5. MIOCENE–PLIOCENE RADIOLARIANS FROM LEG 145, NORTH PACIFIC[1]

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ABSTRACT

Studies of radiolarian assemblages from holes drilled during Leg 145 have revealed the distribution pattern of species in the Miocene–Pliocene deposits of the North Pacific. A brief revision of the application of biostratigraphic zones *Stichocorys peregrina* (Riedel and Sanfilippo, 1970, 1978) and *Sphaeropyle langii* (Foreman, 1975) in the North Pacific has been conducted. A new Miocene–Pliocene zonation based on radiolarians is proposed, which is correlated with diatom biostratigraphic zones and paleomagnetic evidence. New species *Acrospyris lingi* and *Cenosphaera coronataformis* are described.

INTRODUCTION

By now, abundant material has been collected on Miocene–Pliocene radiolarian assemblages from the North Pacific. These include the works on California (Campbell and Clark, 1944; Casey, 1972; Weaver et al., 1981; Kling, 1977; Perez-Guzman, 1985), on Japan (Nakaseko, 1963; Nakaseko and Sugano, 1973; Funayama, 1988), on the far east of Russia (Runeva, 1984; Tochilina et al., 1988; Vituchin, 1992; Shastina, 1993), and the results of the Deep Sea Drilling Project (DSDP) (Kling, 1971, 1973; Ling, 1973, 1980; Foreman, 1975; Sakai, 1980; Reynolds, 1980; Wolfart, 1981; Morley, 1985).

In the course of fulfilling the objectives of Ocean Drilling Program (ODP) Leg 145 in the North Pacific, holes were drilled that penetrated Miocene–Pliocene deposits, with well-preserved radiolarian assemblages. Enclosing deposits for radiolarian assemblages are diatomaceous oozes and carbonate sediments.

Samples from Sites 882, 883, 884, and 887 were studied and a zonal biostratigraphic chart based on radiolarians was proposed. It can be successfully used for biostratigraphy in other holes from Leg 145.

The materials obtained are significant, possibly unique, for a Miocene–Pliocene biostratigraphy of the North Pacific based on radiolarians. This is because they contain: (1) well-preserved radiolarian assemblages; (2) complete sections (therefore, the zonation developed for Sites 883 and 884 can have a stratotype character); and (3) distinct biostratigraphic zones that can be correlated with diatom zones and magnostratigraphy (Rea, Basov, Janecek, Palmer-Julson, et al., 1993).

PROCEDURES

The method used to process samples for radiolarian analysis, as well as to characterize the preservation and abundance of radiolarians is described in the paper "Eocene-Oligocene Radiolarians from Leg 145" (Shilov, this volume).

BIOSTRATIGRAPHY

The biostratigraphic interpretation of deep-sea drilling materials on Miocene–Pliocene radiolarians for the North Pacific was commonly associated with the use of zonal charts proposed by Hays (1970) for the Pliocene–Pleistocene, by Foreman (1975) for the Pliocene, and by Riedel and Sanfilippo (1970, 1978) and by Sanfilippo et al. (1985) for the Miocene–Pliocene, which were developed for the tropical areas of the world's oceans. The application of the Riedel and Sanfilippo Miocene–Pliocene zonal chart to interpret drilling materials of Leg 145 has other limitations. For instance, the species *Stichocorys delmontensis,* which defines the base of the *S. delmontensis* Zone of Riedel and Sanfilippo, appears in Sample 145-887C-25H-CC (*D. dimorpha* Zone), in Sample 145-887A-23H-CC (*D. katayamae* Zone), and Sample 145-884B-64X-CC (*A. ingens* Zone). In tropical areas, this zone is much older than its first occurrence (FO) (20.6 Ma), whereas in the North Pacific it corresponds to the *T. fraga* Zone.

Commonly, to interpret borehole sections of deep-sea drilling in the North Pacific, two zones, *Stichocorys peregrina* (Riedel and Sanfilippo, 1970, 1978) and *Sphaeropyle langii* (Foreman, 1975) (first distinguished in DSDP Site 310, 31°N), were used for the late Miocene–Pliocene. During the study of the Leg 145 materials, there were a great number of difficulties in distinguishing these zones and drawing their boundaries.

The lower boundary of the *Stichocorys peregrina* Zone is drawn on the basis of the evolutionary transition of *Stichocorys delmontensis* into *Stichocorys peregrina;* the upper boundary is drawn from the appearance of *Sphaeropyle langii* (Foreman, 1975). In the North Pacific, the evolutionary transition *S. delmontensis–S. peregrina* has vague boundaries, extending from the middle to the late Miocene *Dorcadospyris alata* Zone (Sakai, 1980) and the *Didymocyrtis antepenultima–Didymocyrtis penultima* Zone (Wolfaart, 1981), whereas in the tropical areas, it appears in the late Miocene (Riedel and Sanfilippo, 1970, 1978).

The taxonomic characteristic of the species, described in the North Pacific as *Stichocorys elongatum peregrina* (Riedel), is not quite clear. Kling (1973) presumes that this is possibly a subspecies of the species *Stichocorys peregrina;* Nakaseko (1963) assigns a similar form to *Stichocorys delmontensis* Campbell and Clark. Petrushevskaya (1975) suggests (for the Antarctic area) assigning a similar form to *Cyrtocapsella cylindroides* Principi. Sanfilippo (1988) has provided an illustration of the species *Stichocorys peregrina* for low and high latitudes that differs from the one discovered in the North Pacific. Weaver et al. (1981) and Perez-Guzman (1985) give illustrations of the warm-water and cold-water *Stichocorys peregrina* (in Leg 145, these forms are discovered in Sample 145-883B-47H-CC). A cold form is typical of the species *Lithocampe subligata* Stohr (Petrushevskaya and Kozlova, 1972). Therefore, the interpretation of the species described for the North Pacific as *Stichocorys elongatum peregrina* is not unambiguous. Its abundance in sections of Leg 145 is generally low; elevated numbers are seen in only certain samples. Thus, the use of this species for biostratigraphic purposes in the North Pacific is very difficult since it does not conform to the requirements imposed on zonal species (Hollis, 1976).

We should also like to make similar remarks concerning the *Sphaeropyle langii* Zone (Foreman, 1975). The species *Sphaeropyle langii*

[1] Rea, D.K., Basov, I.A., Scholl, D.W., and Allan, J.F. (Eds.), 1995. *Proc. ODP, Sci. Results,* 145: College Station, TX (Ocean Drilling Program).

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Dreyer can be interpreted in different ways: Dreyer (1889) categorized it as a holotype, and Kling (1973), Riedel and Westberg-Smith (1984), and Petrushevskaya and Kozlova (1972) described it from one side. Foreman (1975) introduced an additional feature of species difference from *Sphaeropyle robusta* Kling. The age correlation of the FO of *Sphaeropyle langii* is also different: the early Miocene–Pliocene (Petrushevskaya and Kozlova, 1972), Pleistocene (Kling, 1973), and Pliocene–Pleistocene (Foreman, 1975) are taken from data on one hole; and the Miocene–Pleistocene, from the Leg 145 data.

In sediments from Leg 145 holes, the abundance of the species is low and irregular in the pre-Pleistocene part of the section and is common in the Pleistocene. Problems connected with the identification of *Stichocorys peregrina* in the North Pacific do not allow a reliable use of the last occurrence (LO) of a species as an event, defining the lower boundary of the *Androcyclas (Lamprocyclas) heteroporos* Zone (Hays, 1970).

During Leg 145, while interpreting samples containing radiolarian assemblages, an attempt was made to use the zonation developed by Reynolds (1980). Of all the zones proposed by Reynolds, only the *Eucyrtidium inflatum* Zone can be used in the study of geological sections. Funajama (1988), in using this zone to interpret materials from the Miocene sections of the Isles of Japan, distinguished two more zones there (i.e., *Eucyrtidium asanoi* and *Lychnocanium nipponicum magnacornutum*).

During the study of the Miocene–Pliocene radiolarian assemblages from the sections of Leg 145 holes, the following biostratigraphic zonation based on radiolarians was proposed for deposits of this age range:

Diplocyclas cornutoides Interval Zone (new)

Age. Late Pliocene.
Diatom zones. *N. kamtschatica–N. koizumii* and *N. koizumii–A. oculatus.*
Paleomagnetic epoch. Matuyama–Gauss.
Base. FO *Diplocyclas davisiana.*
Top. FO *Fucyrtidium matuyamai.*
Assemblage. This zone contains the following species: *Diplocyclas davisiana, Doplocyclas cornutoides, Stylosphaera angelina, Androcyclas heteroporos,* and *Axoprunum acquilonius.*

Axoprunum acquilonius Interval Zone (new)

Age. Early Pliocene.
Diatom zones. *N. kamtschatica* subzone b–c; *N. kamtschatica–N. koizumii.*
Paleomagnetic epoch. Gauss–Gilbert.
Base. LO *Lipmanella redondoensis.*
Top. FO *Diplocyclas davisiana.*
Assemblage. This zone contains the following species: *Diplocyclas cornutoides, Stylosphaera angelina, Axoprunum acquilonius, Sphaeropyle robusta,* and *Androcyclas heteroporos* (FO).

Axoprunum acquilonius–Lipmanella redondoensis Interval Zone (new)

Age. Late Miocene–early Pliocene.
Diatom zones. *N. kamtschatica* subzone a–*N. kamtschatica* subzone b–c.
Paleomagnetic epoch. Gilbert–Chron 3B.
Base. FO *Axoprunum acquilonius.*
Top. LO *Lipmanella redondoensis.*
Assemblage. This zone contains the following species: *Diplocyclas cornutoides, Stylosphaera angelina, Axoprunum acquilonius, Sphaeropyle robusta, Lipmanella redondoensis,* and *Stichocorys delmontensis.*

Limpanella redondoensis Interval Zone (Reynolds, 1980) (new range)

Reynolds distinguished this zone, which fully coincides with the *Stichocorys peregrina* Zone (Foreman, 1975). To distinguish the zone, he did not use the characteristic species but its varieties.
Age. Late Miocene.
Diatom zones. *D. katayamae–T. schrederi–N. kamtschatica subzone a.*
Paleomagnetic epoch. Chron 3B–Chron 4.
Base. LO Lychnocanium nipponicum magnocornutum.
Top. FO *Axoprunum acquilonius.*
Assemblage. This zone contains the following species: *Lipmanella redondoensis, Stylosphaera angelina, Sphaeropyle robusta, Cornytella profunda, Stichocorys delmontensis,* and *Lychnocanium nipponicum.*

Lychnocanium nipponicum magnacornutum Range Zone (Funayama, 1988)

Age. Middle–late Miocene.
Diatom zones. *D. praedimorpha–T. yabej–D. dimorpha–D. katayamae.*
Paleomagnetic epoch. Chron 4–Chron 5A.
Base. FO *Lychnocanium nipponicum magnacornutum.*
Top. LO *Lychnocanium nipponicum magnacornutum.*
Assemblage. This zone contains the following species: *Lychnocanium nipponicum, Lychonocanium nipponicum magnacornutum, Stylosphaera angelina, Lipmanella redondoensis, Lithocarpium polyacantha, Sphaeropyle robusta,* and *Cyrtocapsella japonica.*

Eucyrtidium inflatum Interval Zone (Funayama, 1988)

Age. Middle Miocene.
Diatom zones. *D. hyalina–C. nicobarica–D. praedimorpha.*
Paleomagnetic epoch. Chron 5A–Chron 5AD.
Base. FO *Eucyrtidium inflatum.*
Top. FO *Lychonocanium nipponicum magnacornutum.*
Assemblage. This zone contains the following species: *Eucyrtidium inflatum, Eucurtidium asanoi, Eucyrtidium ciencowskii* gr., *Stylosphaera angelina, Sphaeropyle robusta, Lipmanella redondoensis, Lithocarpium polyacantha,* and *Cyrtocapsella japonica.*

Eucyrtidium asanoi Interval Zone (Funayama, 1988)

Age. Middle Miocene.
Diatom zones. *D. lauta–D. hyalina.*
Paleomagnetic epoch. Chron 5B.
Base. FO *Eucyrtidium asanoi.*
Top. FO *Eucyrtidium inflatum.*
Assemblage. This zone contains the following species: *Eucyrtidium asanoi, Lipmanella redondoensis, Stylosphaera angelina, Cyrtocapsella tetrapera,* and *Cyrtocapsella cornuta.*

Acrospyris lingi Interval Zone (new)

Age. Early Miocene.
Diatom zones. *D. praelauta–D. lauta.*
Paleomagnetic epoch. Chron 5B–Chron 5C.
Base. FO *Acrosphyris lingi.*
Top. FO *Eucyrtidium asanoi.*
Assemblage. This zone contains the following species: *Acrospyris lingi, Lipmanella redondoensis, Stylosphaera angelina, Cyrtocapsella tetrapera, Cyrtocapsella cornuta, Cyrtocapsella japonica, Stichocorys diploconus,* and *Amphymenium amphistylium.*

Lithocampe subligata Interval Zone (new)

Age. Early Miocene.
Diatom zones. *A. ingens.*
Paleomagnetic epoch. Chron 5C.
Base. LO *Cenosphaera coronataformis.*
Top. FO *Acrospyris lingi.*
Assemblage. This zone contains the following species: *Lithocampe subligata, Cyrtocapsella tetrapera, Cyrtocapsella cornuta, Stylosphaera angelina,* and *Stichocorys diploconus.*

Cenosphaera coronataformis Range Zone (new)

Age. Early Miocene.
Diatom zones. *T. fraga–A. ingens.*
Paleomagnetic epoch. Chron 5D–Chron 6A.
Base. FO *Cenosphaera coronataformis.*
Top. LO *Cenosphaera coronataformis.*
Assemblage. This zone contains the following species: *Cenosphaera coronataformis, Cenosphaera coronata, Cyrtocapsella tetrapera, Cyrtocapsella cornuta,* and *Stylosphaera angelina.*

Cenosphaera coronata Interval Zone (new)

Age. Upper part of late Oligocene–early Miocene.
Diatom zones. *R. gelida–T. spinosa–T. fraga.*
Paleomagnetic epoch. Chron 6C–Chron 6A.
Base. FO *Cenosphaera coronataformis.*
Top. FO *Cenosphaera coronata.*
Assemblage. This zone contains the following species: *Cenosphaera coronata, Cyrtocapsella tetrapera, Cyrtocapsella cornuta, Lithocarpium titan,* and *Stylosphaera angelina.*

RADIOLARIANS IN EACH HOLE

Hole 882A

Hole 882A (Table 1) is located at 50°21.797′N, 167°35.999′E, in a water depth of 3243 m. The upper Miocene–Pliocene deposits were penetrated. The interval between Samples 145-882A-9H-CC and -10H-CC yielded a radiolarian assemblage from the *Diplocyclas cornutoides* Zone. The abundance of species ranged from few to common, preservation was good to moderate. The interval between Samples 145-882A-11H-CC and -35H-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius* Zone. The abundance of species was rare, and the preservation was good to moderate. This interval contained redeposited species *Lipmanella redondoensis*. The interval between Samples 145-882A-36H-CC and -42H-CC yielded a radiolarian assemblage from the *Axoprunum aquilonius* to *Lipmanella redondoensis* zones. The abundance of species was rare, and the preservation was good to moderate.

Hole 882B

Hole 882B (Table 2) is located at 50°21.798′N, 167°35.976′E, in a water depth of 3255 m. Pliocene deposits were penetrated. The interval between Samples 145-882B-10H-CC and -11H-CC yielded a radiolarian assemblage from the *Diplocyclas cornutoides* Zone. The abundance of species ranged from rare to common, and preservation ranged from good to moderate. The interval between Samples 145-882B-12H-CC and -29H-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius* Zone. The abundance of species was rare, and preservation ranged from good to moderate.

Hole 883B

Hole 883B (Table 3) is located at 51°11.908′N, 167°46.128′E, in a water depth of 2395 m. Upper Oligocene–Pliocene deposits were penetrated. The interval between Samples 145-883B-8H-CC and -12H-CC yielded a radiolarian assemblage from the *Diplocyclas cornutoides* Zone. The abundance of species ranged from rare to abundant, and preservation ranged from good to moderate. The interval between Samples 145-883B-13H-CC and -33H-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius* Zone. The abundance of species was rare, and preservation ranged from good to moderate. The interval between Samples 145-883B-34H-CC and -47H-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius–Lipmanella redondoensis* Zone. The abundance of the species was rare, and preservation ranged from good to moderate. The interval between Samples 145-883B-48X-CC and -54X-CC yielded a radiolarian assemblage from the *Lipmanella redondoensis* Zone. The abundance of the species was rare, and preservation ranged from good to moderate. The interval between Samples 145-883B-55X-CC and -57X-CC yielded a radiolarian assemblage from the *Lychnocanium nipponicum magnocornutum* Zone. The abundance of the species was rare, and preservation ranged from good to moderate. The Core 883B-58X yielded a radiolarian assemblage from the *Eucyrtidium inflatum* Zone. The species was abundant, and preservation was moderate. The interval between Samples 145-883B-59X-CC and -60X-CC yielded a radiolarian assemblage from the *Eucyrtidium asanoi* Zone. The abundance of species was abundant, and preservation was good. The interval between Samples 145-883B-61X-CC and -62X-CC yielded a radiolarian assemblage from the *Acrospyris lingi* Zone. The species was abundant, and preservation ranged from good to moderate. Sample 145-883B-63X-CC yielded a radiolarian assemblage from the *Lithocampe subligata* Zone. The species was abundant, and preservation was good. The interval between Samples 145-883B-64X-CC and -65X-CC yielded a radiolarian assemblage from the *Cenosphaera coronataformis* Zone. The abundance of the species was common to abundant, and preservation was moderate. The interval between Samples 145-883B-66X-CC and -68X-CC yielded a radiolarian assemblage from the *Cenosphaera coronata* Zone. The abundance of the species ranged from rare to abundant, and preservation ranged from good to moderate.

Hole 883C

Hole 883C (Table 4) is located at 51°11.919′N, 167°46.123′E, in a water depth of 2385 m. Upper Miocene–Pliocene deposits were penetrated. The interval between Samples 145-883C-9H-CC and -13H-CC yielded a radiolarian assemblage from the *Diplocyclas cornutoides* Zone. The abundance of the species was rare to abundant, and preservation ranged from good to moderate. The interval between Samples 145-883C-14H-CC and -34X-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius* Zone. The abundance of the species was rare, and preservation ranged from good to moderate. The interval between Samples 145-883C-35X-CC and -38X-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius–Lipmanella redondoensis* Zone. The abundance of the species was rare, and preservation was moderate.

Hole 883E

Hole 883E is located at 51°11.917′N, 167°46.098′E, in a water depth of 2385 m. Lower–middle Miocene deposits were penetrated. Sample 145-883E-1R-CC yielded a radiolarian assemblage from the *Eucyrtidium inflatum*? Zone. The abundance of the species was common, and preservation was moderate. The interval between Samples 145-883E-2R-CC and -3R-CC yielded a radiolarian assemblage from the radiolarian *Cenosphaera coronata* Zone. The abundance of the species was rare, and preservation was poor.

Hole 884B

Hole 884B (Table 5) is located at 51°27.026′N, 168°20.228′E, in a water depth of 3836 m. Upper Oligocene–Pliocene deposits were penetrated. The interval between Samples 145-884B-12X-CC and -15X-CC yielded a radiolarian assemblage from the *Diplocyclas cornutoides* Zone. The abundance of the species ranged from abundant to rare, and preservation ranged from poor to good. The interval between Samples 145-884B-16X-CC and -33X-CC yielded a radiolarian assemblage of the *Axoprunum acquilonius* Zone. The abundance of the species was rare, and preservation ranged from good to moderate. The interval between Samples 145-884B-34X-CC and -40X-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius–Lipmanella redondoensis* Zone. The abundance of the species was rare, and preservation ranged from poor to good. The interval between Samples 145-884B-41X-CC and -47X-CC yielded a radiolarian assemblage from the *Lipmanella redondoensis* Zone. The abundance of the species was rare, and preservation ranged from good to moderate. The interval between Samples 145-884B-48X-CC and -57X-CC yielded a radiolarian assemblage from the *Lychnocanium nipponicum magnacornutum* Zone. The abundance of the species ranged from rare to abundant, and preservation ranged from poor to good. Sample 145-884B-58X-CC yielded a radiolarian assemblage from the *Eucyrtidium inflatum* Zone. The abundance of the species was common, and preservation was moderate. The interval between Samples 145-884B-59X-CC and -61X-CC yielded a radiolarian assemblage of the *Eucyrtidium asanoi* Zone. The abundance of the species ranged from rare to abundant, and preservation ranged from poor to moderate. The interval between Samples 145-884B-62X-CC and -63X-CC yielded a radiolarian assemblage from the *Acrospyris lingi* Zone. The species was abundant, and preservation was good. The *Lithocampe subligata* Zone is not present. The interval between Samples 145-884B-64X-CC and -65X-CC yielded a radiolarian assemblage from the *Cenosphaera coronataformis* Zone. The abundance of the species ranged from few to common, and preservation ranged from poor to moderate. The interval between Samples 145-884B-66X-2, 103 cm, and -68X-CC yielded a radiolarian assemblage from the *Cenosphaera coronata* Zone. The

Table 1. Radiolarians at Hole 882A.

Age	Late Pliocene									Early Pliocene																		Late Miocene						
Radiolarian zones	K		J																									I						
Core, section, interval (cm)	9H-CC	10H-CC	11H-CC	12H-CC	13H-CC	14H-CC	15H-CC	16H-CC	17H-CC	18H-CC	19H-CC	20H-CC	21H-CC	22H-CC	23H-CC	24H-CC	25H-CC	26H-CC	27H-CC	28H-CC	29H-CC	30H-CC	31H-CC	32H-CC	33H-CC	34H-CC	35H-CC	36H-CC	37H-CC	38H-CC	39H-CC	40H-CC	41H-CC	42H-CC
Abundance	A	F	R	R	F	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F	R	F	R	R	R	R	R	R
Preservation	G	M	G	G	G	G	G	G	M	M	M	M	M	M	M	G	G	G	G	G	G	G	G	G	G	G	G	G	M	G	G	G	G	G
Cenosphaera coronataformis																																		
Acrospyris lingi																																		
Amphymenium amphistylium gr.																																		
Axoprunum acquilonius	C	R		R	F	R	R	R		R	R	R	R				R									F	R	F	R	R	R	R	R	R
Axoprunum bispiculum																																		
Botryostrobus aquilonaris	R								R		R	R	R	R	R	R															R		R	R
Botryostrobus auritus/australis	R	R	R			R										R		R	R		R		R	R		R						R		
Botryostrobus bramlettei																																		
Cenosphaera coronata																																		
Cornutella profunda			R													R	R	R										R	R		R		R	R
Cyrtocapsella cornuta																																		
Cyrtocapsella japonica																																		
Cyrtocapsella tetrapera	R*		R*																															
Clathrocyclas bicornis gr.																																		
Diplocyclas cornutoides	A	F			R				F	R		R	R	R	R	R	R	R	R	R	R	R	R							R	R			
Diplocyclas davisiana	A	F																																
Eucyrtidium asanoi																																		
Eucyrtidium calvertense																																		
Eucyrtidium inflatum																																		
Eucyrtidium cienkowskii	R																																	
Androcyclas heteroporos																			R						R		R							
Androcyclas neoheteroporos																																		
Lychnocanium nipponicum																									R	R		R	R					
Lychnocanium nipponicum magnacornutum																																		
Lithocampe subligata																																		
Lithocarpium polyacantha gr.																																		
Lithocarpium titan																												R						
Sphaeropyle langii																																		
Sphaeropyle robusta	R										R													R	R			R			R	R		
Stichocorys delmontensis																										R?		R					R	
Stichocorys sp. P												R			R		R								R	R		R			R	R	R	R
Stichocorys wolffii																																		
Stichocorys diploconus																																		
Stylosphaera angelina	C			R	R	R	R	R	R	R	F	R		R		R		R						R	R	R	R	R	R	R	F		R	R
Lipmanella redondoensis																					R*		R*			R*		R			R		R	R

Notes: Radiolarian zones: K = *Diplocyclas cornutoides;* J = *Axoprunum acquilonius*; I = *Axoprunum acquilonius–Lipmanella redondoensis.* Abundance and Preservation: A = abundant; C = common; F = frequent; R = rare; G = good; M = moderate; * = reworked.

Table 2. Radiolarians at Hole 882B.

Age	Late Pliocene									Early Pliocene										
Radiolarian zones	K			J																
Core, section	10H-CC	11H-CC	12H-CC	13H-CC	14H-CC	15H-CC	16H-CC	17H-CC	18H-CC	19H-CC	20H-CC	21H-CC	22H-CC	23H-CC	24H-CC	25H-CC	26H-CC	27H-CC	28H-CC	29H-CC
Abundance	C	C	R	R	B	B	R	R	R	R	R	R	R	R	R	R	R	R	R	F
Preservation	G	M	M	M			G	G	G	G	G	G	G	G	G	G	M	G	M	M
Cenosphaera coronataformis																				
Acrospyris lingi																				
Amphymenium amphistylium gr.																				
Axoprunum acquilonius	C	F	R	R				R		R		R	R	R	R	F	R	R	R	F
Axoprunum bispiculum																				
Botryostrobus aquilonaris		R																		
Botryostrobus auritus/australis									R		R	R	R		R					
Botryostrobus bramlettei																				
Cenosphaera coronata																				
Cornutella profunda											R	R								
Cyrtocapsella cornuta																				
Cyrtocapsella japonica																				
Cyrtocapsella tetrapera																				
Clathrocyclas bicornis gr.																		R		
Diplocyclas cornutoides	F-C	R-F	R	R			R				R					R			R	F
Diplocyclas davisiana	F-C	R																		
Eucyrtidium asanoi																				
Eucyrtidium calvertense																				
Eucyrtidium inflatum																				
Eucyrtidium cienkowskii																	R			
Androcyclas heteroporos	R	R														R				
Androcyclas neoheteroporos																				
Lychnocanium nipponicum											R*		R*							R
Lychnocanium nipponicum magnacornutum																				
Lithocampe subligata																				
Lithocarpium polyacantha gr.																				
Lithocarpium titan																				
Sphaeropyle langii							R				R									
Sphaeropyle robusta	F												R			R	R			R
Stichocorys delmontensis							R?											R?		
Stichocorys sp. P	R	R							R								R	R		R
Stichocorys wolffii																				
Stichocorys diploconus																				
Stylosphaera angelina	F	R	R				R		R			R		R	R	R	R	R	R	F
Lipmanella redondoensis											R*						R*			

Notes: Radiolarian zones: K = *Diplocyclas cornutoides;* J = *Axoprunum acquilonius*; Abundance and Preservation: B = barren; C = common; F = frequent; R = rare; G = good; M = moderate; * = reworked.

abundance of the species ranged from rare to common, and preservation ranged from poor to good.

Hole 884C

Hole 884C (Table 6) is located at 51°27.038′N, 168°20.217′E, in a water depth of 3824 m. Upper Miocene–Pliocene deposits were penetrated. The interval between Samples 145-884C-10X-CC and -14X-CC yielded a radiolarian assemblage from the *Diplocyclas cornutoides* Zone. The abundance of the species ranged from rare to common, and preservation ranged from moderate to good. The interval between Samples 145-884C-15X-CC and -31X-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius* Zone. The abundance of the species was rare, and preservation ranged from moderate to good. The interval between Samples 145-884C-32X-CC and -38X-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius–Lipmanella redondoensis* Zone. The abundance of the species ranged from rare to few, and preservation was moderate.

Hole 887A

Hole 887A (Table 7) is located at 54°21.921′N, 148°26.765′W, in a water depth of 3642 m. Lower Miocene–Pliocene deposits were penetrated. The interval between Samples 145-887A-10H-CC and -16X-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius* Zone. The abundance of the species ranged from rare to common, and preservation ranged from good to moderate. The interval between Samples 145-887A-17X-CC and -21X-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius–Lipmanella redondoensis* Zone. The abundance of the species was rare, and preservation ranged from good to poor. This interval contains redeposited species: *Lychnocanium nipponicum magnacornutum.* The interval between Samples 145-887A-22X-CC and -23X-CC yielded a radiolarian assemblage from *Lipmanella redondoensis* Zone. The abundance was rare, and preservation ranged from moderate to poor. The interval between Samples 145-887A-24X-CC and -25X-CC yielded a radiolarian assemblage from the *Lychnocanium nipponicum magnacornutum* Zone. The abundance ranged from rare to common, and preservation was poor. The interval between Samples 145-887A-27X-CC and -28X-CC yielded a radiolarian assemblages from the *Eucyrtidium inflatum* Zone. The abundance ranged from few to abundant, and preservation ranged from moderate to good. The *Eucyrtidium asanoi* Zone is not present. Sample 145-887A-29X-CC yielded a radiolarian assemblage from *Acrospyris lingi* Zone. The species was abundant, and preservation was good. The *Lithocampe subligata* Zone is not present. The interval 145-887A-30X-CC yielded a radiolarian assemblage from the *Cenosphaera coronataformis* Zone. The species was abundant, and preservation was good.

Hole 887C

Hole 887C (Table 8) is located at 54°21.934′N, 148°26.778′W, in a water depth of 3633 m. Lower Miocene–Pliocene deposits were penetrated. Sample 145-887C-10H-CC yielded radiolarians from the *Diplocyclus cornutoides* Zone. The abundance was few, and preservation ranged from moderate to poor. The interval between Samples

Table 3 . Radiolarians at Hole 883B.

Age	Late Pliocene																Early Pliocene								
Radiolarian zones	K						J																		
Core, section	8H-CC	9H-CC	10H-CC	11H-CC	12H-CC	13H-CC	14H-CC	15H-CC	16H-CC	17H-CC	18H-CC	19H-CC	20H-CC	21H-CC	22H-CC	23H-CC	24H-CC	25H-CC	26H-CC	27H-CC	28H-CC	29H-CC	30H-CC	31H-CC	32H-CC
Abundance	A	A	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Preservation	G	G	G	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	G	M
Cenosphaera coronataformis																									
Acrospyris lingi																									
Amphymenium amphistylium gr.																									
Axoprunum acquilonius	A	A	C	R	F	R	F	F	R	R				R		R	R		R		R				R
Axoprunum bispiculum																									
Botryostrobus aquilonaris			R					R		R	R														
Botryostrobus auritus/australis						R			R									R		R	R	R	R		
Botryostrobus bramlettei																					R				
Cenosphaera coronata																									
Cornutella profunda			R									R	R		R					R	R	R	R		
Cyrtocapsella cornuta																									
Cyrtocapsella japonica																									
Cyrtocapsella tetrapera						R*																			
Clathrocyclas bicornis gr.										R								R							
Diplocyclas cornutoides	A	A		C	R	F	R	R	R			R		R	R	R		R	F				R	R	
Diplocyclas davisiana	A	A	R	C	R																				
Eucyrtidium asanoi																									
Eucyrtidium calvertense							R																		
Eucyrtidium inflatum																									
Eucyrtidium cienkowskii																									
Androcyclas heteroporos		R		R	R																	R			
Androcyclas neoheteroporos																									
Lychnocanium nipponicum																									
Lychnocanium nipponicum magnacornutum																									
Lithocampe subligata																									
Lithocarpium polyacantha gr.																									
Lipmanella titan																									
Sphaeropyle langii	R		R	R			R																		
Sphaeropyle robusta		R							R								R		R			R			R
Stichocorys delmontensis																									
Stichocorys sp. P							R	R																	R
Stichocorys wolffii																									
Stichocorys diploconus																									
Stylosphaera angelina	R	R	R	R	F	R		R									R		R	R	R	R	R		
Lipmanella redondoensis																									

Notes: Radiolarian zones: K = *Diplocyclas cornutoides;* J = *Axoprunum acquilonius;* I = *Axoprunum acquilonius–Lipmanella redondoensis.* H = *Lipmanella redondoensis;* G = *Lychnocanium nipponicum magnacornutum;* F = *Eucyrtidium inflatum;* E = *Eucyrtidium asanoi;* D = *Acrospyris lingi;* C = *Lithocampe subligata* B = *Cenosphaera coronataformis;* A = *Cenosphaera coronata*. Abundance and Preservation: A = abundant; C = common; F = frequent; R = rare; G = good; M = moderate; * = reworked.

Table 3 (continued).

Age	Late Miocene																Late Miocene							
Radiolarian zones		I														H						G		
Core, section	33H-CC	34H-CC	35H-CC	36H-CC	37X-CC	38X-CC	39X-CC	40X-CC	41X-CC	42X-CC	43X-CC	44X-CC	45X-CC	46X-CC	47X-CC	48X-CC	49X-CC	50X-CC	51X-CC	53X-CC	54X-CC	55X-CC	56X-CC	57X-CC
Abundance	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	A	R	R	R	R
Preservation	G	G	G	G	M	G	M	M	M	M	M	M	M	M	M	M	M	M	G	G	M	G	G	G
Cenosphaera coronataformis																								
Acrospyris lingi																								
Amphymenium amphistylium gr.																								
Axoprunum acquilonius	R		R	R		R	F		R		R			R	R									
Axoprunum bispiculum																								
Botryostrobus aquilonaris																								
Botryostrobus auritus/australis	R																	R						
Botryostrobus bramlettei		R				R	R																	
Cenosphaera coronata																								
Cornutella profunda	R	R	R		R	R	F	C	C	C	R		R	R		R		R	R		R			
Cyrtocapsella cornuta																				R				
Cyrtocapsella japonica															R									
Cyrtocapsella tetrapera																				C				
Clathrocyclas bicornis gr.						R																		
Diplocyclas cornutoides	R	R	R	R			R	R	R	R	F	R	R						R		R			
Diplocyclas davisiana																								
Eucyrtidium asanoi																				R*				
Eucyrtidium calvertense																								
Eucyrtidium inflatum																								
Eucyrtidium ciencowskii																								
Androcyclas heteroporos	R																							
Androcyclas neoheteroporos																								
Lychnocanium nipponicum																				R				
Lychnocanium nipponicum magnacornutum																				R*		R	R	R
Lithocampe subligata																								
Lithocarpium polyacantha gr.								R															R	R
Lipmanella titan																								
Sphaeropyle langii																								
Sphaeropyle robusta	R							R	R	R	R	R							R				R	R
Stichocorys delmontensis							R	R	R	R	R		R		R		R		R	R				
Stichocorys sp. P						R				R		R	C	R	R									
Stichocorys wolffii				R*											R*									
Stichocorys diploconus																								
Stylosphaera angelina					R	R	R	R	R	R	R		R	R	R					F	R	R	R	R
Lipmanella redondoensis		R		R			F	F-C	F-C	R-C	R	R	R	R-C	R	R		R	R	A	R	R	R	R

Table 3 (continued).

Age	Middle Miocene							Early Miocene			
Radiolarian zones	G	F	E		D		C	B		A	
Core, section	58X-CC	59X-CC	60X-CC	61X-CC	62X-CC	63X-CC	64X-CC	65X-CC	66X-CC	67X-CC	68X-CC
Abundance	A	A	A	A	A	A	A	C	A	F	R
Preservation	M	G	G	G	M	G	M	M	G	M	M
Cenosphaera coronataformis							C	C			
Acrospyris lingi				A	A						
Amphymenium amphistylium gr.					R					R	
Axoprunum acquilonius											
Axoprunum bispiculum			R								
Botryostrobus aquilonaris											
Botryostrobus auritus/australis											
Botryostrobus bramlettei											
Cenosphaera coronata							C	C	A	F	R
Cornutella profunda			R								
Cyrtocapsella cornuta		C	F	R		R	R		F		
Cyrtocapsella japonica		R									
Cyrtocapsella tetrapera		A	A	F		A	A	C	A	F	
Clathrocyclas bicornis gr.											
Diplocyclas cornutoides	R				F		R				
Diplocyclas davisiana											
Eucyrtidium asanoi		C	R								
Eucyrtidium calvertense			R								
Eucyrtidium inflatum	C										
Eucyrtidium ciencowskii											
Androcyclas heteroporos											
Androcyclas neoheteroporos											
Lychnocanium nipponicum											
Lychnocanium nipponicum magnacornutum											
Lithocampe subligata						A					
Lithocarpium polyacantha gr.	R	R	R	R	R	R					
Lipmanella titan	R	R	R	R	R					R	R
Sphaeropyle langii											
Sphaeropyle robusta	R		R	R?						R?	
Stichocorys delmontensis	R					R	R				
Stichocorys sp. P.			R								
Stichocorys wolffii											
Stichocorys diploconus				R		R					
Stylosphaera angelina	R	C	C	R	C	C	R	C		F	
Lipmanella redondoensis	A	C	A	A	C	R				R	

Table 4. Radiolarians at Hole 883C.

Age	Late Pliocene								Early Pliocene															Late Miocene						
Radiolarian zones	K						J																				I			
Core, section	9H-CC	10H-CC	11H-CC	12H-CC	13H-CC	14H-CC	15H-CC	16H-CC	17H-CC	18H-CC	19H-CC	20H-CC	21H-CC	22H-CC	23H-CC	24H-CC	25H-CC	26H-CC	27H-CC	28X-CC	29X-CC	30X-CC	31X-CC	32X-CC	33X-CC	34X-CC	35X-CC	36X-CC	37X-CC	38X-CC
Abundance	A	C	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F	R	R	R	R	R	R	R
Preservation	G	G	G	M	M	M	M	G	G	M	G	G	M	M	G	M	M	M	M	M	M	M	M	M	G	G	M	M	M	M
Cenosphaera coronataformis																														
Acrospyris lingi																														
Amphymenium amphistylium gr.																														
Axoprunum acquilonius	C	R	R	R-F	F	C	F		R	R	R				R		R	R	R		R	R	R	R	R	R	R	F-C	R	R
Axoprunum bispiculum																														
Botryostrobus aquilonaris	R	R	R				R	R																		R				
Botryostrobus auritus/australis								R							R		R	R	R											
Botryostrobus bramlettei																														
Cenosphaera coronata																														
Cornutella profunda	F		R		R	R	R		R		R	R			R					R			R	R	R	R		C		
Cyrtocapsella cornuta																														
Cyrtocapsella japonica																														
Cyrtocapsella tetrapera																														
Clathrocyclas bicornis gr.																														
Diplocyclas cornutoides	A	R	R-F			F	R		R	R					R			R	R				F	R	R	R	R	R		
Diplocyclas davisiana	F-C	C	R-F	R	R																									
Eucyrtidium asanoi																														
Eucyrtidium calvertense													R										R		R					
Eucyrtidium inflatum																														
Eucyrtidium cienkowskii																							R		R	R				
Androcyclas heteroporos																														
Androcyclas neoheteroporos																							R			R				
Lychnocanium nipponicum																														
Lychnocanium nipponicum magnacornutum																														
Lithocampe subligata																														
Lithocarpium polyacantha gr.																			R	R	R	R			R					
Lithocarpium titan																							R		R					
Sphaeropyle langii	R								R?																	R				
Sphaeropyle robusta			R						R										R			R				R	R	R	R	
Stichocorys delmontensis																													R	R
Stichocorys sp. P															R?							R			R		R		R	R
Stichocorys wolffii																														
Stichocorys diploconus																														
Stylosphaera angelina	F	R				C	R		R			R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Lipmanella redondoensis																											R	F	R	R

Notes: Radiolarian zones: K = *Diplocyclas cornutoides;* J = *Axoprunum acquilonius*; I = *Axoprunum acquilonius–Lipmanella redondoensis.* Abundance and Preservation: A = abundant; C = common; F = frequent; R = rare; G = good; M = moderate.

Table 5. Radiolarians at Hole 884B.

Age	Late Pliocene								Early Pliocene									
Radiolarian zones	K					J												
Core, section	12X-CC	13X-CC	14X-CC	15X-CC	16X-CC	17X-CC	18X-CC	19X-CC	21X-CC	22X-CC	23X-CC	24X-CC	25X-CC	26X-CC	27X-CC	28X-CC	29X-CC	30X-CC
Abundance	C	R	C	A	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Preservation	G	P	G	G	M	M	M	M	G	M	M	M	M	M	M	M	M	M
Cenosphaera coronatafomis																		
Acrospyris lingi																		
Amphymenium amphistylium gr.																		
Axoprunum acquilonius	F		C	C	R	R		R	C	C	C-A	F	R	R	R	F	C	C
Axoprunum bispiculum		R																
Botryostrobus aquilonaris				F					F	R	R							R
Botryostrobus auritus/australis	R		R	C		R	R	R			R	R	R		R			
Botryostrobus bramlettei											R							R
Cenosphaera coronata																		
Cornutella profunda			F	R					R	R	R	F		R	R-F	F-C	R	R
Cyrtocapsella cornuta																		
Cyrtocapsella japonica																		
Cyrtocapsella tetrapera																		
Clathrocyclas bicornis gr.						R	R											
Diplocyclas cornutoides	C		C	A		R	R	R	R	F	F	R	R		F	R		R
Diplocyclas davisiana	C		C	A														
Eucyrtidium asanoi																		
Eucyrtidium calvertense											R							
Eucyrtidium inflatum																		
Eucyrtidium cienkowskii																		
Androcyclas heteroporos														R	R			R
Androcyclas neoheteroporos			R															
Lychnocanium nipponicum																		
Lychnocanium nipponicum magnacornutum																		
Lithocampe subligata																		
Lithocarpium polyacantha gr.	R			F	R	R	R	R								R	R-F	
Lithocarpium titan			R	R	R													
Sphaeropyle langii	R								R	R	R	R		R	R	R	R	
Sphaeropyle robusta			C	C		R		R	R	R	R	R		R			R	R
Stichocorys delmontensis																		
Stichocorys sp. P											R							
Stichocorys wolffii																		
Stichocorys diploconus																		
Stylosphaera angelina	F			F	R			R		R		C	F		F	C	C	F
Lipmanella redondoensis																		

Notes: Radiolarian zones: K = *Diplocyclas cornutoides;* J = *Axoprunum acquilonius*; I = *Axoprunum acquilonius–Lipmanella redondoensis.* H = *Lipmanella redondoensis;* G = *Lychnocanium nipponicum magnacornutum;* F = *Eucyrtidium inflatum;* E = *Eucyrtidium asanoi;* D = *Acrospyris lingi;* B = *Cenosphaera coronataformis;* A = *Cenosphaera coronata.* Abundance and Preservation: A = abundant; C = common; F = frequent; R = rare; G = good; M = moderate.

Table 5 (continued).

Age		Late Miocene																		
Radiolarian zones					I									H					G	
Core, section	31X-CC	32X-CC	33X-CC	34X-CC	35X-CC	36X-CC	37X-CC	38X-CC	39X-CC	40X-CC	41X-CC	42X-CC	43X-CC	44X-CC	45X-CC	46X-CC	47X-CC	48X-CC	49X-CC	50X-CC
Abundance	R	R	R	R	R	R	R	R	R	C	R	R	R	R	R	R	R	R	C	A
Preservation	M	P	P	M	G	M	G	M	G	G	M	G	M	M	M	M	M	M	G	G
Cenosphaera coronatafomis																				
Acrospyris lingi																				
Amphymenium amphistylium gr.																				
Axoprunum acquilonius	C	C	R		R	R	R		F	R										
Axoprunum bispiculum																				
Botryostrobus aquilonaris			R				R													
Botryostrobus auritus/australis				R			R							R	R		R		R	F
Botryostrobus bramlettei						R	R	R		R				R		R			R	R
Cenosphaera coronata																				
Cornutella profunda	R	R-F			R	R		R	R	C	R	R			R	R	R	F		R
Cyrtocapsella cornuta																		R		
Cyrtocapsella japonica																				R?
Cyrtocapsella tetrapera													R							
Clathrocyclas bicornis gr.										C				R		R	R	F	C	A
Diplocyclas cornutoides	R	R	R				R	R	R	R		R	R	R	R				R	C
Diplocyclas davisiana																				
Eucyrtidium asanoi																				
Eucyrtidium calvertense																				
Eucyrtidium inflatum																				
Eucyrtidium cienkowskii																				
Androcyclas heteroporos																				
Androcyclas neoheteroporos																				
Lychnocanium nipponicum																				
Lychnocanium nipponicum magnacornutum																		F	C	A
Lithocampe subligata																				
Lithocarpium polyacantha gr.					R	R	R		R	R		R		R	R		R	F	C	C
Lithocarpium titan																				R
Sphaeropyle langii	R							R?	R?			R?							R	R
Sphaeropyle robusta		R						R	R	R		R		R					R	R
Stichocorys delmontensis											R			R						R
Stichocorys sp. P									R		R								R	R
Stichocorys wolffii																				R
Stichocorys diploconus																				
Stylosphaera angelina	F	R	R		R	R	R			R			R		R	R	R	R	R	C
Lipmanella redondoensis				R		R		R	R	R	R	R	R	F	R	R	R	F	C	A

Table 5 (continued).

Age	Late Miocene							Middle Miocene									Early Miocene		
Radiolarian zones	G							F	E			D		B		A			
Core, section	51X-CC	52X-CC	53X-CC	54X-CC	55X-CC	56X-CC	57X-CC	58X-CC	59X-CC	60X-CC	61X-CC	62X-CC	63X-CC	64X-CC	65X-CC	66X-2	66X-CC	67X-CC	68X-CC
Interval (cm)																103			
Abundance	C	C	R	R	R	R	R	C	C	A	A	A	A	C	F	C	R	R-F	R-F
Preservation	M	M	P-M	P-M	P	P	P	M	M	M	M	G	G	P-M	P	G	M	M	M
Cenosphaera coronatafomis														R	A				
Acrospyris lingi												A	R						
Amphymenium amphistylium gr.										F	R								
Axoprunum acquilonius																			
Axoprunum bispiculum																			
Botryostrobus aquilonaris																			
Botryostrobus auritus/australis																			
Botryostrobus bramlettei																			
Cenosphaera coronata														C	A	C	R	R	R
Cornutella profunda		F-C	F	R		R		R-F		A?	R	F	R						
Cyrtocapsella cornuta										R			C-A	C	R	R			
Cyrtocapsella japonica	R										C	C		R	R				
Cyrtocapsella tetrapera						R				R/F	C		C-A	C	F	F	R		
Clathrocyclas bicornis gr.	F			R				R-F											
Diplocyclas cornutoides	C	R	R	C	R		R	R		R		R	R						
Diplocyclas davisiana																			
Eucyrtidium asanoi										R	R								
Eucyrtidium calvertense										R	C	C							
Eucyrtidium inflatum								R											
Eucyrtidium cienkowskii																			
Androcyclas heteroporos																			
Androcyclas neoheteroporos																			
Lychnocanium nipponicum																			
Lychnocanium nipponicum magnacornutum	C	A	C	C	C	F	F-C												
Lithocampe subligata																			
Lithocarpium polyacantha gr.		R				R	R	R	R	R	R	R?	R?	R?	R?	R?	R?		
Lithocarpium titan									R	R		R	R-F	R	R		R?	R	R?
Sphaeropyle langii	R												R?						
Sphaeropyle robusta		R	R	R	R			R	R	R	R	R-F	R-F		R				
Stichocorys delmontensis													R	R-F					
Stichocorys sp. P																			
Stichocorys wolffii														R					
Stichocorys diploconus										R	R			R					
Stylosphaera angelina	R	R	R	F	R	F	R	C	A	A	F	C	A	C	F	C	R	R	
Lipmanella redondoensis	F	R	F		R	R	R	R		F-R		C-A	C						

Table 6. Radiolarians at Hole 884C.

Age	Late Pliocene									Late Miocene													Middle Miocene					
Radiolarian zones	K					J																		I				
Core, section	10X-CC	11X-CC	12X-CC	13X-CC	14X-CC	15X-CC	16X-CC	17X-CC	18X-CC	19X-CC	20X-CC	21X-CC	22X-CC	23X-CC	24X-CC	25X-CC	26X-CC	27X-CC	28X-CC	29X-CC	30X-CC	31X-CC	32X-CC	34X-CC	35X-CC	36X-CC	37X-CC	38X-CC
Abundance	R	R	R	A	C	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F	R	R	R	R	R	F	F	R
Preservation	M	M	M	G	G	G	G	G	G	M	M	M	G	G	G	G	G	G	G	C	G	G	M	M	M	M	M	M
Cenosphaera coronataformis																												
Acrospyris lingi																												
Amphymenium amphistylium gr.																												
Axoprunum acquilonius	A	C	A	A	C	R	R	R	R	R	R	R	R	R	R		R		R	F	R	R	R	C	F	R	R	R
Axoprunum bispiculum																												
Botryostrobus aquilonaris			R																					R				
Botryostrobus auritus/australis					F	R							R	R			R	R	R	R								
Botryostrobus bramlettei					R						R				R					R						R		
Cenosphaera coronata																												
Cornutella profunda		R	R			R				R				R	R				R	F	R	R	R	R	R	C	R	
Cyrtocapsella cornuta																												
Cyrtocapsella japonica																												
Cyrtocapsella tetrapera																												
Clathrocyclas bicornis gr.					C	R	R		R	R	R	R			R								R	R		R	R	
Diplocyclas cornutoides		F		F	C		R	R			R	R		R	R		R	R	R	R	R	R		R	R		R	R
Diplocyclas davisiana	C	R	R		R																							
Eucyrtidium asanoi																												
Eucyrtidium calvertense																												
Eucyrtidium inflatum																												
Eucyrtidium cienkowskii																												
Androcyclas heteroporos																	R			R	R							
Androcyclas neoheteroporos																	R			R								
Lychnocanium nipponicum																												
Lychnocanium nipponicum magnacornutum																												
Lithocampe subligata																												
Lithocarpium polyacantha gr.					F		R	R	R	R	R				R	R				R				R				
Lithocarpium titan						R?	R?			R?	R?	R									R?							
Sphaeropyle langii	F	F	R		R					R	R						R											
Sphaeropyle robusta				R	F		R		R	R	R	R			R	R	R		R			R			R	R	R	R
Stichocorys delmontensis																											R	
Stichocorys sp. P																			R							R	R	
Stichocorys wolffii																												
Stichocorys diploconus																												
Stylosphaera angelina	C	C		F	F	R	R	R				R	R	R	R	R	R	R				R		R	R	C	C	R
Lipmanella redondoensis																							R	R				R

Notes: Radiolarian zones: K = *Diplocyclas cornutoides;* J = *Axoprunum acquilonius*; I = *Axoprunum acquilonius–Lipmanella redondoensis*. Abundance and Preservation: A = abundant; C = common; F = frequent; R = rare; G = good; M = moderate.

Table 7. Radiolarians at Hole 887A.

Age	Late Pliocene		Early Pliocene					Late Miocene									Middle Miocene		Early Miocene	
Radiolarian zones	J							I				H		G		F		D	B
Core, section	10H-CC	11H-CC	12H-CC	13H-CC	14H-CC	15X-CC	16X-CC	17X-CC	18X-CC	20X-CC	21X-CC	22X-CC	23X-CC	24X-CC	25X-CC	27X-CC	28X-CC	29X-CC	30X-CC
Abundance	R	R	F	C	C	R	F	R	R	R	R	R	R	R	C	F	A	A	A
Preservation	G	G	G	G	G	G	M	M	G	P	P	M	P	P	P	P	M	G	G
Cenosphaera coronataformis																			A
Acrospyris lingi																	R	A	
Amphymenium amphistylium gr.																	R		
Axoprunum acquilonius	R	R	F	R	R	R	C	R	R	F	R								
Axoprunum bispiculum				F	R			R	R	R-F	R	R		R					
Botryostrobus aquilonaris		R																	
Botryostrobus auritus/australis			R	R															
Botryostrobus bramlettei	R			R					R			R			R				
Cenosphaera coronata																			A
Cornutella profunda									R-F		R	F-C	F-C	R	R	R			
Cyrtocapsella cornuta							R*			R	R	R	R			F	F-C	C	R
Cyrtocapsella japonica			R*								R				A		C		
Cyrtocapsella tetrapera												R						F	A
Clathrocyclas bicornis gr.		R			F	R													
Diplocyclas cornutoides	R	R		R	R	R	R	R	R			R	R						
Diplocyclas davisiana																			
Eucyrtidium asanoi																	R		
Eucyrtidium calvertense				R															
Eucyrtidium inflatum																R	R		
Eucyrtidium cienkowskii																			
Androcyclas heteroporos					R														
Androcyclas neoheteroporos							R?												
Lychnocanium nipponicum							R?*	R?*	R?*	R?*									
Lychnocanium nipponicum magnacornutum			R*					R*		R*	R*	R*		F	C-A				
Lithocampe subligata																			F?
Lithocarpium polyacantha gr.	R															F	R	R	R
Prunopyle titan																R	F	F	F
Sphaeropyle langii																			R?
Sphaeropyle robusta	R	R	R	R	F		F	R	R	R	R	F-C	F			R			
Stichocorys delmontensis					R				R		R	C-A	F-C						
Stichocorys sp. P									R?	R?									
Stichocorys wolffii									R?*		R*		R*						
Stichocorys diploconus																		R	R
Stylosphaera angelina			F	F	F	R	F	R	R			R	R	R	R	C	R	A	C
Lipmanella redondoensis								R	R	R	R	C	C-A	R	R	R	F		

Notes: Radiolarian zones: J = *Axoprunum acquilonius*; I = *Axoprunum acquilonius–Lipmanella redondoensis*. H = *Lipmanella redondoensis;* G = *Lychnocanium nipponicum magnacornutum;* F = *Eucyrtidium inflatum;* D = *Acrospyris lingi;* B = *Cenosphaera coronataformis*. Abundance and Preservation: A = abundant; C = common; F = frequent; R = rare; G = good; M = moderate; P = poor; * = reworked.

145-887C-11H-CC and -14H-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius* Zone. The abundance was rare, and preservation ranged from moderate to poor. The interval between Samples 145-887C-15H-CC and -21H-CC yielded a radiolarian assemblage from the *Axoprunum acquilonius–Lipmanella redondoensis* Zone. The abundance ranged from rare to few, and preservation ranged from moderate to poor. This interval contains redeposited species *Lichnocanium nipponicum magnacornutum.* The interval between Samples 145-887C-22H-CC and -23H-CC yielded a radiolarian assemblage from the *Lipmanella redondoensis* Zone. The species ranged from abundant to common, and preservation ranged from moderate to good. The interval between Samples 145-887C-24H-CC and -26H-CC yielded a radiolarian assemblage from the *Lychnocanium nipponicum magnacornutum* Zone. The species was abundant, and preservation ranged from poor to good. The interval between Samples 145-887C-27H-CC and -28H-CC yielded a radiolarian assemblage from the *Eucyrtidium inflatum* Zone. The species was abundant, and preservation ranged from moderate to good. The *Lithocampe subligata* Zones is not present. The interval between Sample 145-887C-29H-CC yielded a radiolarian assemblage from the *Acrospyrias lingi* Zone. The species was abundant, and preservation was good. The interval between Samples 145-887C-30H-1, 54–55 cm, and -30H-CC yielded a radiolarian assemblage from the *Cenosphaera coronataformis* Zone. The species was abundant, and preservation ranged from moderate to good.

Hole 887D

Hole 887D is located at 54°21.935′N, 148°26.788′W, in a water depth of 3645 m. Upper Oligocene–lower Miocene deposits were penetrated. The interval between Samples 145-887D-3R-CC and -6R-CC yielded a radiolarian assemblage from the *Cenosphaera coronata* Zone. The abundance of the species ranged from rare to common, and preservation ranged from moderate to good.

SYSTEMATICS

The taxonomy adopted for this study is after Sanfilippo and Riedel (1970), Riedel and Sanfilippo (1971), Petrushevskaya and Kozlova (1972), and Petrushevskaya (1981).

Subclass RADIOLARIA Muller, 1858
Superorder POLYCYSTINA Ehrenberg, 1838, emend. Riedel, 1967
Order SPUMELLARIA Ehrenberg, 1875
Family ACTINOMIDAE, 1862, emend. Riedel 1967
Genus *AXOPRUNUM,* 1887

Axoprunum bispiculum (Popofsky)

Stylacontarium bispiculum Popofsky, 1912, pl. 2, fig. 2; Kling, 1973, pl. 15, figs. 11–14.

Axoprunum bispiculum (Popofsky), Takemura, 1992, p. 741, pl. figs. 1–2.

Occurrences. Oligocene-Miocene.

Table 8. Radiolarians at Hole 887C.

Age	Late Pliocene			Early Pliocene				Late Miocene									Middle Miocene				Early Miocene		
Radiolarian zones	K	J					I						H		G			F		D	B		
Core, section	10H-CC	11H-CC	12H-CC	13H-CC	14H-CC	15H-CC	16H-CC	17H-CC	18H-CC	19H-CC	20H-CC	21H-CC	22H-CC	23H-CC	24H-CC	25H-CC	26H-CC	27H-CC	28H-CC	29H-CC	30H-1	30H-5	30H-CC
Interval (cm)																					54	54	
Abundance	F	R	R	R	R	R	R	R	R	R	F	F	A	C	A	A	A	A	A	A	A	A	A
Preservation	P-M	M	M	P-M	P	M	P	P	P	P	M	M	G	M	M	P-M	M-G	M-G	M-G	G	G	G	M-G
Cenosphaera coronataformis																					F	A	A
Acrospyris lingi																				R			
Amphymenium amphistylium gr.														R	R	R		R					
Axoprunum acquilonius	A	C	F-C	C	F	F-C	F	R	R	R	F	F											
Axoprunum bispiculum								R	R	R	R		R										
Botryostrobus aquilonaris			R																				
Botryostrobus auritus/australis																							
Botryostrobus bramlettei			R				R								R								
Cenosphaera coronata																				R	F	C	A
Cornutella profunda	R	R	R		R		R		R		R	R		C									
Cyrtocapsella cornuta				R*							R	R	R	R	R		R	F		R	C	F	R-F
Cyrtocapsella japonica							R*		R*			R	R	R	R	A							
Cyrtocapsella tetrapera				R*					R*						R			A	A	C	C	C	A
Clathrocyclas bicornis gr.			R											R									
Diplocyclas cornutoides	F		F		R	R-F		R						R									
Diplocyclas davisiana	F-C																						
Eucyrtidium asanoi																	R		R?				
Eucyrtidium calvertense	R																		A				
Eucyrtidium inflatum					R*								R*		R*		R*	F	R				
Eucyrtidium cienkowskii																			C				
Androcyclas heteroporos				R		F																	
Androcyclas neoheteroporos																							
Lychnocanium nipponicum															F	C	C						
Lychnocanium nipponicum magnacornutum				R*	R*		R*	R*	R*	R*		R*	R*		A	A	A						
Lithocampe subligata																					R	F	F
Lithocarpium polyacantha gr.								R							C			C			C	F	
Lithocarpium titan															F					F			
Sphaeropyle langii	R		R	R	R	R					R				R		R						
Sphaeropyle robusta		R	R	F	R	R	F	R	R	R	R	F	R	R	F	R	R						
Stichocorys delmontensis					R			R	R	R		R	A	C	F	R							
Stichocorys sp. P				R?									R			R							
Stichocorys wolffii												C*			R*						R		
Stichocorys diploconus																					A	F	
Stylosphaera angelina	R	R	F	R	R	R	F		R	R	R	F	C	R	R	F	R		A	C	F	F	R
Lipmanella redondoensis				R*		R	R	R	R	R	R	R	R	C	C	R	A	F					

Notes: Radiolarian zones: K = *Diplocyclas cornutoides;* J = *Axoprunum acquilonius*; I = *Axoprunum acquilonius–Lipmanella redondoensis.* H = *Lipmanella redondoensis;* G = *Lychnocanium.nipponicum magnacornutum;* F = *Eucyrtidium inflatum;* D = *Acrospyris lingi;* B = *Cenosphaera coronataformis*. Abundance and Preservation: A = abundant; C = common; F = frequent; R = rare; G = good; M = moderate; P = poor; * = reworked.

Axoprunum acquilonius (Hays)
(Pl. 5, Fig. 1a–1b)

Druppatractus acquilonius Hays, 1970, p. 214, pl. 1, figs. 4, 5; Morley, 1985, p. 410, pl. 4, figs. 1A, 1B; Ling, 1980, p. 367, pl. 1, fig. 1.
Stylacontarium acquilonium (Hays) Kling, 1973, p. 634, pl. 1, figs. 17–20, pl. 14, figs. 1–4; Ling, 1973, p. 777, pl. 1, figs. 6, 7; Sakai, 1980, p. 704, pl. 2, figs. 2a, 2b; Wolfart, 1981, p. 500.
?*Lithatractus santaennae* Campbell and Clark, 1944, p. 19, pl. 2, figs. 20–22.

Occurrences. Upper Miocene–Pleistocene.

Genus *CENOSPHAERA,* 1854
Cenosphaera coronata
(Pl. 1, Figs. 5a–5b)

Cenosphaera coronata, 1887, p. 26, fig. 11.

Description. The species is interpreted in a slightly broader sense than in Haeckel (1887), whose paper does not present the full illustration of the species. *Cenosphaera coronata,* discovered in samples from Sites 883 and 884, contains well-developed ridges, surrounding pores. They have a slightly fewer number of denticles than the typical form. Dimensions: shell diameter, 100–160 μm; diameter of pores, 10–12 μm.

Occurrences. Samples 145-884B-64X-CC and 145-884B-68X-CC. Upper Oligocene–middle Miocene.

Cenosphaera coronataformis n. sp.
(Pl. 1, Figs. 4a–4c, holotype)

Description. Shell composed of one sphere. On the sphere, ridges are well developed on the pores, particularly on the marginal part of the shell. They seem to make a rim around the shell, forming a peculiar corona. On the shell surface, in the center, there is a large pore (d = 20–25 μm), which is adjoined by smaller pores (d = 15–18 μm) across, forming a hexahedron. Shell diameter: with ridges, 160–180 μm; without ridges, 90–120 μm; height of ridges, 30–70 μm. Measurements taken on 20 specimens.

Name. *coronataformis* (lat.). Similar with "coronata."

Occurrences. Sample 145-884B-64X-CC. Lower Miocene.

Genus *SPHAEROPYLE* Dreyer, 1889
Sphaeropyle langii Dreyer

Sphaeropyle langii Dreyer, 1889, p. 13, pl. 4, fig. 54; Kling, 1973, p. 634, pl. 13, figs. 6–8; Sakai, 1980, pl. 2, figs. 3a, b; Morley, 1985, pl. 5, figs. 3A, B; Westberg-Smith and Riedel, 1984, p. 486, pl. 1, fig. 9; Wolfart, 1984, p. 499.

Occurrences. Miocene–Pleistocene.

Sphaeropyle robusta Kling
(Pl. 1, Figs. 6a–6b)

Sphaeropyle robusta Kling, 1973, p. 634, pl. 1, figs. 11, 12, pl. 6, figs. 9–13, pl. 13, figs. 1–5; Sakai, 1980, pl. 2, figs. 4a, 4b; Morley, 1985, pl. 5, fig. 4; Westberg-Smith and Riedel, 1984, p. 487, pl. 1, fig. 8(?).

Occurrences. Miocene–Pleistocene.

Genus *THECOSPHAERA*, 1881

Thecosphaera japonica Nakaseko

Thecosphaera japonica Nakaseko, 1972, p. 61, pl. 1, figs. 3a, b.

Occurrences. Upper Miocene–Pleistocene.

Genus *STYLOSPHAERA*, 1847
(Pl. 2, Figs. 1a–1b)

Stylosphaera angelina Campbell and Clark

Stylosphaera angelina Campbell and Clark, 1944, p. 12, pl. 1, figs. 14–20.
Stylatractus universus Hays, 1970, p. 215, pl. 1, figs. 1, 2; Morley, 1985, p. 410, pl. 4, figs. 2A, 2B; Ling, 1980, p. 369, pl. 1, fig. 2.
Axoprunum angelinum (Campbell and Clark), Kling, 1973, p. 634, pl. 1, figs. 13–17; Ling, 1973, p. 777, pl. 1, figs. 1–4; Foreman, 1975, p. 618, pl. 9, figs. 28, 29; Sakai, 1980, p. 704, pl. 2, figs. 1a, 1b; Wolfart, 1981, p. 496.

Occurrences. Upper Oligocene–Pleistocene.

Family SPONGODISCIDAE, 1862
Genus *AMPHYMENIUM*, 1881

Amphymenium amphistylium group
(Pl. 1, Fig. 3)

Amphymenium amphistylium, Haeckel, 1887, p. 520, pl. 44, fig. 9.

Occurrences. Oligocene–Middle Miocene.

Genus *SPONGODISCUS* Ehrenberg, 1854

Spongodiscus osculosus (Dreyer)

Spongopyle osculosa Dreyer, 1889, p. 213, pl. 11, figs. 99, 100.

Occurrences. Miocene–Pleistocene.

Family LITHELIIDAE Haeckel, 1862
Genus *LITHOCARPIUM* Stohr, emend. Petrushevskaya, 1975.

Lithocarpium polyacantha (Campbell and Clark)

Larnacantha polyacantha Campbell and Clark, 1944, p. 30, pl. 5, figs. 4–7.
Lithocarpium polyacantha (Campbell and Clark) group, Petrushevskaya, 1975, p. 572, pl. 3, figs. 6–8, pl. 29, fig. 6; Ling, 1980, pl. 1, fig. 10.

Occurrences. Miocene–Pliocene.

Lithocarpium titan (Campbell and Clark)
(Pl. 1, Figs. 1–2)

Prunopyle titan Campbell and Clark, 1944, p. 20, pl. 3, figs. 1–3; Petrushevskaya, 1975, p. 572, pl. 4, fig. 5; Weaver et al., 1981, pl. 2, figs. 6, 7.

Occurrences. Miocene.

Order NASSELLARIA Ehrenberg, 1875
Family LAMPROMITRIDAE Haeckel, 1881
Genus *CORNUTELLA* Ehrenberg, 1838, emend. Petrushevskaya, 1967

Cornutella profunda Ehrenberg

Cornutella profunda (Ehrenberg) Kling, 1973, p. 635, pl. 3, figs. 1–4, pl. 9, figs. 8–17; Morley, 1985, pl. 1, fig. 3.

Occurrences. Miocene–Pleistocene.

Family SETHOPHORMIDIDAE Haeckel, 1881
Genus *CLATHROCYCLAS* Haeckel, 1881, emend. Foreman, 1968

Clathrocyclas bicornis (Hays)
(Pl. 5, Fig. 2)

Calocyclas bicornis (Hays) Petrushevskaya, 1975, p. 586, pl. 15, fig. 25, pl. 23, fig. 3; Sakai, 1980, p. 709, pl. 6, figs. 9, 10, 11.

Occurrences. Miocene–Pleistocene.

Genus *DIPLOCYCLAS* Haeckel, 1881

Diplocyclas davisiana (Ehrenberg)
(Pl. 5, Figs. 5–6)

Pterocodon davisianus Ehrenberg, 1872, p. 299, pl. 2, fig. 10.
Cycladophora davisiana Ehrenberg, 1862, p. 297; 1972, p. 299, pl. 2, fig. 11; Petrushevskaya, 1967, p. 122, pl. 69, fits. 1–7; Ling, 1973, p. 780, pl. 2, fig. 2; Sakai, 1980, p. 709, pl. 6, figs. 6, 7a, 7b, 8a, 8b; Morley, 1985, p. 412, pl. 1, figs. 6A, 6B.
Theocalyptra davisiana (Ehrenberg) Kling, 1973, p. 638, pl. 3, figs. 9–12.

Occurrences. Pliocene–Pleistocene.

Diplocyclas cornutoides (Petrushevskaya)
(Pl. 5, Figs. 3–4)

Cycladophora davisiana v. cornutoides Petrushevskaya, 1967, p. 124, pl. 71, figs. 1–3; Ling, 1973, p. 780, pl. 2, fig. 3; Ling, 1980, pl. 2, fig. 1; Morley, 1985, p. 412, pl. 2, figs. 2A, 2B.
Theocalyptra davisiana? (Ehrenberg) Kling, 1973, pl. 3, figs. 5–8.

Remarks. The shell differs significantly from the type species *Diplocyclas davisiana* Ehrenberg. Petrushevskaya described it as the subspecies *Diplocyclas davisiana* Ehrenberg, though the differences, given by her in the description of the subspecies, have the species character: different number of segments (i.e., four in the case of *D. davisiana* and two in the case of *D. davisiana cornutoides*. Shell size is different. Therefore, there is good reason to regard it as a different species. The first description of the species was given by Petrushevskaya. The species name *cornutoides* remains the priority one for the species.
Occurrences. Miocene–Pleistocene.

Family EUCYRTIDIIDAE Ehrenberg, 1874
Genus *EUCYRTIDIUM* Ehrenberg, 1847

Eucyrtidium asanoi Sakai
(Pl. 3, Figs. 1a–1b)

Eucyrtidium asanoi Sakai, 1980, p. 709, pl. 7, figs. 12a, 12b, 13a, 13b, 14a, 14b; Funayama, 1988, pl. 3, figs. 5, 7, 8, 13.
Eucyrtidium sp. Ling, 1973, p. 781, pl. 2, fig. 9.
Eucyrtidium cienkowskii Haeckel group, Weaver et al., 1981, pl. 1, figs. 6–8.

Occurrences. Middle Miocene.

Eucyrtidium inflatum Kling
(Pl. 3, Figs. 2a–2b)

Eucyrtidium inflatum Kling, 1973, p. 636, pl. 11, figs. 7, 8, pl. 15, fig. 7–10; Sakai, 1980, p. 710, pl. 7, fig. 11; Weaver et al., 1981, pl. 2, figs. 10–12; Funayama, 1988, pl. 3, figs. 1, 2, 12.

Occurrences. Middle Miocene.

Eucyrtidium cienkowskii Haeckel group

Eucyrtidium cienkowskii Haeckel, 1887, p. 1493, pl. 80, fig. 9; Sakai, 1980, p. 710, pl. 7, figs. 8, 9, 10.

Occurrences. Middle Miocene.

Eucyrtidium calvertense Martin group

Eucyrtidium calvertense (Martin) group Sakai, 1980, p. 710, p l. 7, figs. 2, 4, 5, 6; Kling, 1973, pl. 4, figs. 16, 18, 19, pl. 11, figs. 1–5.

Occurrences. Miocene–Pleistocene.

Genus *LITHOCAMPE* Ehrenberg, 1838

Lithocampe subligata Stohr group
(Pl. 2, Figs. 3a–b)

Lithocampe subligata (Stohr) group Petrushevskaya and Kozlova, 1972, p. 546, pl. 25, figs. 7–10; Petrushevskaya, 1975, p. 581, figs. 6–9; Perez-Guzman, 1985, pl. 2, fig. 7b.

Occurrences. Miocene.

Genus *CYRTOCAPSELLA* Haeckel, 1887, emend. Sanfilippo and Riedel, 1970

Cyrtocapsella cornuta Haeckel

Cyrtocapsella cornuta Haeckel, 1887, p. 1513, pl. 78, fig. 9; Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 19, 20; Riedel and Sanfilippo, 1971, p. 1593, pl. E, figs. 1–4; Kling, 1973, p. 636, pl. 11, figs. 16–18; Sakai, 1980, p. 709, pl. 8, fig. 8; Morley, 1985, p. 412, pl. 8, fig. 8.
Lithocampe cornuta (Haeckel) Petrushevskaya and Kozlova, 1972, p. 546, pl. 25, figs. 15, 16.

Occurrences. Miocene.

Cyrtocapsella tetrapera Haeckel
(Pl. 2, Figs. 5a–5b)

Cyrtocapsella tetrapera (Haeckel) Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 16–18; Riedel and Sanfilippo, 1971, p. 1594, pl. E, figs. 5–7; Kling, 1973, p. 636, pl. 11, figs. 1 2–15; Ling, 1973, p. 780, pl. 2, fig. 4; Ling, 1980, pl. 2, fig. 5; Sakai, 1980, p. 709, pl. 8, figs. 5, 6; Wolfart, 1981, pl. 3, fig. 4; Morley, 1985, p. 412, pl. 8, fig. 6; Weaver et al., 1981, pl. 6, fig. 2.
Lithocampe tetrapera (Haeckel) Petrushevskaya and Kozlova, 1972, p. 546, pl. 25, fig. 14.

Occurrences. Miocene.

Cyrtocapsella japonica (Nakaseko)
(Pl. 2, Figs. 2a–2b)

Eucyringium japonicum Nakaseko, 1963, p. 193, text-figs. 20, 21, pl. 4, figs. 1–3.
Cyrtocapsella japonicum (Nakaseko) Sanfilippo and Riedel, 1970, p. 452. pl. 1, figs. 13–15; Kling, 1973, p. 636, pl. 11, figs. 12–15; Ling, 1980, p. 367, pl. 2, fig. 4; Sakai, 1980, p. 709, pl. 8, figs. 7a, 7b; Wolfart, 1981, p. 497, pl. 3, figs. 10, 11.

Occurrences. Miocene.

Genus *LITHOPERA* Ehrenberg, 1847

Lithopera renzae Sanfilippo and Riedel

Lithopera renzae Sanfilippo and Riedel, 1970, p. 454, pl. 4, figs. 21–23, 27; Funayama, 1988, pl. 4, fig. 2.

Occurrences. Miocene.

Genus *STICHOCORYS* Haeckel, 1881, emend. Riedel and Sanfilippo, 1970

Stichocorys wolfii Haeckel

Stichocorys wolfii Haeckel, 1887, p. 1479, pl. 80, fig. 10; Riedel, 1959, p. 300, pl. 2, fig. 4; Nakaseko, 1963, p. 186, text-fig. 16, pl. 4, figs. 10, 15, 16; Riedel and Sanfilippo, 1971, p. 1595, pl. E, figs. 8, 9; Wolfart, 1981, p. 500, pl. 1, fig. 1–2.

Occurrences. Miocene.

Stichocorys diploconus Haeckel
(Pl. 4, Figs. 1a–1b)

Cyrtocapsa diploconus Haeckel, 1887, p. 1513, pl. 78, fig. 6.
Stichocorys diploconus (Haeckel) Sanfilippo and Riedel, 1970, p. 451, pl. 1, figs. 31, 32; Riedel and Sanfilippo, 1971, p. 1595, pl. E, fig. 16; Kling, 1973, p. 638, pl. 11, fig. 11, pl. 13, fig. 12.

Occurrences. Early–middle Miocene.

Stichocorys armata Haeckel

Cyrtophormis armata Haeckel, 1887, p. 1460, pl. 78, fig. 17.
Stichocorys armata (Haeckel) Riedel and Sanfilippo, 1971, p. 1595, pl. E, figs. 13–15; Kling, 1973, p. 638, pl. 13, fig. 11.

Occurrences. Early–middle Miocene.

Stichocorys delmontensis Campbell and Clark
(Pl. 4, Figs. 3–4)

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; Kling, 1973, p. 638, pl. 11, figs. 8–10; Foreman, 1975, p. 622, pl. 9, figs. 5–7; Sakai, 1980, p. 711, pl. 8, fig. 3; Wolfart, 1981, p. 499, pl. 1, figs. 10–11; Weaver et al., 1981, pl. 3, figs. 1, 2; Perez-Guzman, 1985, p. 332, pl. 2, fig. 6; Morley, 1985, p. 412, pl. 7, fig. 2.

Occurrences. Miocene–Pliocene.

Stichocorys sp. P
(Pl. 4, Figs. 5a–5b)

Stichocorys peregrina (Riedel) Kling, 1973, p. 638, pl. 4, fig. 27, pl. 11, fig. 29, pl. 13, fog. 9, 10; Ling, 1980, pl. 2, fig. 11; Sakai, 1980, pl. 8, figs. 1, 2; Weaver et al., 1981, pl. 4, figs. 1, 2; Perez-Guzman, 1985, pl. 2, fig. 7a; Morley, 1985, pl. 7, fig. 1B.
Stichocorys delmontensis (Campbell and Clark) Nakaseko, 1963, text-fig. 17, pl. 4, fig. 13.

Description. The species was defined as *Stichocorys peregrina* in the course of studies of deposits from North Pacific. It my opinion that this is not correct as it differs significantly from the holotype. This is, possibly, a new species. A typical illustration of this species is given in the paper by Sakai (1980).
Occurrences. Middle Miocene–Pliocene.

Family LYCHNOCANIIDAE Haeckel, 1881
Genus *LYCHNOCANIUM* Ehrenberg, 1847

Lychnocanium nipponicum Nakaseko
(Pl. 3, Figs. 4a–4b)

Lychnocanium nipponicum Nakaseko, 1963, p. 168, text-fig. 2, pl. 1, figs. 1a, 1b; Sakai, 1980, p. 710, pl. 9, figs. 2a, 2b.
Lychnocanium grande Campbell and Clark, 1944, p. 42, pl. 6, fig. 3 (only).
?Lychnocanoma grande (Campbell and Clark) Kling, 1973, p. 637, pl. 10, figs. 11–14; Perez-Guzman, 1985, p. 332, pl. 2, fig. 5.

Occurrences. Middle–upper Miocene.

Lychnocanium nipponicum magnacornutum Sakai
(Pl. 3, Figs. 3a–b)

Lychnocanoma nipponica magnacornuta Sakai, 1980, p. 710, pl. 9, figs. 3a, b; Funayama, 1988, pl. 3, figs. 10, 14.
Lychnocanium sp., Ling, 1973, p. 781, pl. 2, figs. 10, 11.

Occurrences. Middle Miocene.

Family ARTOSTROBIIDAE Riedel, 1967
Genus *BOTRYOSTROBUS* Haeckel, 1887, emend. Petrushevskaya and Kozlova, 1972

Botryostrobus auritus-australis Ehrenberg

Botryostrobus auritus-australis (Ehrenberg) group Nigrini, 1977, p. 246, pl. 1, figs. 2–5.
Siphocampe caminosa Haeckel, 1887, p. 1500, pl. 79, fig. 12.
Lithostrobus seriatus Haeckel, 1887, p. 1474, pl. 79, fig. 15.
Artostrobium auritum (Ehrenberg) group Riedel and Sanfilippo, 1971, p. 1599, pl. 1H, figs. 5–7; Kling, 1973, p. 639, pl. 5, figs. 27–30, pl. 12, figs. 24–27.

Occurrences. Upper Miocene–Pliocene.

Botryostrobus bramlettei (Campbell and Clark)

Lithomitra bramlettei Campbell and Clark, 1944, p. 53, pl. 7, fig. 10–14.
Botryostrobus bramlettei (Campbell and Clark) Nigrini, 1977, p. 248, pl. 1, figs. 7, 8.

Occurrences. Upper Miocene–Pliocene.

Botryostrobus aquilonaris (Bailey)

Eucyrtidium aquilonaris Bailey, 1856, p. 4, pl. 1, fig. 9.
Siphocampe erucosa Haeckel, 1887, p. 1500, pl. 79, fig. 11.
Dictyocephalus miralestensis Campbell and Clark, 1944, p. 45, pl. 6, figs. 12–14.
Artostrobium miralestense (Campbell and Clark) Kling, 1973, p. 639, pl. 5, figs. 31–35, pl. 12, figs. 28–31.
Eucyrtidium tumidulum (Bailey) Ling, 1973, p. 781, pl. 2, figs. 7, 8.
Botryostrobus aquilonaris (Bailey) Nigrini, 1977, p. 246, pl. 1, fig. 1; Ling, 1980, p. 367, pl. 2, fig. 20; Morley, 1985, p. 411, pl. 1, fig. 1.
Botryostrobus miralestensis (Campbell and Clark) Wolfart, 1981, p. 496, pl. 2, figs. 8–10.

Occurrences. Upper Miocene–Pleistocene.

Genus *LITHAMPHORA* Popofsky, 1908, emend. Petrushevskaya, 1971

Lithamphora fistula (Nigrini)
(Pl. 4, Fig. 2)

Phormostichoartus fistula Nigrini, 1977, p. 253, pl. 1, figs. 11–13.

Occurrences. Miocene–Pliocene.

Family PTEROCORYIDAE Haeckel, 1881
Genus *ANDROCYCLAS* Jorgensen, 1905

Androcyclas heteroporos (Hays)
(Pl. 4, Figs. 6a–6b)

Lamprocyclas heteroporos Hays, 1965, p. 179, pl. 3, fig. 1.

Lamprocyrtis heteroporos (Hays) Kling, 1973, p. 639, pl. 5, figs. 19, 20; Foreman, 1975, p. 620, pl. 8, fig. 21; Sakai, 1980, p. 711, pl. 9, figs. 9–11; Morley, 1985, p. 411, pl. 6, figs. 3A, B; Wolfart, 1981, p. 498, pl. 2, figs. 4, 6, 7.

Occurrences. Pliocene–Pleistocene.

Androcyclas neoheteroporos (Kling)

Lamprocyclas neoheteroporos Kling, 1973, pl. 5, figs. 17, 18, pl. 15, figs. 4, 5; Foreman, 1975, p. 620, pl. 9, fig. 12; Sakai, 1980, p. 711, pl. 9, figs. 9a, 9b; Wolfart, 1981, p. 498, pl. 2, figs. 3, 5.

Occurrences. Pliocene–Pleistocene.

Genus *LIPMANELLA* Loeblich and Tappan, 1961

Lipmanella redondoensis (Campbell and Clark)
(Pl. 3, Figs. 5a–5b, 6?)

Theocyrtis redondoensis Campbell and Clark, 1944, p. 49, pl. 7, fig. 4; Nakaseko, 1963, p. 179, pl. 2, fig. 4; text-fig. 12.
Theocorys redondoensis Kling, 1973, p. 638, pl. 11, figs. 26–28; Ling, 1973, p. 781, pl. 2, fig. 13; Ling, 1980, pl. 2, fig. 13; Sakai, 1980, p. 711, pl. 8, fig. 13; Weaver et al., 1981, pl. 2, figs. 1, 2; Perez-Guzman, 1985, pl. 2, fig. 8.

Occurrences. Miocene–Pliocene.

Family TRIOSPYRIDIDAI Haeckel, 1881
Genus *ACROSPYRIS* Haeckel, 1881

Acrospyris lingi n. sp.
(Pl. 2, Figs. 4a–4b, holotype)

Acanthodesmid sp., Ling, 1973, p. 780, pl. 2, fig. 1.

Description. A shell with a well-developed cephalis. Apical spine not developed. Shell thick-walled. Sagittal ring slightly protruding on to the outer surface on cephalis. Cephalis pores of different size, commonly arranged symmetrically relative to the sagittal ring. Diameter of large pores about 20 μm; that of small ones, 8–11 μm. Dimensions of cephalis: length, 55–80 μm; width, 75–100 μm (based on measurements of 20 specimens). Commonly about 6 basal feet. They are connected by transverse bars and form something similar to a thorax with large pores and smaller fine bars. Single pores are visible in places of their junction. When there are 6 basal feet, they form a hexahedron in the section. The diameter of pores is 40–45 μm; thickness of bars, 10–15 μm. Width of "pseudothorax" 100–110 μm; the preserved length 50–60 μm.

Name. This form was first discovered by paleontologist H. Ling, and is named *lingi* after him.

Occurrences. Sample 145-883B-62X-CC. Lower Miocene.

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* Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

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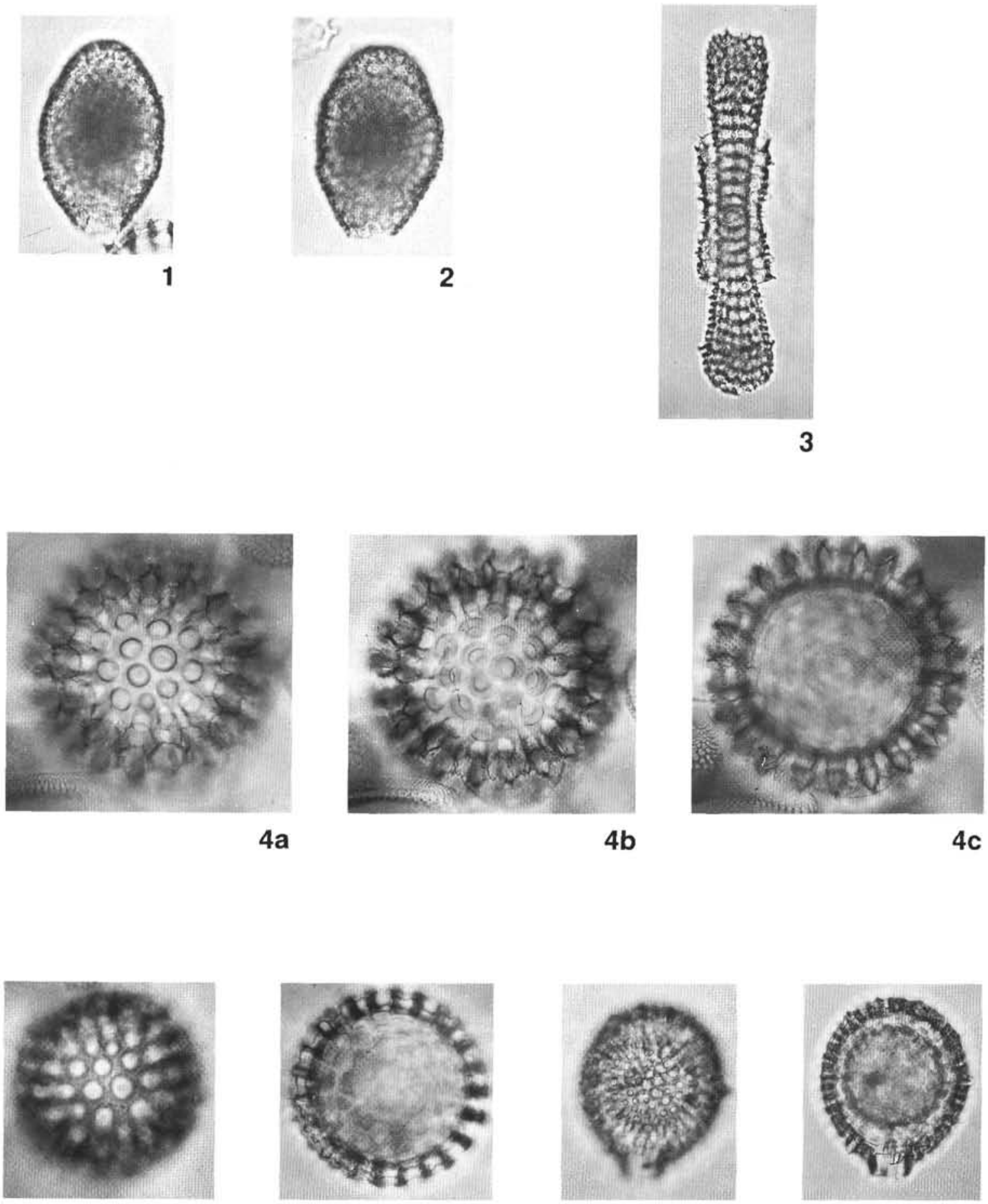

Plate 1. **1, 2.** *Lithocarpium titan* Campbell and Clark. Sample 145-884B-66X-CC. **3.** *Amphymenium amphistylium* Haeckel group. Sample 145-884B-60X-CC. **4.** *Cenosphaera coronataformis* n. sp. (holotype). Sample 145-883B-64X-CC. **5.** *Cenosphaera coronata* Haeckel. Sample 145-883B-66X-CC. **6.** *Sphaeropyle robusta* Kling. Sample 145-884B-60X-CC. (All ×200)

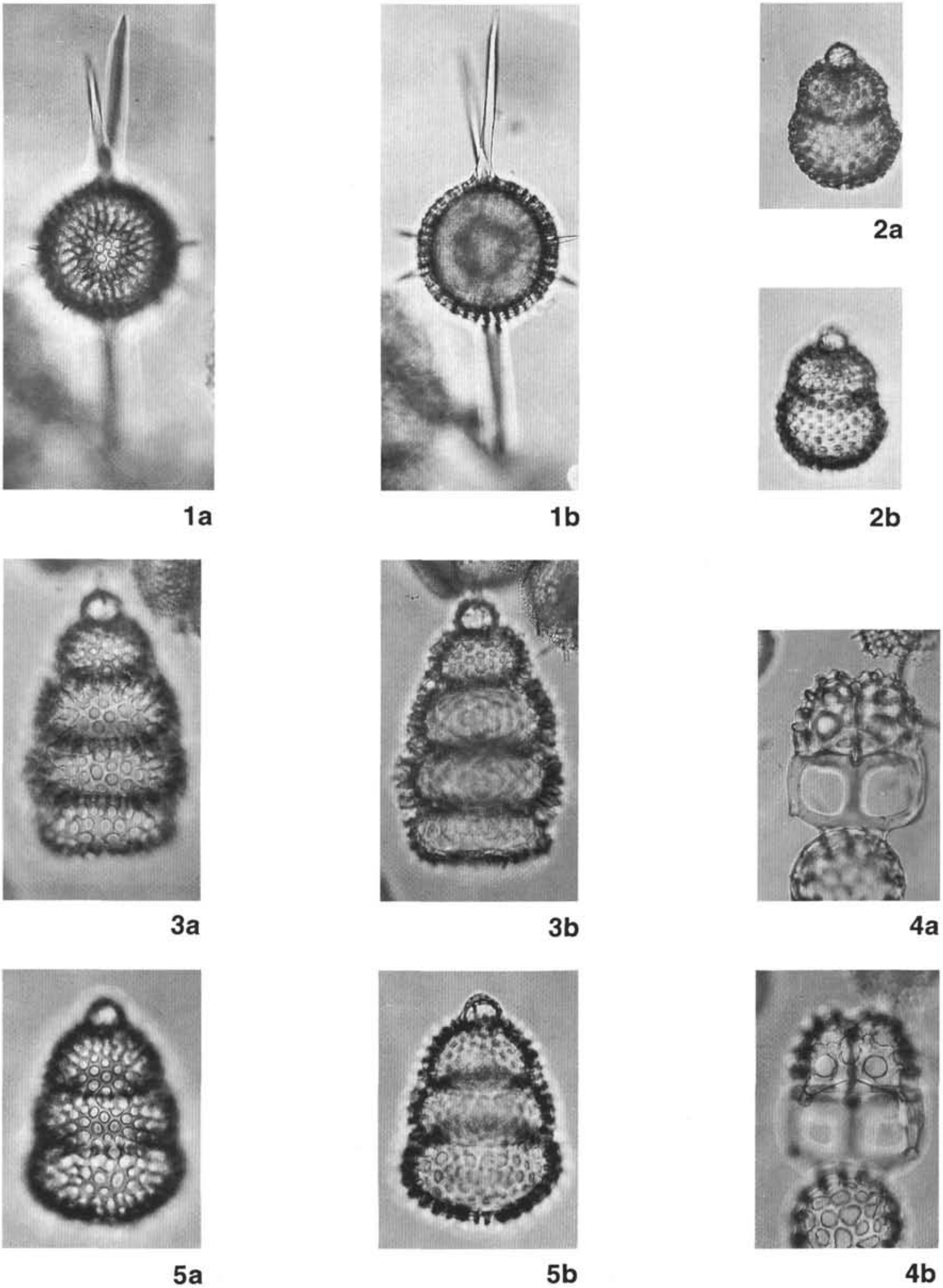

Plate 2. **1.** *Stylosphaera angelina* Campbell and Clark. Sample 145-883B-67X-CC. **2.** *Cyrtocapsella japonica* Nakaseko. Sample 145-887C-25X-CC. **3.** *Lithocampe subligata* Stohr. Sample 145-883B-63X-CC. **4.** *Acrospyris lingi* n. sp. (holotype). Sample 145-883B-62X-CC. **5.** *Cyrtocapsella tetrapera* Haeckel. Sample 145-883B-66X-CC. (All ×200)

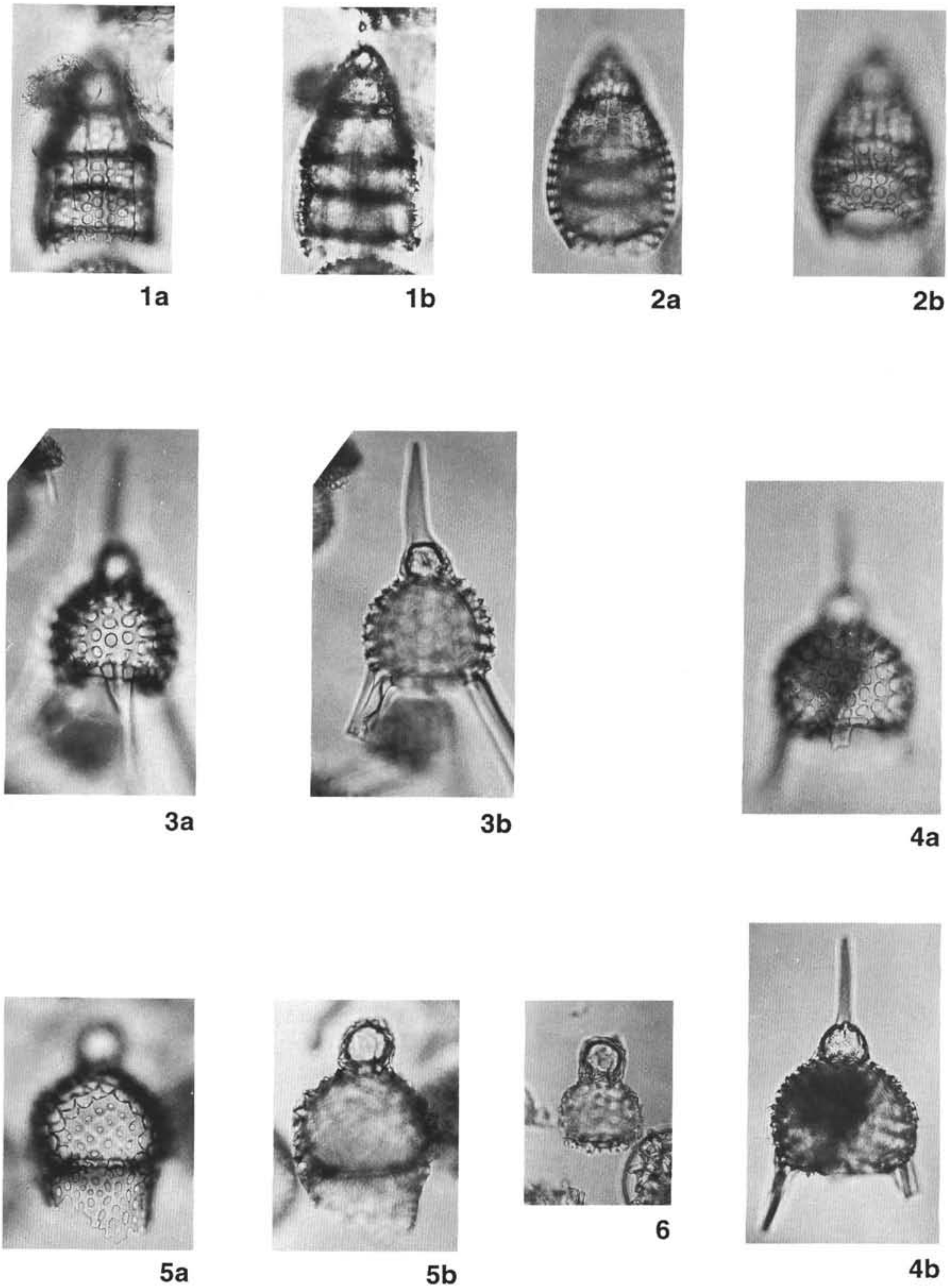

Plate 3. **1.** *Eucyrtidium asanoi* Sakai. Sample 145-884B-60X-CC. **2.** *Eucyrtidium inflatum* Kling. Sample 145-887C-28H-CC. **3.** *Lychnocanium nipponicum magnacornutum.* Sample 145-884B-51X-CC. **4.** *Lychnocanium nipponicum.* Sample 145-887C-25H-CC. **5.** *Lipmanella redondoensis* Campbell and Clark. Sample 145-884B-60X-CC. **6.** *Lipmanella redondoensis*? Campbell and Clark (ancestor). Sample 145-883B-62X-CC. (All ×200)

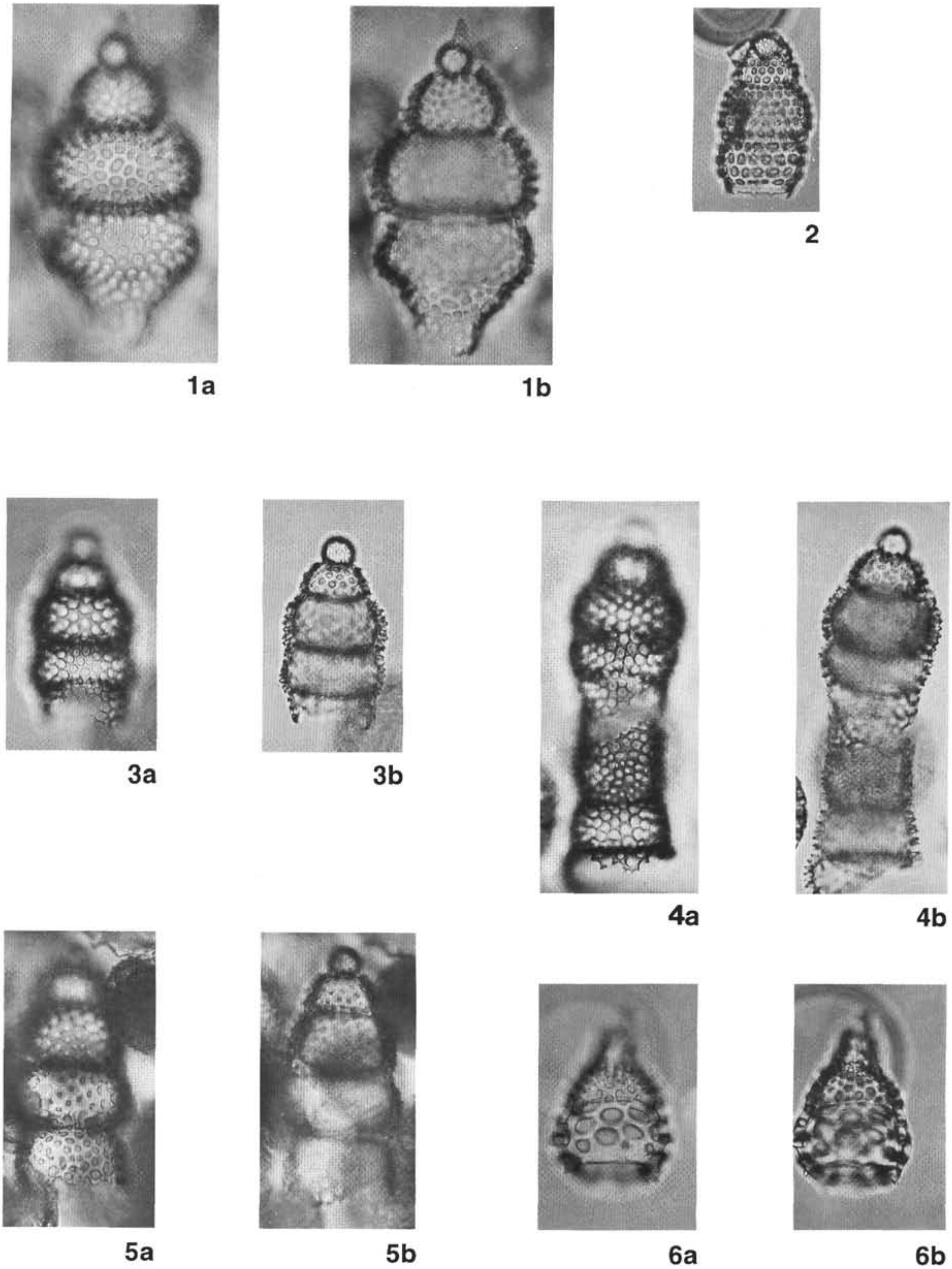

Plate 4. **1.** *Stichocorys diploconus* Haeckel. Sample 145-887C-29H-CC. **2.** *Lithamphora fistula* Nigrini. Sample 145-883B-59X-CC. **3, 4.** *Stichocorys delmontensis* Campbell and Clark. Sample 145-887C-22H-CC. **5.** *Stichocorys* sp. P. Sample 145-883B-47H-CC. **6.** *Androcyclus heteroporos* Hays. Sample 145-887C-15H-CC. (All ×200)

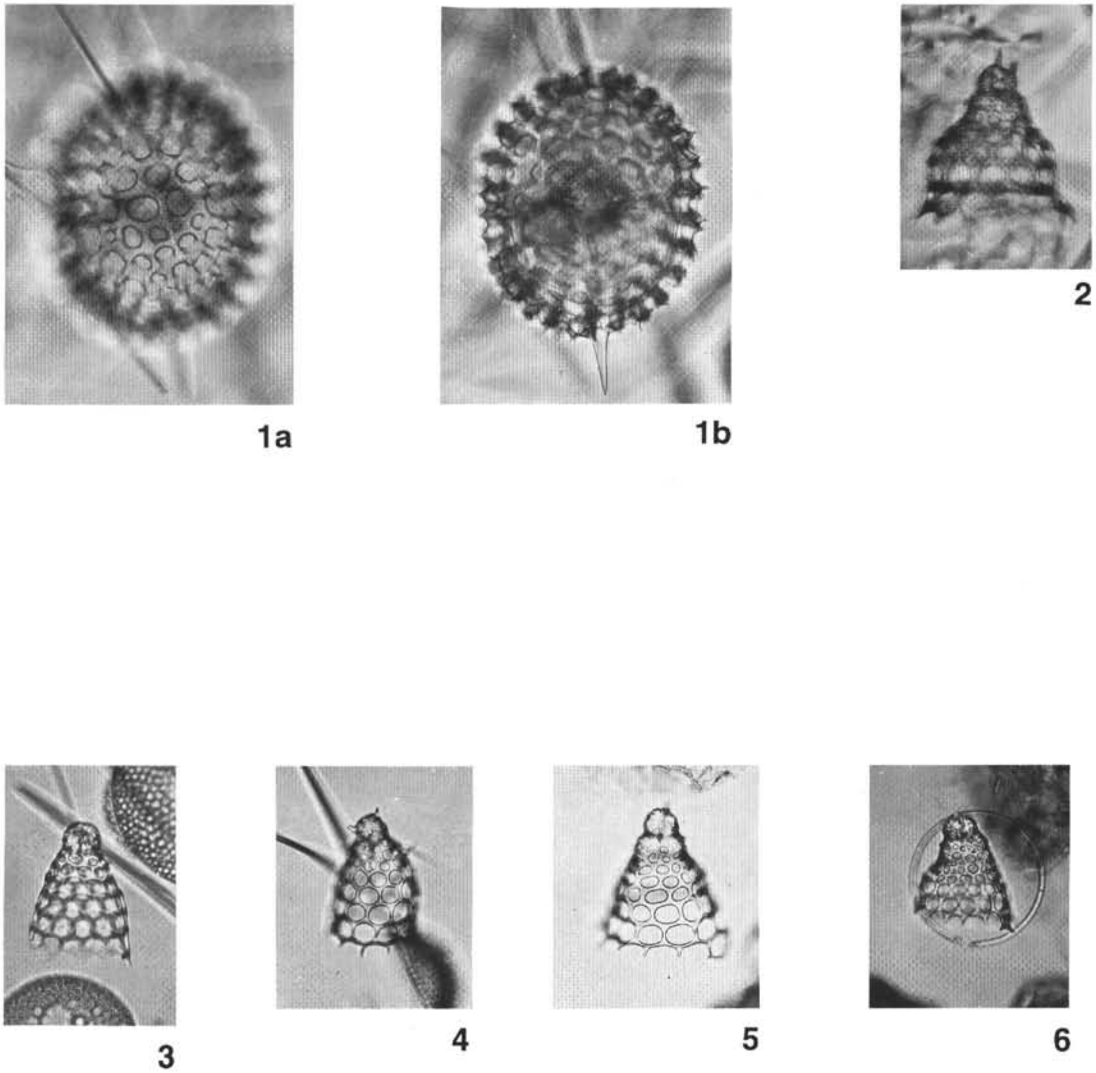

Plate 5. **1.** *Axoprunum acquilonius* Hays. Sample 145-887C-15H-CC. **2.** *Clathrocyclas bicornis* Hays. Sample 145-887C-12H-CC. **3, 4.** *Diplocyclas cornutoides* Petrushevskaya. Sample 145-887C-10H-CC. **5, 6.** *Diplocyclas davisiana* Ehrenberg. Sample 145-887C-10H-CC. (All ×200)