary sediment cores and microfossils from the Pacific Ocean floor. Quarterly Journal of the Geological Society of London, 120:305-368.
- RIEDEL, W. R. and SANFILIPPO, A., 1970. Radiolaria, Leg 4, Deep Sea Drilling Project. In: Bader, R.G. et al. Initial reports of the Deep Sea Drilling Project, Volume 4:503-575. US Government Printing Office.
- , 1971. Cenozoic Radiolaria from the western tropical Pacific, Leg 7. In: Winterer, E.L. et al. Initial Reports of the Deep Sea Drilling Project, Volume 7:1529-1672. Washington, DC: US Government Printing Office.
- , 1977. Cainozoic Radiolaria. In: Ramsay, A.T.S., Ed., Oceanic Micropaleontology (Volume 2):847-912. Academic Press, London.
- , 1978. Stratigraphy and evolution of tropical Cenozoic radiolarians. Micropaleontology, 23:61-96.
- SAKAI, T., 1980. Radiolarians from sites 434, 435 and 436, northwest Pacific, Leg 56, Deep Sea Drilling Project. In: Langseth, M. et al. Initial Reports of the Deep Sea Drilling Project, Volume 56, 57, Part 2:695-733. Washington, DC: US Government Printing Office.
- SANCETTA, C., 1979. Paleogene Pacific microfossils and paleoceanography. Marine Micropaleontology, 4:363-398.
- SANFILIPPO, A., 1990. Origin of the Subgenera *Cyclampterium*, *Paralampterium* and *Sciadiopeplus* from *Lophocyrtis* (*Lophocyrtis*) (Radiolaria, Theoperidae). Marine Micropaleontology, 15:287-312.
- SANFILIPPO, A., BURCKLE, L. H., MARTINI, E. and RIEDEL, W. R., 1973. Radiolarians, diatoms, silicoflagellates and calcareous nanofossils in the Mediterranean Neogene. Micropaleontology, 19:209-234.
- SANFILIPPO, A. and NIGRINI, C., 1995. Radiolarian stratigraphy across the Oligocene/Miocene transition. Marine Micropaleontology, 24:239-285.
- , 1996. Radiolarian biostratigraphy at the Oligocene/Miocene boundary. In: Moguevsky, A. and Whatley, R., Eds., Microfossils and Oceanic Environments. University of Wales, Aberystwyth - Press. pp.317-326.
- , 1998. Code numbers for Cenozoic low latitude radiolarian biostratigraphic zones and GPTS conversion tables. Marine Micropaleontology, 33:109-156.
- SANFILIPPO, A. and RIEDEL, W. R., 1970. Post-Eocene "closed" theoperid radiolarians. Micropaleontology, 16:446-462.
- , 1973. Cenozoic Radiolaria (Exclusive of theoperids, artostroboids and amphipyndacids) from the Gulf of Mexico, Deep Sea Drilling Project Leg 10. In: Worzel, J.L. et al. Initial Reports of the Deep Sea Drilling Project, Volume 10:475-611. Washington, DC: US Government Printing Office.
- , 1974. Radiolaria from the west-central Indian Ocean and Gulf of Aden. In: Fisher, R.L. et al. Initial Reports of the Deep Sea Drilling Project, Volume 24:997-1035. Washington, DC: US Government Printing Office.
- , 1979. Radiolaria from the northeastern Atlantic Ocean, DSDP Leg 48. In: Montadert, L. et al. Initial Reports of the Deep Sea Drilling Project, Volume 48:493-511. Washington, DC: US Government Printing Office.
- , 1980. A revised generic and suprageneric classification of the Artiscins (Radiolaria). Journal of Paleontology, 54:1008-1011.
- , 1982. Revision of the radiolarian genera *Theocotyle*, *Theocotylissa* and *Thysocyrtis*. Micropaleontology, 28:170-188.
- , 1992. The origin and evolution of Pterocorythidae (Radiolaria): a Cenozoic phylogenetic study. Micropaleontology, 38:1-36.
- SANFILIPPO, A., WESTBERG-SMITH, M. J. and RIEDEL, W. R., 1985. Cenozoic Radiolaria. In: Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K., Eds., Plankton stratigraphy. Cambridge University Press. pp.631-712.
- SAUNDERS, J. B., BERNOULLI, D., MÜLLER-MERZ, E., OBERHÄNSLI, H., PERCH-NIELSEN, K., RIEDEL, W. R., SANFILIPPO, A. and TORRINI, R., jr., 1984. Stratigraphy of the late Middle Eocene to early Oligocene in the Bath Cliff section, Barbados, West Indies. Micropaleontology, 30:390-425.
- STEIGER, T., 1997. Miocene radiolarian biostratigraphy of the décollement zone (northern Barbados Ridge). In: Shipley, T.H. et al. Proceedings of the Ocean Drilling Program, Scientific Results, Volume 156:33-48. College Station, Texas.
- STÖHR, E., 1880. Die Radiolarienfauna der Tripoli von Grotte, Provinz Girgenti in Sicilien. Palaeontographica, Volume 26 (ser.3, vol.2):69-124, pls.1-7.

APPENDIX 2

Distribution of Radiolaria at Te Kopua Poing "+" denotes presence, "?" denotes uncertain identification due to poor preservation or wrong orientation on a strewn slide, a space denotes absence. Samples are quoted by their New Fossil Record File number. See text-figure 1 for a map of sample localities. For systematic details of taxa see O'Connor (1997b).

SPECIES	008/1569	008/1570	SPECIES	008/1569	008/1570
<i>Acrobotrys</i> sp.	+		<i>Lithelius minor</i>	+	+
<i>Acrosphaera</i> sp.	+		<i>Lithelius nautiloides</i>	+	+
Actinommidae gen. et sp. indet.	+	+	<i>Lithelius</i> ? sp.	+	+
<i>Amphipyndax stocki</i> gp.	+	+	<i>Lithomelissa ehrenbergi</i>	+	+
<i>Amphymenium splendiaratum</i>	+	?	<i>Lophocyrtis (Paralampterium ?) galenum</i>	+	+
<i>Antarctissa</i> sp.		+	<i>Lophophaena tekopua</i>	+	+
<i>Anthocyrtidium ehrenbergi</i>	+		<i>Lophophaena</i> ? sp.	+	
<i>Anthocyrtidium aff. pliocenica</i>	+		<i>Lophospyris pentagona aff. pentagona</i>	+	+
<i>Archipilium</i> sp.		+	<i>Lychnocanium conica</i>		+
<i>Bathropyramis</i> sp.	+	+	<i>Lychnocanium elongatum</i>	+	+
<i>Botryostrobos miralestensis</i>	+		<i>Mita</i> ? sp.	+	+
<i>Calocycletta (Calocycletta) cf. virginis</i>	+	?	<i>Ommatogramma</i> ? sp.	+	+
<i>Calocycletta (Calocyclopsis) serrata</i>	+	?	Orosphaeridae gen. et sp. indet.	+	+
<i>Carpocanium</i> spp.	+	+	<i>Peripyramis</i> sp.	+	+
<i>Carpocanopsis cingulata</i>	+	+	<i>Phormocyrtis ligulata</i>		+
<i>Carpocanopsis favosa</i>	+	?	<i>Phormocyrtis striata striata</i>	+	
<i>Ceratocyrtis histicosa</i>	+	+	<i>Phormocyrtis</i> sp.	+	
<i>Circodiscus microporus</i>	+	+	<i>Phormospyris stabilis scaphipes</i>	+	+
<i>Clathrocanium sphaerocephalum</i>	+	+	<i>Phormospyris stabilis stabilis</i>	+	?
<i>Clathrocorys</i> ? sp.	+	+	<i>Phormospyris stabilis aff. capoi</i>	+	
<i>Clathrocyclus aff. aurelia</i>	+		<i>Phormospyris</i> ? sp.		+
<i>Cornutella profunda</i>	+	+	<i>Phortidium pylonium</i>	+	+
<i>Cyrtocapsa comuta</i>	+	+	<i>Plannapus microcephalus</i>	+	+
<i>Cyrtocapsa cylindroides</i>	+	?	<i>Plectopyramis</i> sp.	+	
<i>Cyrtocapsa tetrapera</i>	+	+	<i>Podocyrtis (Podocyrtis) papalis</i>	?	?
<i>Cyrtolagena aglaolampa</i>	+		<i>Prunopyle</i> sp.	+	
<i>Dendrosphyris bursa</i>	+	+	<i>Prunopyle</i> ? sp.	+	+
<i>Dendrosphyris "De1" gp.</i>	+	+	<i>Pseudodictyophimus gracilipes</i>	+	
<i>Dendrosphyris pododendros</i>	+	+	<i>Pterocanium audax</i>		+
<i>Dictyocoryne truncatum</i>	+	+	<i>Siphocampe nodosaria</i>	+	
<i>Dictyomitra</i> sp.	+		<i>Siphostichartus praecorona</i>	+	
<i>Dictyophimus pocillum</i>	+		<i>Spirocyrtis subtilis</i>	+	
<i>Dictyoprora amphora</i>	+	+	<i>Spongodiscus cf. americanus</i>	+	+
<i>Dictyoprora gibsoni</i>	+	+	<i>Spongodiscus cf. pulcher</i>	+	
<i>Dictyoprora mongolfieri</i>	+		<i>Spongodiscus</i> ? sp.	+	+
<i>Didymocyrtis bassanii</i>	+		<i>Spongopyle osculosa</i>	+	+
<i>Didymocyrtis prismatica</i>	+		<i>Spongotrochus glacialis</i>	+	+
<i>Dorcadospyrus ateuchus</i>	+	+	<i>Spongurus</i> ? sp.	+	+
<i>Dorcadospyrus praeforcipata</i>	+	+	<i>Stichocorys coronata</i>	+	+
<i>Eucyrtidium cienkowskii</i> gp.	+	+	<i>Stichocorys delmontensis</i>	+	?
<i>Eucyrtidium punctatum</i> gp.	+	+	<i>Stylatractus universus</i>	+	+
<i>Eucyrtidium cf. acuminatum</i>	+	+	<i>Stylatractus</i> spp.	+	+
<i>Eucyrtidium</i> sp.	+	+	<i>Stylatractus</i> ? sp. A	+	+
<i>Gorgospyris</i> ? sp.	+	+	<i>Stylatractus</i> ? sp. B	+	+
<i>Heliodiscus asteriscus</i> ?	+	+	<i>Stylodictya validispina</i>	+	+
<i>Hymeniastrum</i> sp.	+	+	<i>Tepka perforata</i>	+	?
<i>Lamprocyclas margatensis</i>	+	+	<i>Theocorys longithorax</i>	+	
<i>Lamprocyclas</i> sp.	+		<i>Theocorys puriri</i>	+	
<i>Lamprocyrtes</i> sp.	+		<i>Tholospyris newtoniana</i>	+	+
<i>Larcopyle buetschlii</i>	+	+	<i>Tympanidium binocionum</i>	+	+
<i>Larcopyle</i> ? sp.	+	+	<i>Valkyria pukapuka</i>	+	
<i>Liriospyris</i> ? sp.	+	+	<i>Zygocircus productus</i>	+	+

- STRONG, C.P., HOLLIS, C.J. and WILSON, G.J., 1995. Foraminiferal, radiolarian and dinoflagellate biostratigraphy of Late Cretaceous to Middle Eocene pelagic sediments (Muzzle Group), Mead Stream, Marlborough, New Zealand. *New Zealand Journal of Geology and Geophysics*, 38:171-212.
- SUGIYAMA, K. and FURUTANI, H., 1992. Middle Miocene radiolarians from the Oidawara Formation, Mizunami Group, Gifu Prefecture, central Japan. *Bulletin of the Mizunami Fossil Museum*, 19:199-213, pls.12-20.
- SUYARI, K. and YAMASAKI, T., 1988. Microfossil age of the northern Margin of the Shimanto South Subbelt in Shikoku. Tokushima Daigaku Kyoyobu Kiyo, Shizen Kagaku. *Journal of Science, College of Education, University of Tokushima*, 21:107-133.
- TAKEMURA, A., 1992. Radiolarian Paleogene biostratigraphy in the southern Indian Ocean, Leg 120. In: Wise, S.W., jr. et al. *Proceedings of the Ocean Drilling Program, Scientific Results, Volume 120:735-756*. College Station, Texas.
- TAKEMURA, A. and LING, H., 1997. Eocene and Oligocene radiolarian biostratigraphy from the Southern Ocean: correlation of ODP Legs 114 (Atlantic Ocean) and 120 (Indian Ocean). *Marine Micropaleontology*, 30:97-116.
- VINASSA de REGNY, P. E., 1900. Radiolari Miocenici Italiani. *Memorie Reale Accademia Scienza Istituto Bologna*, ser 5, 8:227-257 (565-595), pls.1-3.
- WESTBERG, M. J. and RIEDEL, W. R., 1978. Accuracy of radiolarian correlations in the Pacific Miocene. *Micropaleontology*, 24:1-23.
- WETZEL, O., 1935. Die Mikropaläontologie des Heiligenhafener Kieseltones (Ober-Eozän). *Jahresbericht des Niedersächsischen geologischen Vereins*, 27:41-75, pls. 8-10.

Manuscript received September 9, 1999

Manuscript accepted November 4, 1999

APPENDIX 3 TAXONOMIC LIST

The following list is in alphabetical order and details taxa mentioned in the text and/or diagrams but not treated as new or recently described species.

Amphirhopalum ypsilon Haeckel 1887, p. 522; Nigrini 1967, p. 35, pl. 3, figs. 3a-d

Amphisphaera aotea Hollis 1991, p. 66, pl. 3, figs. 1-3; Hollis 1993, p. 316, pl. 1, fig. 12; Strong et al. 1995, p. 208, fig. 8E; Hollis 1997, p. 33, pl. 2, figs. 1-3, ?4a, b

Amphisphaera kina Hollis 1991, p. 68, pl. 3, figs. 6-10; Hollis 1993, p. 318, pl. 1, figs. 2, 3; Strong et al. 1995, p. 208, fig. 8F; Hollis 1997, p. 34, pl. 2, figs. 5-9

Amphisphaera aff. *spinulosa* (Ehrenberg)

Stylosphaera spinulosa Ehrenberg 1873, p. 259, 1875, pl. 15, fig. 8

Amphisphaera spinulosa (Ehrenberg), Petrushevskaya 1975, p. 570

Amphisphaera aff. *spinulosa* (Ehrenberg), Crouch and Hollis 1996, p. 26; Hollis et al. 1997, p. 43, pl. 1, figs. 1, 2; O'Connor 1996b, p. 186, pl.10, fig. 8, 1999, p. 31, pl. 10, fig. 8

Anthocyrtdium angulare Nigrini 1971, p. 445, pl. 34.1, figs. 3a, b; Sanfilippo et al. 1985, p. 691, figs. 29.4a, b

Artophormis gracilis Riedel 1959, p. 300, pl. 2, figs. 12, 13; Riedel and Sanfilippo 1970, p. 532, pl. 13, fig. 6; Riedel and Sanfilippo 1971, p. 1592, pl. 3B, figs. 5-7, pl. 6, fig. 7; Sanfilippo et al. 1985, p. 666, figs. 12.2a-c; O'Connor 1993, p. 71, pl. 7, figs. 23-25; Sanfilippo and Nigrini 1995, p. 272, pl. I, figs. 1-5; O'Connor in press

Artostrabus pusillum (Ehrenberg)

Eucyrtidium pusillum Ehrenberg 1873, p. 232, 1875, p. 72, pl. 11, fig. 6; Petrushevskaya 1971b, Fig. 92.V

Artostrabus pusillum (Ehrenberg), Petrushevskaya 1975, p. 578, pl. 26, figs. 1, 2

Axoprimum ? irregularis Takemura

Actinomma medusa (Ehrenberg) gr., Petrushevskaya 1975, p. 568, pl. 2, figs. 6-8 (*partim*)

? *Amphisphaera* sp. Chen 1975, pl.6, fig. 1

Axoprimum ? irregularis Takemura 1992, p. 742, pl. 3, figs. 8-11; Hollis et al. 1997, p. 44, pl. 1, fig. 15; Takemura and Ling 1997, p. 111, pl. 1, fig. 2

Bekoma bidartensis Riedel and Sanfilippo

Bekoma bidartensis Riedel and Sanfilippo 1971, p. 1592, pl. 7, figs. 1-7; Foreman 1973, p. 432, pl. 3, figs. 20, 21, pl. 10, fig. 6

Bekoma bidartensis Riedel and Sanfilippo 1978, p. 65; Sanfilippo et al. 1985, p. 667, figs. 13.1a, b; Strong et al. 1995, p. 208, fig. 9G

Bekoma campechensis Foreman 1973, p. 432, pl. 3, fig. 24, pl. 10, figs. 1, 2; Strong et al. 1995, p. 208, fig. 9F

Bekoma divaricata Foreman 1973, p. 433, pl. 10, figs. 3, 4; Strong et al. 1995, p. 208, fig. 9H

Buccinosphaera invaginata Haeckel 1887, p. 99, pl. 5, fig. 11; Nigrini 1971, p. 445, pl. 34.1, fig. 2; Knoll and Johnson 1975, p. 63, pl. 1, figs. 3-7; Sanfilippo et al. 1985, p. 650, fig. 4.1

Buryella clinata Foreman 1973, p. 433, pl. 8, figs. 1-3, pl. 9, fig. 19; Sanfilippo et al. 1985, p. 668, figs. 14.1a, b

- Buryella foremanae* Petrushevskaya
Buryella sp. A Dumitrica 1973, p. 789, pl. 1, fig. 4, pl. 4, figs. 1-4
Buryella foremanae Petrushevskaya 1977, p. 16, pl. 3, figs. d, e; Hollis 1993, p. 322, pl. 1, fig. 12; Strong et al. 1995, p. 208, fig. 8K; Hollis 1997, p. 80, pl. 21, figs. 6-9
- Buryella* ? *granulata* (Petrushevskaya)
 ? *Eusyringium royi* Frizzell and Middour 1951, p. 35, pl. 3, figs. 12, 13
Lithocampe sp. A Dumitrica 1973, p. 789, pl. 10, fig. 3, pl. 11, fig. 3
Lithocampe ? *granulata* Petrushevskaya 1977, p. 18, pl. 3, figs. a, b, v; Kozlova 1983, pl. 3, fig. 7; Kozlova 1984, Table 1
Eucyrtidium sp. A Iwata and Tajika 1986, pl. 7, figs. 10, 11; Suyari and Yamasaki 1988, pl. 1, figs. 5, 6, pl. 7, figs. 4, 6
Stichomitra granulata (Petrushevskaya), Hollis 1991, p. 134, pl. 20, figs. 7-12, 1993, p. 321, pl. 1, figs. 10, 11; Strong et al. 1995, p. 209, fig. 8J
Buryella granulata (Petrushevskaya), Hollis 1997, p. 80, pl. 21, figs. 12, 13
- Buryella tetradica* Foreman 1973, p. 433, pl. 8, figs. 4, 5, pl. 9, figs. 13, 14; Sanfilippo et al. 1985, p. 668, figs. 14.3a, b; Hollis 1993, p. 323; Strong et al. 1995, p. 208, figs. 8N, 9Q; Hollis 1997, p. 81, pl. 21, figs. 16-19
- Calocyclus bandyca* (Mato and Theyer)
Lychnocanoma bandyca Mato and Theyer 1980, p. 225, pl. 1, figs. 1-6; Sanfilippo et al. 1985, p. 676, figs. 19.3a, b
Calocyclus bandyca (Mato and Theyer), Sanfilippo and Riedel in Saunders et al. 1984, p. 411, pl. 5, figs. 1, 5, 6
- Calocyclus* (*Calocyclus*) *parva* Moore
Calocyclus parva Moore 1972, p. 148, pl. 1, figs. 1-5
- Calocyclus* (*Calocyclus*) *parva* Moore, Sanfilippo and Riedel 1992, pp. 28, 36, pl. 1, figs. 3-5, pl. 2, fig. 9; O'Connor in press
- Calocyclus* (*Calocyclus*) *robusta* Moore
Calocyclus robusta Moore 1971, p. 743, pl. 10, figs. 5, 6; Sanfilippo et al. 1985, fig. 28.4
- Calocyclus* (*Calocyclus*) *robusta* Moore, Sanfilippo and Riedel 1992, pp. 28, 36, pl. 1, fig. 6; O'Connor 1993, p. 66, pl. 11, fig. 1, in press
- Calocyclus* (*Calocyclus*) *costata* (Riedel)
Calocyclus virginis Haeckel, Riedel 1957, p. 90, pl. 4, fig. 5 (*partim*)
Calocyclus costata Riedel 1959, p. 296, pl. 2, fig. 9
Calocyclus costata (Riedel), Riedel and Sanfilippo 1970, p. 535, pl. 14, fig. 12; Sanfilippo et al. 1985, p. 691, figs. 28.3a, b
Calocyclus (*Calocyclus*) *costata* (Riedel), Sanfilippo and Riedel 1992, pp. 30, 36
- Calocyclus* (*Calocyclus*) *serrata* Moore
Calocyclus cf. *virginis* Haeckel, Riedel and Sanfilippo 1970, p. 568, pl. 14, fig. 11
Calocyclus serrata Moore 1972, p. 148, pl. 2, figs. 1-3; Sanfilippo et al. 1985, p. 692, fig. 28.2
- Calocyclus* (*Calocyclus*) *serrata* Moore, Sanfilippo and Riedel 1992, pp. 28, 30, 36, pl. 2, fig. 10; O'Connor 1997b, p. 111, pl. 7, fig. 6
- Centrobotrys petrushevskaya* Sanfilippo and Riedel
Centrobotrys ? sp. A Riedel and Sanfilippo 1971, p. 1602, pl. 3F, figs. 15, 16
Centrobotrys petrushevskaya Sanfilippo and Riedel 1973, p. 532, pl. 36, figs. 12, 13; Sanfilippo et al. 1985, p. 704, figs. 35.2a, b; O'Connor 1993, p. 56, pl. 5, figs. 8-11, in press
- Clathrocyclus* ? *diceros* Foreman 1968, p. 46, pl. 5, fig. 4
- Clathrocyclus* ? *hyronia* Foreman 1968, p. 47, pl. 5, figs. 1a, b
- Collosphaera tuberosa* Haeckel 1887, p. 97; Nigrini 1971, p. 445, pl. 34.1, fig. 1; Sanfilippo et al. 1985, p. 651, figs. 4.2a, b
- Cryptocarpium azyx* (Sanfilippo and Riedel)
Carpocanistrum ? *azyx* Sanfilippo and Riedel 1973, p. 530, pl. 35, fig. 9; Sanfilippo et al. 1985, p. 690, figs. 27.1a, b
Cryptocarpium azyx (Sanfilippo and Riedel), Sanfilippo and Riedel 1992, p. 6, pl. 2, fig. 21
- Cryptocarpium ornatum* (Ehrenberg)
Cryptoprora ornata Ehrenberg 1873, p. 222, 1875, pl. 5, fig. 8; Sanfilippo et al. 1985, p. 693, figs. 27.2a, b
Cryptocarpium ornatum (Ehrenberg), Sanfilippo and Riedel 1992, p. 7, pl. 2, figs. 18-20
- Cycladophora* ? *auriculaleporis* (Clark and Campbell)
Lophophaena auriculaleporis Clark and Campbell 1942, p. 76, pl. 8, figs. 20, 27-29; Blueford 1988, p. 246, pl. 3, figs. 1-3; O'Connor 1993, p. 58, pl. 5, figs. 17, 18
Lophocytis biaurata (Ehrenberg), Foreman 1973, p. 442, pl. 8, fig. 23 (*partim*); Chen 1975, p. 461, pl. 3, fig. 2; ? Caulet 1986, p. 853; Takemura 1992, p. 747, pl. 7, fig. 8; Takemura and Ling 1997, p. 113
Artobotrys auriculaleporis (Clark and Campbell), Caulet 1991, p. 937
Lophocytis ? *auriculaleporis* (Clark and Campbell), Strong et al. 1995, p. 208, figs. 10s, t
Cycladophora ? *auriculaleporis* (Clark and Campbell), Hollis et al. 1997, p. 59, pl. 3, fig. 31; O'Connor in press
- Cyrtocalpis compacta* Haeckel 1887, p. 1187, pl. 52, figs. 7, 8
- Cyrtocapsa cornuta* Haeckel
Cyrtocapsa (*Cyrtocapsella*) *cornuta* Haeckel 1887, p. 1513, pl. 78, fig. 9
Cyrtocapsella cornuta Haeckel, Sanfilippo and Riedel 1970, p. 453, pl. 1, figs. 19, 20; Sanfilippo et al. 1985, p. 670, figs. 16.2a, b
Cyrtocapsa cornuta Haeckel, O'Connor 1997b, p. 111
- Cyrtocapsa tetrapera* Haeckel
Cyrtocapsa (*Cyrtocapsella*) *tetrapera* Haeckel 1887, p. 1512, pl. 78, fig. 5
Cyrtocapsella tetrapera Haeckel, Sanfilippo and Riedel 1970, p. 453, pl. 1, figs. 16-18; Sanfilippo et al. 1985, p. 670, figs. 16.1a, b
Cyrtocapsa tetrapera Haeckel, O'Connor 1997b, p. 111
- Diartus petterssoni* (Riedel and Sanfilippo)
Cannartus ? *petterssoni* conditional manuscript name proposed in Riedel and Funnell 1964, p. 310; Riedel and Sanfilippo 1970, p. 520, pl. 14, fig. 3
Diartus petterssoni (Riedel and Sanfilippo), Sanfilippo and Riedel 1980, p. 1010; Sanfilippo et al., 1985, p. 657, figs. 8.10a, b
- Dictyocephalus australis* Haeckel 1887, p. 1306, pl. 62, fig. 1; Nishimura 1990, p. 163, figs. 35.7a-9b
- Dictyocephalus mediterraneus* Haeckel
Dictyocephalus mediterraneus Haeckel 1887, p. 1307, pl. 62, fig. 2; Petrushevskaya 1969, figs. 8.7, 8.8
- Tricolocapsa papillosa mediterranea* (Haeckel), Petrushevskaya 1971b, figs. 91.VII, 91.VIII
- Dictyocephalus* sp. Nishimura 1990, p. 165, figs. 35.6a, b
- Dictyocephalus* sp. Petrushevskaya
Dictyocephalus sp. Petrushevskaya 1969, fig. 8.10
- Tricolocapsa* sp. B (Petrushevskaya), Petrushevskaya 1971b, fig. 91.IX
- Dictyoprora amphora* (Haeckel) group
Dictyocephalus amphora Haeckel 1877, p. 1305, pl. 62, fig. 4
Theocampe amphora (Haeckel) group, Foreman 1973, p. 431, pl. 8, figs. 7, 9-13

- Dictyoprora amphora* (Haeckel) group, Nigrini 1977, p. 250, pl. 4, figs. 1, 2
- Dictyoprora armadillo* (Ehrenberg)
Eucyrtidium armadillo Ehrenberg 1873, p. 225, 1875, p. 70, pl. 9, fig. 10
Thecampe armadillo (Ehrenberg) group, Riedel and Sanfilippo 1971, p. 1601, pl. 3E, figs. 3, 5 (*partim*)
Dictyoprora armadillo (Ehrenberg), Nigrini 1977, p. 250, pl. 4, fig. 4
- Dictyoprora mongolfieri* (Ehrenberg)
Eucyrtidium mongolfieri Ehrenberg 1854, pl. 36, fig. 18, B lower, 1873, p. 230
- Dictyoprora mongolfieri* (Ehrenberg), Nigrini 1977, p. 250, pl. 4, fig. 7; Sanfilippo et al. 1985, p. 702, figs. 33.1a-d; O'Connor 1993, p. 49, pl. 4, fig. 15, in press
- Thecampe mongolfieri* (Ehrenberg), Strong et al. 1995, p. 209, fig. 10P
- Dictyoprora ovata* (Haeckel)
Thecampe ovata Haeckel 1887, p. 1416, pl. 69, fig. 16
- Thecampe armadillo* (Ehrenberg) group, Riedel and Sanfilippo 1971, p. 1601, pl. 3E, figs. 4, 6 (*partim*)
- Dictyoprora ovata* (Haeckel), Nigrini 1977, p. 251, pl. 4, figs. 5, 6
- Dictyoprora physothorax* Caulet 1991, p. 535, pl. 3, fig. 11
- Dictyoprora pirum* (Ehrenberg)
Eucyrtidium pirum Ehrenberg 1873, p. 232, 1875, pl. 10, fig. 14
Dictyoprora pirum (Ehrenberg), Nigrini 1977, p. 251, pl. 4, fig. 8; Sanfilippo et al. 1985, p. 703, figs. 33.2a, b
- Dictyoprora urceolus* (Haeckel)
Dictyocephalus urceolus Haeckel 1887, p. 1305
Dictyoprora urceolus (Haeckel), Nigrini 1977, p. 251, pl. 4, figs. 9, 10; O'Connor 1993, p. 50, pl. 10, fig. 11, 1999, p. 32, pl. 9, fig. 44, in press
Thecampe urceolus (Haeckel), Strong et al. 1995, fig. 10Q
- Didymocyrtis antepenultima* (Riedel and Sanfilippo)
Panarium antepenultima conditional manuscript name proposed by Riedel and Funnell 1964, p. 311
Ommatartus antepenultimus Riedel and Sanfilippo 1970, p. 521, pl. 14, fig. 4
Didymocyrtis antepenultima (Riedel and Sanfilippo), Sanfilippo and Riedel 1980, p. 1010; Sanfilippo et al. 1985, p. 657, fig. 8.6
- Didymocyrtis penultima* (Riedel)
Panarium penultimum Riedel 1957, p. 76, pl. 1, fig. 1; Riedel and Funnell 1964, p. 311
Ommatartus penultimus (Riedel) *sensu stricto*, Riedel and Sanfilippo 1970, p. 521; Westberg and Riedel 1978, p. 22, pl. 2, figs. 6-8
Didymocyrtis penultima (Riedel), Sanfilippo and Riedel 1980, p. 1010; Sanfilippo et al. 1985, p. 658, figs. 8.7a, b
- Didymocyrtis prismatica* (Haeckel)
Pipettella prismatica Haeckel 1877, p. 305, pl. 39, fig. 6; Riedel 1959, p. 287, pl. 1, fig. 1
Pipettella tuba Haeckel 1887, p. 337, pl. 39, fig. 7
Cannartus prismaticus (Haeckel), Riedel and Sanfilippo 1970, p. 520, pl. 15, fig. 1
Didymocyrtis prismatica (Haeckel), Sanfilippo and Riedel 1980, p. 1010; Sanfilippo et al. 1985, p. 659, fig. 8.1; O'Connor 1993, p. 36, pl. 1, figs. 32, 33, in press
- Dorcadospyris alata* (Riedel)
Brachiospyris alata Riedel 1959, p. 293, pl. 1, figs. 11, 12
Dorcadospyris alata (Riedel), Riedel and Sanfilippo 1970, p. 523, pl. 14, fig. 5; Sanfilippo et al. 1985, p. 661, fig. 10.7
- Dorcadospyris ateuchus* (Ehrenberg)
Ceratospyrus ateuchus Ehrenberg 1873, p. 218, 1875, pl. 21, fig. 4D
Cantharospyrus ateuchus (Ehrenberg), Haeckel 1887, p. 1051; Riedel 1959, p. 294, pl. 22, figs. 3, 4
Dorcadospyris ateuchus (Ehrenberg), Riedel and Sanfilippo 1970, p. 523, pl. 15, fig. 4; Sanfilippo et al. 1985, p. 663, figs. 10.4a, b; O'Connor 1993, p. 43, pl. 3, figs. 11-13, in press
- Eucyrtidium papillosum* Ehrenberg
Eucyrtidium papillosum Ehrenberg 1872a, p. 310, 1872b, p. 293, pl. 7, fig. 10
Dictyocephalus papillosus (Ehrenberg), Riedel 1958, p. 236, text-fig. 8, pl. 3, fig. 10
Dictyocryphalus papillosus (Ehrenberg), Nigrini 1967, p. 63, pl. 6, fig. 6
Tricolocapsa papillosa (Ehrenberg), Petrushevskaya 1971b, fig. 91.X
- Eucyrtidium spinosum* Takemura 1992, p. 746, pl. 5, figs. 5-8; Takemura and Ling 1997, p. 113, pl. 1, fig. 10; Hollis et al. 1997, p. 61, pl. 5, figs. 28, 29; O'Connor 1999, p. 32, pl. 9, fig. 16
- Eusyringium fistuligerum* (Ehrenberg)
Eucyrtidium fistuligerum Ehrenberg 1873, p. 229, 1875, pl. 9, fig. 3
Eusyringium fistuligerum (Ehrenberg), Riedel and Sanfilippo 1970, p. 527, pl. 8, figs. 8, 9; Sanfilippo et al. 1985, p. 670, figs. 17.1a, b; O'Connor 1993, p. 74, pl. 8, figs. 15, 16; Strong et al. 1995, p. 208, figs. 11D, E; O'Connor in press, fig. 5C
- Eusyringium lagena* (Ehrenberg)
Lithopera lagena Ehrenberg 1873, p. 241, 1875, pl. 3, fig. 4
Eusyringium lagena (Ehrenberg), Riedel and Sanfilippo 1970, p. 527, pl. 8, figs. 5-7; Foreman 1973, p. 436, pl. 11, figs. 4, 5; Sanfilippo et al. 1985, p. 672, figs. 17.2a-c; Strong et al. 1995, p. 208, fig. 11C
- Heliodiscus inca* Clark and Campbell 1942, p. 38, pl. 3, fig. 17; Hollis et al. 1997, p. 45, pl. 1, figs. 25, 26; O'Connor 1999, p. 32, pl. 10, fig. 13
- Lithocyclia angusta* (Riedel)
Trigonactura ? angusta Riedel 1959, p. 292, pl. 1, fig. 6
Lithocyclia angustum (Riedel), Riedel and Sanfilippo 1970, p. 522, pl. 13, figs. 1, 2
Lithocyclia angusta (Riedel), Sanfilippo and Riedel 1973, p. 523; Sanfilippo et al. 1985, p. 653, figs. 7.3a-c; O'Connor 1993, p. 36, pl. 2, figs. 1, 2, in press
- Lithomelissa tricornis* Chen 1975, p. 458, pl. 8, figs. 6, 7
- Lophocyrtis (Cyclampterium) milowi* Riedel and Sanfilippo
Cyclampterium ? milowi Riedel and Sanfilippo 1971, p. 1593, pl. 3B, fig. 3, pl. 7, figs. 8, 9; 1978, p. 67, pl. 4, fig. 14; Ling 1975, p. 731, pl. 12, fig. 15
Lophocyrtis (Cyclampterium) milowi Riedel and Sanfilippo, Sanfilippo 1990, p. 306, pl. 1, figs. 13-16, pl. 2, figs. 1, 2
- Lophocyrtis (Paralampterium) dumitricai* Sanfilippo 1990, p. 308, pl. 3, figs. 7-13; O'Connor 1993, p. 74, pl. 8, figs. 18, 19; Strong et al. 1995, p. 208, fig. 11N; Hollis et al. 1997, p. 62, pl. 6, fig. 19; O'Connor in press
- Lophocyrtis (Paralampterium ?) galenum* Sanfilippo 1990, p. 308, pl. III, figs. 14, 15; O'Connor 1997a, pl. 9, fig. 6, 1997b, p. 114
- Lophocyrtis (Paralampterium ?) longiventer* (Chen)
Cyclampterium ? longiventer Chen 1975, p. 459, pl. 10, fig. 7
Lophocyrtis (Paralampterium ?) longiventer (Chen), Sanfilippo 1990, p. 309, pl. III, figs. 1-5; Strong et al. 1995, p. 208, fig. 11M; O'Connor 1999, p. 34, pl. 9, figs. 26-29, in press

- Lophocyrtis (Paralampterium)* sp. B O'Connor 1993, p. 75, pl. 8, fig. 22
- Lychnocanium amphitrite* (Foreman)
- Lychnocanoma amphitrite* Foreman 1973, p. 437, pl. 11, fig. 10; O'Connor 1993, p. 76, pl. 8, fig. 29; Strong et al. 1995, p. 208, figs. 11K, L
- Lychnocanium amphitrite* (Foreman), Hollis et al. 1977, p. 63, pl. 6, figs. 1-4; O'Connor 1999, p. 34, pl. 8, fig. 25, pl. 9, fig. 33, in press
- Lychnocanium elongatum* (Vinassa de Regny)
- Tetrahedrina elongata* Vinassa de Regny 1900, p. 243, pl. 2, fig. 31
- Lychnocanium bipes* Riedel 1959, p. 294, pl. 2, figs. 5, 6
- Lychnocanoma elongata* (Vinassa de Regny), Sanfilippo et al. 1973, p. 221, pl. 5, figs. 19, 20; Sanfilippo et al. 1985, p. 676, figs. 19.1a, b; O'Connor 1993, p. 76, pl. 11, fig. 3; Sanfilippo and Nigrini 1995, p. 282, pl. IV, fig. 11
- Lychnocanium elongata* (Vinassa de Regny), O'Connor 1997b, p. 114
- Lychnocanium elongatum* (Vinassa de Regny), O'Connor in press
- Lychnocanium trifolium* Riedel and Sanfilippo
- Lychnocanium trifolium* Riedel and Sanfilippo 1971, p. 1595, pl. 3B, fig. 12, pl. 8, figs. 2, 3; O'Connor in press
- Lychnocanoma trifolium* (Riedel and Sanfilippo), by implication in Sanfilippo et al. 1973, p. 221; Sanfilippo et al. 1985, p. 676, figs. 19.2a, b; O'Connor 1993, p. 76, pl. 11, figs. 4, 5
- Orbula discipulus* Foreman 1973, p. 438, pl. 3, fig. 10, pl. 10, figs. 9, 10
- Peritiviator ? dumitricai* Nishimura 1992, p. 328, pl. 1, figs. 13-16, pl. 11, figs. 11, 12
- Phormocyrtis* cf. *alexandrae* Hollis et al.
- Phormocyrtis* sp. O'Connor 1997b, pl.6, fig.5
- Phormocyrtis* cf. *alexandrae* Hollis et al. 1997, p.65; O'Connor in press
- Phormocyrtis striata striata* Brandt
- Phormocyrtis striata* Brandt in Wetzel 1935, p. 55, pl. 9, fig. 12; Riedel and Sanfilippo 1970, p. 532, pl. 10, fig. 7
- Phormocyrtis striata striata* Brandt, Foreman 1973, p. 438, pl. 7, figs. 5, 6, 9; Sanfilippo et al. 1985, p. 679, figs. 20.1a, b; O'Connor 1993, p. 78, pl. 9, fig. 8; Strong et al. 1995, p. 209, figs. 9O, P; O'Connor in press
- Phormostichoartus doliolum* (Riedel and Sanfilippo)
- Artostrobium doliolum* Riedel and Sanfilippo 1971, p. 1599, pl. 1H, figs. 1-3, pl. 8, figs. 14, 15
- Phormostichoartus doliolum* (Riedel and Sanfilippo), Nigrini 1977, p. 252, pl. 1, fig. 14; Sanfilippo et al. 1985, p. 704, figs. 34.1a-c
- Podocyrtis (Lampterium) chalara* Riedel and Sanfilippo 1970, p. 535, pl. 12, figs. 2, 3; Riedel and Sanfilippo 1978, p. 71, pl. 8, text-fig. 3; Sanfilippo et al. 1985, p. 697, fig. 30.11
- Podocyrtis (Lampterium) goetheana* (Haeckel)
- Cycladophora goetheana* Haeckel 1887, p. 1376, pl. 65, fig. 5
- Podocyrtis (Lampterium) goetheana* (Haeckel), Riedel and Sanfilippo 1970, p. 535; Sanfilippo et al. 1985, p. 697, fig. 30.12
- Podocyrtis (Lampterium) mitra* Ehrenberg
- Podocyrtis mitra* Ehrenberg 1854, pl. 36, fig. B20, 1873, p. 251; non Ehrenberg, 1875, pl. 15, fig. 4
- Podocyrtis (Lampterium) mitra* Ehrenberg, Riedel and Sanfilippo 1970, p. 534, pl. 11, figs. 5, 6; Riedel and Sanfilippo 1978, text-fig. 3; Sanfilippo et al. 1985, p. 698, fig. 30.10
- Podocyrtis (Podocyrtoges) ampla* Ehrenberg
- Podocyrtis ? ampla* Ehrenberg, 1873, p. 248, 1875, pl. 16, fig. 7
- Podocyrtis (Podocyrtis) ampla* Ehrenberg, Riedel and Sanfilippo 1970, p. 533, pl. 12, figs. 7, 8; Sanfilippo et al. 1985, p. 695, fig. 30.4
- Podocyrtis (Podocyrtoges) ampla* Ehrenberg, Sanfilippo and Riedel 1992, p. 14, pl. 5, fig. 4
- Prunopyle fragilis* (Stöhr)
- Ommatodiscus fragilis* Stöhr 1880, p. 116, pl. 6, fig. 10
- Prunopyle fragilis* (Stöhr), Crouch and Hollis 1996, p. 26; Hollis et al. 1997, p. 47, pl. 2, figs. 28, 29; O'Connor 1999, p. 36, pl. 8, fig. 8, in press
- Prunopyle monikae* (Petrushevskaya)
- Lithocarpium monikae* Petrushevskaya 1975, p. 572, pl.4, figs. 6-10, pl. 30, figs. 1-7
- Prunopyle monikae* (Petrushevskaya), Caulet 1991, p. 539
- Prunopyle polyacantha* Campbell and Clark
- Prunopyle polyacantha* Campbell and Clark 1944, p. 30, pl. 5, figs.4-6 (*partim*); Hollis et al. 1997, p. 48, pl. 2, figs. 25-27; O'Connor 1999, p. 36, pl. 10, fig. 18, in press
- Lithocarpium polyacantha* (Campbell and Clark), Petrushevskaya 1975, p. 572, pl. 3, figs. 6-8 (*partim*); O'Connor 1993, p. 37, pl. 2, figs. 12, 13
- Pseudodictyophimus gracilipes* (Bailey)
- Dictyophimus gracilipes*, Bailey 1856, p. 4, pl. 1, fig. 8
- Pseudodictyophimus gracilipes* (Bailey), Petrushevskaya 1971b, p. 93, figs. 47-49; Hollis et al. 1997, p. 53, pl. 3, fig. 27; O'Connor 1999, p. 36, pl. 9, fig. 38, in press
- Pterocanium audax* (Riedel)
- Lychnodictyum audax* Riedel 1953, p. 810, pl. 85, fig. 9; Sanfilippo and Riedel 1974, p. 1022, pl. 2, fig. 8; Sanfilippo et al. 1985, p. 677, fig. 21.2; O'Connor 1993, p. 77, pl. 9, figs. 4, 5
- Pterocanium audax* (Riedel), Lazarus et al. 1985, p. 202, figs. 19.1-4, 20.1, 2; O'Connor 1997b, p. 116, in press
- Pterocanium ? gigas* Nishimura 1992, p. 348, pl. 7, figs.9, 10, pl. 13, fig. 7
- Pterocanium prismatium* Riedel 1957, p. 87, pl. 3, figs. 4, 5; emend. Riedel and Sanfilippo 1970, p. 529; Sanfilippo et al. 1985, p. 679, figs. 21.1a, b
- Pterocanium ? procerum* Nishimura 1992, p. 348, pl. 7, figs. 1-3, pl. 13, fig.3
- Pterocodon ? ampla* (Brandt)
- Theocyrtis ampla* Brandt in Wetzel 1935, p. 56, pl. 9, figs. 13-15
- Pterocodon ? ampla* (Brandt), Foreman 1973, p. 438, pl. 5, figs. 3-5
- Pterocodon ? poculum* Nishimura 1992, p. 350, pl. 8, figs. 1-3, pl. 13, fig. 3
- Spongodiscus nitidus* (Sanfilippo and Riedel)
- Stylotrochus nitidus* Sanfilippo and Riedel 1973 p.525, pl.13, figs.9-14, pl.30, figs.7-10
- Spongodiscus nitidus* (Sanfilippo and Riedel), O'Connor 1999, p. 38, pl. 8, fig. 16, in press
- Stichocorys delmontensis* (Campbell and Clark)
- Eucyrtidium delmontense* Campbell and Clark 1944, p. 56, pl. 7, figs. 19, 20
- Stichocorys delmontensis* (Campbell and Clark), Sanfilippo and Riedel 1970, p. 451, pl. 1, fig. 9; Sanfilippo et al. 1985, p. 681, figs. 23.1a, b; O'Connor 1997b, p. 116
- Stichocorys peregrina* (Riedel)
- Eucyrtidium elongatum peregrinum* Riedel 1953, p. 812, pl. 85, fig. 2, 1957, p. 94
- Stichocorys peregrina* (Riedel), Sanfilippo and Riedel 1970, p. 451, pl. 1, fig. 10; Sanfilippo et al. 1985, p. 682, fig. 23.2

- Stichocorys wolffii* Haeckel 1887, p. 1479, pl. 80, fig. 10;
Riedel 1957, p. 92, pl. 4, figs. 6, 7; Sanfilippo et al. 1985,
p. 682, figs. 23.3a, b
- Stylatractus universus* Hays [= *Axoprimum angelinum* (Campbell and Clark)]
- Stylatractus* sp. Hays 1965, p. 167, pl. 1, fig. 6
- Stylatractus universus* Hays 1970, p. 215, pl. 1, figs. 1, 2
- Theocampe ? stathmepora* Foreman 1968, p. 54, pl. 6, fig. 16
- Theocotyle cryptocephala* (Ehrenberg)
Eucyrtidium cryptocephalum Ehrenberg 1873, p. 227,
1875, pl. 11, fig. 11
- Theocotyle cryptocephala* (Ehrenberg), Sanfilippo and Riedel
1982, p. 178, pl. 2, figs. 4-7; Sanfilippo et al. 1985, p.
685, figs. 25.2a, b
- Theocyrtis ? annikae* Nishimura 1992, p. 356, pl. 7, figs. 4-6
- Theocyrtis tuberosa* Riedel 1959, p. 298, figs. 10, 11; emend.
Sanfilippo et al. 1985, p. 701, figs. 32.1a-d; O'Connor
1993, p. 70, pl. 7, figs. 21, 2, in press
- Thyrsoyrtis (Pentalacorys) triacantha* (Ehrenberg)
Podocyrtis triacantha Ehrenberg 1873, p. 254, 1875, pl.
13, fig. 4
- Thyrsoyrtis triacantha* (Ehrenberg), Riedel and
Sanfilippo 1970, p. 526, pl. 8, figs. 2, 3
- Thyrsoyrtis (Pentalacorys) triacantha* (Ehrenberg),
Sanfilippo and Riedel 1982, p. 176, pl. 1, figs. 8-10, pl. 3,
figs. 3, 4; Sanfilippo et al. 1985, p. 690, figs. 26.7a, b
- Thyrsoyrtis (Thyrsoyrtis) bromia* Ehrenberg
Thyrsoyrtis bromia Ehrenberg 1873, p. 260, 1875, pl. 12,
fig. 2
- Thyrsoyrtis (Thyrsoyrtis) bromia* Ehrenberg, Sanfilippo
and Riedel 1982, p. 172, pl. 1, figs. 17-20; Sanfilippo et
al. 1985, p. 687, figs. 26.4a, b
- Tristylospyris tricerus* (Ehrenberg)
- Ceratospyris tricerus* Ehrenberg 1873, p. 220, 1875, pl.
21, fig. 5
- Tristylospyris tricerus* (Ehrenberg), Haeckel 1887, p.
1033; Riedel 1959, p. 292, pl. 1, figs. 7, 8; Sanfilippo et
al. 1985, p. 665, figs. 10.3a, b; O'Connor 1993, p. 47, pl.
3, figs. 27, 28, 1999, p. 40, pl. 8, fig. 26, in press
- Zealithapium anoectum* (Riedel and Sanfilippo)
Lithapium ? anoectum Riedel and Sanfilippo, 1970, p. 520,
pl. 4, figs. 4, 5
- Lithapium anoectum* Riedel and Sanfilippo, Sanfilippo and
Riedel 1973, p. 516, pl. 24, figs. 6, 7; Strong et al. 1995,
p. 208
- Zealithapium anoectum* (Riedel and Sanfilippo), O'Connor
1999, p. 5, 6, pl. 9, fig. 47
- Zealithapium mitra* (Ehrenberg)
Cornutella mitra Ehrenberg 1873, p. 221, 1875, pl. 2, fig.
8
- Lithapium ? mitra* (Ehrenberg), Riedel and Sanfilippo
1970, 520, pl. 4, figs. 6, 7
- Lithapium mitra* (Ehrenberg), Sanfilippo and Riedel 1973,
p. 516; Nishimura 1990, p. 156, figs. 2a-7b; Strong et al.
1995, p. 208, fig. 11Z; Hollis et al. 1997, p. 45, pl. 1, fig.
20
- Zealithapium mitra* (Ehrenberg), O'Connor 1999, p. 5, 6,
pl. 9, fig. 47
- Zealithapium plegmacantha* (Riedel and Sanfilippo)
Lithapium ? plegmacantha Riedel and Sanfilippo 1970, p.
520, pl. 4, figs. 2, 3
- Lithapium plegmacantha* Riedel and Sanfilippo,
Sanfilippo and Riedel 1973, p. 516, pl. 3, figs. 1, 2, pl. 24,
figs. 8, 9
- Lithapium ? sp.* Nishimura 1990, p. 156, figs. 33.8a, b
- Zealithapium plegmacantha* (Riedel and Sanfilippo),
O'Connor 1999, p. 5, 6