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6. EOCENE–OLIGOCENE RADIOLARIANS FROM LEG 145, NORTH PACIFIC[1]

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ABSTRACT

During the Leg 145 cruise in the North Pacific Ocean, well-preserved Paleogene radiolarians were obtained from Holes 883B, 883E, and 884B. Their distribution pattern in these sections has been revealed and high-latitude radiolarian assemblages in the North Pacific are described. Biostratigraphic schemes proposed in low latitudes and other Northern Hemisphere regions are not applicable in the subarctic Pacific, because most zone marker species of other regions are absent here. Two new species, *Dictyomitra amygdala* and *Lithomitra micropore* are described.

INTRODUCTION

At the present, the Eocene–Oligocene radiolarians of the Northern Pacific have not been adequately analyzed because of the absence of well-studied and continuous geological sections that contain them. Many of the earlier studied sections contain breaks or do not correlate reliably with any scales (paleomagnetic, scales based on nannoplankton or foraminifers). Among the earlier studies on the Eocene–Oligocene radiolarians in the Northern high latitudes, the works by Clark and Campbell (1942, 1945) and Blueford (1988) on California and Vitukhin (1992) and Runeva (1984) on far eastern of Russia should be noted. Eocene radiolarians of the Boreal Realm have been studied by Kozlova (1983, 1984). Lipman (1987) described radiolarians in sections of the western Siberian Lowland and distinguished zonal units. Eocene–Oligocene radiolarians from Norwegian Sea deposits have been studied by Petrushevskaya and Kozlova (1979) and Bjørklund (1976).

During Leg 145 of the Ocean Drilling Program (ODP) in the North Pacific (North Pacific Transect) several holes were drilled that penetrated Eocene–Oligocene deposits on the Emperor Seamounts at the latitude of 51°N (Sites 883 and 884), and yielded well-preserved radiolarians. Nannofossil chalks, calcareous chalks and claystones were the enclosing deposits for these radiolarian assemblages.

The materials obtained in the course of drilling appear to be unique for the Eocene–Oligocene biostratigraphy of the Boreal Realm of the Pacific for several reasons: (1) at present, they contain the most complete information on the middle Eocene–Oligocene of the Boreal Realm of the Pacific; (2) they contain well-preserved radiolarians that are sufficiently representative for use in biostratigraphic correlations; (3) they can be correlated with biostratigraphic zones based on the nannoplankton observed (Holes 883B and 883E).

PROCEDURES

Preparation of radiolarian samples for microscopic examination during Leg 145 and next period followed the methods described by Sanfilippo et al (1985) and Petrushevskaya (1986). Between 3 and 5 cm^3 of sediments was disaggregated and oxidized in a 10% hydrogen peroxide solution. In addition, those samples containing carbonate were treated with a solution of hydrochloric acid to dissolve all calcareous microfossils. Brief treatment of most samples in an ultrasonic bath was followed by washing in a 63-µm mesh sieve. Strewn slides were prepared from the residue for examination of radiolarians.

Radiolarian assemblage abundance was assessed as follows:

A = abundant (>500 specimens on a 22 × 50 mm slide),
C = common (100–500 specimens on a slide),
F = few (50–100 specimens on a slide), and
R = rare (<50 specimens on a slide).

The abundance of each species in such slide is indicated by:

A = abundant (>20),
C = common (10–20),
F = few (5–10), and
R = rare (<5).

Preservation of the radiolarian assemblage was based on the following criteria:

1. Good = radiolarians show little sign of dissolution with only minor fragmentation;
2. Moderate = radiolarians show evidence of moderate dissolution with obvious fragmentations; and
3. Poor = radiolarians show signs of a high degree of dissolution with few intact specimens.

BIOSTRATIGRAPHY

Study of the Eocene–Oligocene geological succession from Sites 883 and 884 required an analysis of the available Boreal biostratigraphic zonations and described species from different regions.

Many radiolarian species of the middle–late Eocene from Sites 883 and 884 were described from Californian sections by Clark and Campbell (1942, 1945).

Blueford (1988) who had studied radiolarians from the middle Eocene deposits of California, distinguished two biostratigraphic zones: *Podocyrtis fasciata* and *Calocyclas semipolita.* Their use for Leg 145 sections appeared to be unacceptable because of the lack of zonal species.

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Vitukhin, in his thesis on materials from geological sections of far eastern Russia (1992), suggested that beds with fauna should be distinguished in the Eocene–Oligocene deposits with radiolarian assemblages. Beds with *Theocotyle* (?)*bicornis–Buryella tetradica, Theocyrtis litos*, and *Theocyrtis litos–Ceratospyris tons* have been distinguished for the Eocene. In the Oligocene, beds with *Lithomitrissa conica–Theocotyle multichornia* and *Lithomitrissa conica-Haliomma* (?)*extima* have been distinguished. It was also impossible to apply this scheme of distinguishing beds with fauna for subdivision of the sedimentary succession from Sites 883 and 884 because of the lack of zonal species.

Some Eocene–Oligocene radiolarian species discovered in the deposits of Sites 883 and 884 (*Cenosphaera aspera, Spongodiscus osculosus,* and *Clathrocyclas extensa*) were revealed earlier in samples taken from holes drilled in the Norwegian Sea during Deep Sea Drilling Project Leg 38 (Petrushevskaya and Kozlova, 1979).

Application of the zonal biostratigraphic scale for the Eocene–Oligocene based on radiolarians and developed for the tropical part of the World Ocean (Riedel and Sanfilippo, 1970, 1978; Foreman, 1973; Sanfilippo et al., 1985) appeared to be impossible because of the lack of zone marker species. Among the events that could be revealed in the sedimentary succession of Hole 883B are the following: (1) the presence of *Eusyringium striata* Brandt (one specimen in Sample 145-883B-79X-CC) and (2) the appearance of *Dictyoprora mongolfieri* Ehrenberg. Therefore, there were no grounds for distinguishing biostratigraphic zones based on radiolarians, applied for the tropical area.

The materials obtained during Leg 145 enabled us to determine the specific distribution features of the Eocene–Oligocene radiolarians in Sites 883 and 884 and to propose a new biostratigraphic zonation (for discussion) correlated with nannoplankton zones for the middle–late Eocene.

The middle–late Eocene geological sections yield well-preserved radiolarian assemblages.

The following zonation is proposed (Hollis, 1976) for the middle–late Eocene:

1. *Podocyrtis mitrella* Range Zone (middle Eocene; NP 12–14).
   Base: First Occurrence (FO) of *Podocyrtis mitrella.*
   Top: Last Occurrence (FO) of *Podocyrtis mitrella.*
   Radiolarian assemblages from this zone comprise the following species: *Podocyrtis mitrella, Dictyoprora amphora, Dictyomitra amygdala*, and *Lithomitra micropore.*
2. *Dictyomitra amygdala* Interval Zone (middle Eocene: NP 14).
   Base: LO of *Podocyrtis mitrella.*
   Top: FO of *Dictyoprora mongolfieri.*
   Radiolarian assemblages from this zone comprise the following species: *Dictyoprora amphora* and *Dictyomitra amygdala.*
3. *Dictyoprora amphora* Interval Zone (middle–late Eocene; NP 14–18).
   Base: FO of *Dictyoprora mongolfieri.*
   Top: LO of *Dictyoprora amphora.*
   Radiolarian assemblages from this zone comprise the following species: *Dictyoprora amphora, Phormocyrtis embolum* gr. (the appearance of this species is close to the base of the zone), *Dictyomitra amygdala, Clathrocyclas extensa, Clathrocyclas universa* gr., *Artobotrys auriculaleporis,* and *Lychnocanella babylonis.*

Several events can be recorded in the Oligocene part of the section: (1) appearance and disappearance of *Calocyclas asperum,* (2) abundance of *Axoprunum losbanosensis,* (3) appearance of *Stylosphaera angelina,* (4) appearance of *Lithocarpium titan,* (5) appearance of *Spongodiscus osculosus,* (6) disappearance of *Cenosphaera aspera,* and (7) appearance of *Axoprunum bispiculum.*

RADIOLARIANS IN EACH HOLE

Hole 883B

Hole 883B (Table 1) is located at 51°11.908′N, 167°46.128′E, in a water depth of 2384 m. There are no radiolarians within the interval between Samples 145-883B-87X-CC and -88X-CC. In the interval between Samples 145-883B-85X-CC and -86X-CC, radiolarians have been replaced by ore substance. In addition, single impressions of the Jurassic–Cretaceous forms *Stichocapsa* spp. occur in this interval. In the interval between Samples 145-883B-84X-CC and -84X-1, 38–39 cm, single specimens of *Cenosphaera* spp. occur. In the interval between Samples 145-883B-83X-CC and -82X-CC, single, strongly altered radiolarians occur, indefinable as to genus. Section 145-883B-81X-CC yielded a radiolarian assemblage from the *Podocyrtis mitrella* Zone. The first and the last appearance of the species *Podocyrtis mitrella* is recorded. The radiolarian assemblage is represented by the following species: *Dictyoprora amphora, Dictyomitra amygdala, Lithomitra micropore, Gorgospyris hemisphaerica,* and *Stylosphaera coronata.* Sample 145-883B-80X-CC contains radiolarians *Dictyoprora amphora* and *Dictyoprora amygdala.* Within the interval between Samples 145-883B-79X-CC and -75X-CC, a radiolarian assemblage from the *Dictyoprora amphora* Zone was discovered, comprising the following species: *Dictyoprora amphora, Dictyoprora mongolfieri, Phormocyrtis embolum* group?, *Dictyomitra amygdala, Clathrocyclas extensa, Clathrocyclas universa, Artobotrus auriculaleporis, Lychnocanella babylonis,* and *Stylatractus ostracion.* Sample 145-883B-74X-CC contains no radiolarians. In the interval between Samples 145-883B-73X-CC and -69X-1, 90–92 cm (Oligocene), a radiolarian assemblage occurs that contains the following species: *Cenosphaera aspera, Cenosphaera eocenica, Spongodiscus osculosa, Axoprunum bispiculum, Axoprunum losbanosensis, Stylosphera angelina, Lithocarpium titan,* and *Calocyclas asperum.* Main radiolarian events of the Oligocene are associated with samples from the following cores: (1) appearance and disappearance of *Calocyclas asperum* in Sample 145-883B-71X-CC, (2) common occurrence (CO) of *Axoprunum losbanosensis* in Sample 145-883B-71X-5, 90–91 cm, (3) appearance of *Stylosphaera angelina* in Sample 145-883B-71X-5, 90–91 cm, (4) appearance of *Lithocarpium titan* in Sample 145-883B-70X-CC, (5) appearance of *Spongodiscus osculosa* in Sample 883B-70X-2, 90–91 cm, (6) disappearance of *Cenosphaera aspera* in Sample 145-883B-69X-1, 90–91 cm, and (7) appearance of *Axoprunum bispiculum* in Sample 145-883B-71X-5, 90–91 cm.

Hole 883E

Hole 883E (Table 2), is located at 51°11.917′N, 167°46.098′E, in a water depth, 2385 m. The interval between Samples 145-883E-16R-CC and -19R-CC yielded no radiolarians. Sample 145-883E-15R-CC contained a few well-preserved radiolarians (*Spongurus bilobatus* and *Axocorys* sp.), as well as strongly altered forms (*Buryella tetradica* and *Eusyringium striata exquisita*), possibly redeposited from the lower Eocene sediments. Apparently, the deposits from this interval could be placed into the lower middle Eocene to the *Podocyrtis mitrella* Zone. Core 145-883E-14R could be assigned to the *Dictyomitra amygdala* Zone as it contains no species of *Podocyrtis mitrella* and *Dictyoprora mongolfieri.* It comprises single specimens of *Dictyomitra amygdala* and *Dictyoprora amphora.* The interval between Samples 145-883E-13R-CC and -9R-1, 66–68 cm, yielded a radiolarian assemblage from the *Dictyoprora amphora* Zone: FO *Dictyoprora mongolfieri* (Sample 145-883E-13R-CC) and LO *Dictyoprora amphora* (Sample 145-883E-9R-1, 66–68 cm). The assemblage comprises the following species: *Artobotrys auriculaleporis, Lithomitra micropore, Phormocyrtis embolum, Clathrocyclas extensa, Lychnocanella babylonis,* and *Dictyomitra amygdala.* The interval between Samples 145-883E-8R-CC and -6R-CC yielded a

Table 1. Radiolarians at Hole 883B.

Age	late Oligocene						early Oligocene																	
Nannoplankton zone	NP 23–NP 25						NP 22																	
Radiolarian zone	Unzoned																							
Core, section:	69X-1	69X-2	69X-3	69X-CC	70X-2	70X-3	70X-4	70X-5	70X-6	70X-CC	71X-5	71X-6	71X-CC	72X-1	72X-2	72X-3	72X-4	72X-CC	73X-1	73X-2	73X-3	73X-4	73X-5	73X-6
Interval (cm):	90	90	90–91		90	90	90–91	90	90–91	91	90	90	91	90	90–92	90–92	88–92	89	90	90–91	90–91	90–91	90–91	90
Abundance:	R	F	R	R	F	F	R	B	R	R	A	R	R	B	B	R	R	R	B	R	R	R	R	B
Preservation:	P	M	M	P	M	M	M		M	M	M	P	P			M	M	P		M	P	P	P	
Artobotrys auriculaleporis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Artobotrys titanothriceros	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Artobotrys bicorne	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axocorys sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axoprunum bispiculum	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Axoprunum losbanosensis	.	.	.	.	.	.	.	.	.	R	A	R	.	.	.	.	.	.	.	.	.	.	.	.
Buryella tetradica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calocyclas asperum	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.
Carposphaera magnaporylosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera aspera	R	.	R	.	.	.	R	.	.	.	R	.	.	.	.	.	.	.	.	R	.	.	.	.
Cenosphaera eocenica	.	F	.	.	F	F	R	.	R	.	.	.	.	.	.	R	R	R	.	R	.	.	R	.
Cenosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas universa gr.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas extensa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora amphora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora mongolfieri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora urceolus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.
Dictyomitra amygdala	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithocarpium titan	.	.	R	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitrella elizabethae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitrella minuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitra micropore	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	R	.
Lychnocanella babylonis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lychnocanium conicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gorgospyris hemisphaerica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Podocyrtis mitrella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata striata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata exquisita	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phormocyrtis embolum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongodiscus osculosa	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongosphaera pachystyla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongurus bilobatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stichocapsa spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylatractus ostracion	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera coronata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.
Stylosphaera angelina	.	.	.	.	R	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera liostylus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera minor	.	.	R	R	.	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Theocyrtis litos	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Notes: Radiolarian Zone A = *Podocyrtis mitrella* Zone, Radiolarian Zone B = *Dictyomitra amygdala* Zone. Abundance and Preservation: A = abundant; F = frequent; C = common; R = rare; G = good; M = moderate; B = barren. P = poor.

Table 1 (continued).

Age	e. Oligocene		late Eocene									middle Eocene											
Nannoplankton zone	NP 22	NP 17?–NP 18															NP 15–NP 16						
Radiolarian zone	Unzoned							*Dictyoprora amphora*															
Core, section:	73X-CC	74X-1	74X-2	74X-CC	75X-1	75X-3	75X-4	75X-CC	76X-1	76X-3	76X-4	76X-5	76X-CC	77X-1	77X-2	77X-3	77X-4	77X-5	77X-CC	78X-1	78X-2	78X-3	78X-4
Interval (cm):	91	90	90–91	91	89	89–90	89–90		90	90–91	90	90	91	90	90–91	90–91	90	90–91	91	90	90–91	90–91	88–91
Abundance:	R	B	B	B	C	B	F	R	B	F	A	C	R	C	R	C	B	R	R	R	R	C	R
Preservation:	P				M		M	P		M	G	M	P	M	M	P		P	M	M	M	P	M
Artobotrys auriculaleporis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	R
Artobotrys titanothriceros	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Artobotrys bicorne	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axocorys sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axoprunum bispiculum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axoprunum losbanosensis	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.
Buryella tetradica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calocyclas asperum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carposphaera magnaporylosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera aspera	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera eocenica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas universa gr.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas extensa	R	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora amphora	.	.	.	.	.	.	.	R	.	.	F	R	R	R	.	R	.	.	.	.	.	.	.
Dictyoprora mongolfieri	.	.	.	.	.	.	.	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora urceolus	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyomitra amygdala	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	F	R
Lithocarpium titan	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitrella elizabethae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.
Lithomitrella minuta	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.
Lithomitra micropore	.	.	.	.	.	.	F	R	.	R	R	A	.	R	R	F	.	.	.	R	R	F	R
Lychnocanella babylonis	.	.	.	.	.	.	R	R	.	R	C	.	.	.	.	.	.	.	.	.	.	.	.
Lychnocanium conicum	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.
Gorgospyris hemisphaerica	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Podocyrtis mitrella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata striata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata exquisita	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phormocyrtis embolum	.	.	.	.	.	.	.	R	.	F	A	.	.	.	.	.	.	.	.	.	.	R	R
Spongodiscus osculosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongosphaera pachystyla	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongurus bilobatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stichocapsa spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylatractus ostracion	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.
Stylosphaera coronata	.	.	.	.	.	.	.	R	.	F	R	.	.	F	.	.	.	.	.	.	.	.	R
Stylosphaera angelina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera liostylus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera minor	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Theocyrtis litos	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 1 (continued).

Age	middle Eocene								early Eocene														
Nannoplankton zone	NP 15–NP 16							NP 14	NP 12														
Radiolarian zone	*Dictyoprora amphora*							B	A														
Core, section:	78X-5	78X-6	78X-CC	79X-1	79X-2	79X-3	79X-CC	80X-CC	81X-CC	82X-1	82X-2	82X-3	82X-4	82X-5	82X-6	82X-CC	83X-1	83X-2	83X-3	83X-4	83X-CC	84X-1	84X-CC
Interval (cm):	88–89	89–89	90	90	88	91				90	90–91	90–91	90–91	90–91	90–91	91	90	90-91	90-91	89–91	90	38	
Abundance:	R	R	C	B	B	C	R	R	F	B	B	B	B	B	B	B	R	B	B	B	B	R	R
Preservation:	P	M	M			M	P	P	P								P					P	P
Artobotrys auriculaleporis	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Artobotrys titanothriceros	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Artobotrys bicorne	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axocorys sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axoprunum bispiculum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axoprunum losbanosensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Buryella tetradica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calocyclas asperum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carposphaera magnaporylosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera aspera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera eocenica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	R	R
Clathrocyclas universa gr.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas extensa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora amphora	R	.	R	.	.	R	R	R	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora mongolfieri	.	.	R	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora urceolus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyomitra amygdala	.	R	C	.	.	A	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithocarpium titan	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitrella elizabethae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitrella minuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitra micropore	R	R	.	.	.	R	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lychnocanella babylonis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lychnocanium conicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gorgospyris hemisphaerica	.	.	.	.	.	F	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Podocyrtis mitrella	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata striata	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata exquisita	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phormocyrtis embolum	R	.	R	.	.	R		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongodiscus osculosa	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongosphaera pachystyla	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongurus bilobatus	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stichocapsa spp.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylatractus ostracion	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera coronata	R	R	.	.	.	R	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera angelina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera liostylus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera minor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Theocyrtis litos	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 1 (continued).

Age	Cretaceous							
Nannoplankton zone	Campanian?							
Radiolarian zone								
Core, section:	85X-CC	86X-CC	86X-1	86X-2	86X-4	86X-5	86X-5	86X-CC
Interval (cm):			90	90	90	64	90	
Abundance:	R	R	R	B	B	R	B	R
Preservation:	P	P	P			P		P
Artobotrys auriculaleporis	.	.	.	.	.	.	.	.
Artobotrys titanothriceros	.	.	.	.	.	.	.	.
Artobotrys bicorne	.	.	.	.	.	.	.	.
Axocorys sp.	.	.	.	.	.	.	.	.
Axoprunum bispiculum	.	.	.	.	.	.	.	.
Axoprunum losbanosensis	.	.	.	.	.	.	.	.
Buryella tetradica	.	.	.	.	.	.	.	.
Calocyclas asperum	.	.	.	.	.	.	.	.
Carposphaera magnaporylosa	.	.	.	.	.	.	.	.
Cenosphaera aspera	.	.	.	.	.	.	.	.
Cenosphaera eocenica	.	.	.	.	.	.	.	.
Cenosphaera spp.	.	.	.	.	.	.	.	.
Clathrocyclas universa gr.	.	.	.	.	.	.	.	.
Clathrocyclas extensa	.	.	.	.	.	.	.	.
Dictyoprora amphora	.	.	.	.	.	.	.	.
Dictyoprora mongolfieri	.	.	.	.	.	.	.	.
Dictyoprora urceolus	.	.	.	.	.	.	.	.
Dictyomitra amygdala	.	.	.	.	.	.	.	.
Lithocarpium titan	.	.	.	.	.	.	.	.
Lithomitrella elizabethae	.	.	.	.	.	.	.	.
Lithomitrella minuta	.	.	.	.	.	.	.	.
Lithomitra micropore	.	.	.	.	.	.	.	.
Lychnocanella babylonis	.	.	.	.	.	.	.	.
Lychnocanium conicum	.	.	.	.	.	.	.	.
Gorgospyris hemisphaerica	.	.	.	.	.	.	.	.
Podocyrtis mitrella	.	.	.	.	.	.	.	.
Eusyringium striata striata	.	.	.	.	.	.	.	.
Eusyringium striata exquisita	.	.	.	.	.	.	.	.
Phormocyrtis embolum	.	.	.	.	.	.	.	.
Spongodiscus osculosa	.	.	.	.	.	.	.	.
Spongosphaera pachystyla	.	.	.	.	.	.	.	.
Spongurus bilobatus	.	.	.	.	.	.	.	.
Stichocapsa spp.	R	R	R	.	.	R	.	R
Stylatractus ostracion	.	.	.	.	.	.	.	.
Stylosphaera coronata	.	.	.	.	.	.	.	.
Stylosphaera angelina	.	.	.	.	.	.	.	.
Stylosphaera liostylus	.	.	.	.	.	.	.	.
Stylosphaera minor	.	.	.	.	.	.	.	.
Theocyrtis litos	.	.	.	.	.	.	.	.

Table 2. Radiolarians at Hole 883E.

Age	early Oligocene		late Eocene					middle Eocene													early–middle Eocene				
Nannoplankton zone	NP 22		NP 17?–NP 18								NP 15–NP 16								P14	NP 12					
Radiolarian zone	Unzoned			*Dictyoprora amphora*																*D. amyg.*	Unzoned				
Core, section, interval (cm)	6R-CC	7R-CC	8R-CC	9R-1, 66–68	9R-2, 61–62	9R-CC	10R-CC	11R-1, 70–72	11R-2, 70–72	11R-3, 70–71	11R-CC	12R-2, 70–71	12R-3, 70–72	12R-4, 70–71	12R-CC	13R-2, 70–71	13R-3, 69–71	13R-4	13R-CC	14R-CC	15R-CC	16R-CC	17R-CC	18R-CC	19R-CC
Abundance	R	R	R	F	R	C	C	A	C	R	R	R	C	R	F	R	R	F	F	R	F	B	B	B	B
Preservation	P	P	P	M	M	C	P	M	M	M	C	M	M	M	P	M	M	M	P	M	P				
Artobotrys auriculaleporis	.	.	.	.	.	.	R	R	R	.	.	.	.	R	R	.	.	.	R	.	.	.	.	.	.
Axocorys sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
Axoprunum bispiculum	R	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axoprunum losbanosensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Buryella tetradica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
Calocyclas asperum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carposphaera magnaporulosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera aspera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera eocenica	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cenosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas universa gr.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Clathrocyclas extensa	.	.	.	.	.	C	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyoprora amphora	.	.	.	R	R	C	R	R	R	.	.	.	.	.	R	.	R	R	C	R	.	.	.	.	.
Dictyoprora mongolfieri	.	.	.	.	.	C	.	R	.	.	.	.	.	.	F	.	.	.	R	.	.	.	.	.	.
Dictyoprora urceolus	.	.	.	.	.	F	R	.	.	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Dictyomitra amygdala	.	.	.	F	R	R	.	R	.	R	R	R	A	R	F	.	F	R	F	R	.	.	.	.	.
Lithocarpium titan	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithomitrella elizabethae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	R	.	.	.	.	.	.
Lithomitrella minuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.
Lithomitra micropore	.	.	R	F	.	.	R	A	C	R	.	R	F	R	R	R	C	F	R	.	.	.	.	.	.
Lychnocanella babylonis	.	.	.	.	.	R	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lychnocanium conicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gorgospyris hemisphaerica	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	R	R	R	.	.	.	.	.	.
Podocyrtis mitrella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata striata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eusyringium striata exquisita	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
Phormocyrtis embolum	.	.	.	R	.	C	C	.	.	.	.	.	.	.	R	.	.	.	R	.	.	.	.	.	.
Spongosphaera pachystyla	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spongurus bilobatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
Stichocapsa spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylatractus ostracion	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera coronata	.	.	.	R	R	.	F	C	R	.	.	.	R	.	.	.	R	.	.	.	.	.	.	.	.
Stylosphaera liostylus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stylosphaera minor	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Theocyrtis litos	.	.	.	.	.	.	.	.	R	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.

Note: See Table 1 for abbreviations.

poor radiolarian assemblage. It comprises the following species: *Axoprunum bispiculum* (FO in sample 145-883E-8R-CC), *Lithomitra micropore*, and *Cenosphaera eocenica*. The interval between Samples 145-883E-5R-CC and -4R-CC contained no radiolarians.

Hole 884B

Hole 884B (Table 3) is located at 51°27.026′N, 163°20.228′E, in a water depth of 3824 m. No radiolarians were discovered in the interval between Samples 145-884B-91X-CC and -79X-CC. The interval between Samples 884-78X-CC and -70X-CC yielded a poor radiolarian assemblage that contained the following species: *Cenosphaera eocenica, Stylatractus ostracion, Carposphaera magnaporulosa*, and *Lithocarpium titan* (FO in Sample 145-884D-72X-CC). Core 145-884B-69X contained no radiolarians.

SYSTEMATIC DESCRIPTIONS

The taxonomy adopted for this study follows Sanfilippo and Riedel (1973), Petrushevskaya and Kozlova (1972), and Petrushevskaya (1981).

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

Axoprunum bispiculum Popofsky

Stylacontrarium bispiculum Popofsky, 1912, pl. 2, fig. 2; Kling, 1973, pl. 15, figs. 11–14.
Axoprunum bispiculum (Popofsky), Takemura, 1992, p. 741, pl. 1, figs.1–2.

Occurrences: Oligocene–Miocene.

Axoprunum losbanosensis (Clark and Campbell)
(Pl. 3, Figs. 1a–1b)

Stylosphaera losbanosensis Clark and Campbell, 1945, p. 12, pl. 1, figs. 20–21.

Occurrences: Oligocene.

Genus *CENOSPHAERA* Ehrenberg, 1854
Cenosphaera aspera Stoch

Cenosphaera aspera (Stoch) Petrushevskaya and Kozlova, 1979, p. 87, figs. 204, 426.

Occurrences: Oligocene.

Cenosphaera eocenica Clark and Campbell

Cenosphaera eocenica Clark and Campbell, 1945, p. 7, pl. 1, figs. 2, 3, 9.

Occurrences: Eocene–Oligocene.

Cenosphaera spp.

Remarks: Number of spheres, one; its diameter, 80 µm and 150 µm. Pores rounded, seven on a semicircumference.
Occurrences: Single specimens from Sample 145-883B-84X-CC. Lower Eocene.

Genus *CARPOSPHAERA* Haeckel, 1887

Carposphaera magnaporulosa Clark and Campbell, Pl. 2, figs. 4a–4b.
Carposphaera magnaporulosa Clark and Campbell, 1942, p. 21, pl. 5, figs. 15, 17, 21, 23.

Occurrences: Oligocene–Miocene.

Genus *STYLATRACTUS* Haeckel, 1887

Stylatractus ostracion Haeckel
(Pl. 3, Figs. 3a–3b)

Druppatractus ostracion Haeckel, 1887, p. 326, pl. 16, figs. 8, 9.
Stylatractus ostracion (Haeckel), Petrushevskaya and Kozlova, 1972, p. 520, pl. 11, fig. 1.

Occurrences: Oligocene.

Genus *STYLOSPHAERA* Ehrenberg, 1847.

Stylosphaera coronata Ehrenberg
(Pl. 2, Figs. 2a–2c)

Stylosphaera coronata Ehrenberg, 1873, p. 258, pl. 25, fig. 4; Sanfilippo and Riedel, 1973, p. 520, pl. 1, figs. 13–17, pl. 25, fig. 4; Blome, 1992, pl. 1, figs. 11, 15.
Stylatractus coronatus (Ehrenberg), Petrushevskaya and Kozlova, 1972, p. 520, pl. 11, fig. 9.
Xiphostylis plasianus Haeckel, 1887, pl. 13, fig. 9.
Druppatractus trichopterus Clark and Campbell, 1942, p. 34, pl. 5, fig. 4.
Lighatractus hederae Clark and Campbell, 1942, p. 33, pl. 5, fig. 3.

Occurrences: Eocene.

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.

Stylosphaera liostylus Ehrenberg

Stylosphaera liostylus Ehrenberg, 1873, p. 259; 1875, pl. 25, fig. 3.
?*Lithatractus pierinae* Clark and Campbell, 1942, p. 34, pl. 5, fig. 25.

Occurrences: Eocene–Oligocene.

Stylosphaera minor Clark and Campbell
(Pl. 3, Fig. 2)

Stylosphaera minor Clark and Campbell, 1942, p. 27, pl. 5; 1945, p. 11, pl. 1, figs. 13–18; figs. 1, 2, 12; Petrushevskaya and Kozlova, 1972, p. 520, pl. 10, fig. 4; Blueford, 1988, pl. 4, figs. 3, 4.
Amphisphaera minor (Clark and Campbell) Sanfilippo and Riedel, 1973, p. 486, pl. 1, figs. 1–5, pl. 22, fig. 4; Blome, 1992, pl. 3, fig. 23.

Occurrences: Eocene–Oligocene.

Genus *SPONGOSPHAERA* Ehrenberg, 1847
Spongosphaera pachystyla Ehrenberg

Spongosphaera pachystyla Ehrenberg, 1873, p. 256; 1875, pl. 26, fig. 3.
Spongotractus pachystylus (Ehrenberg) Sanfilippo and Riedel, 1973, p. 519, pl. 2, figs. 4–6, pl. 25, fig. 3.

Occurrences: Eocene.

Family SPONGODISCIDAE Haeckel, 1862
Genus *SPONGURUS* Haeckel, 1862

Spongurus bilobatus Clark and Campbell

Spongurus bilobatus Clark and Campbell, 1942, p. 36, pl. 1, figs. 7, 9; Campbell and Clark, 1945, p. 20, pl. 3, figs. 5–7; Blueford, 1988, p. 252, pl. 6, fig. 9, pl. 7, fig. 1.

Table 3. Radiolarians at Hole 884B.

Age	Oligocene				late Eocene					
Nannoplankton zone		NP 23–25	NP 22		NP 21	NP 19–NP 20				
Core, section	69X-CC	70X-CC	71X-CC	72X-CC	73X-CC	74X-CC	75X-CC	76X-CC	77X-CC	78X-CC
Abundance	B	R	F	R	R	R	R	R	R	R
Preservation		P	M	M	P	P	P	P	P	P
Artobotrys auriculaleporis	.	.	.	.	.	.	.	.	.	.
Axocorys sp.	.	.	.	.	.	.	.	.	.	.
Axoprunum bispiculum	.	.	.	.	.	.	.	.	.	.
Axoprunum losbanosensis	.	.	.	.	.	.	.	.	.	.
Buryella tetradica	.	.	.	.	.	.	.	.	.	.
Calocyclas asperum	.	.	.	.	.	.	.	.	.	.
Carposphaera magnaporulosa	.	.	F	.	.	.	.	.	.	.
Cenosphaera aspera	.	.	.	.	.	.	.	.	.	.
Cenosphaera eocenica	.	.	.	.	R	R	R	.	.	.
Cenosphaera spp.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas universa gr.	.	.	.	.	.	.	.	.	.	.
Clathrocyclas extensa	.	.	.	.	.	.	.	.	.	.
Dictyoprora amphora	.	.	.	.	.	.	.	.	.	.
Dictyoprora mongolfieri	.	.	.	.	.	.	.	.	.	.
Dictyoprora urceolus	.	.	.	.	.	.	.	.	.	.
Dictyomitra amigdala	.	.	.	.	R	.	.	.	.	.
Lithocarpium titan	.	R	R	R	.	.	.	.	.	.
Lithomitrella elizabethae	.	.	.	.	.	.	.	.	.	.
Lithomitrella minuta	.	.	.	.	.	.	.	.	.	.
Lithomitra micropore	.	.	.	.	.	.	.	.	.	.
Lychnocanella babylonis	.	.	.	.	.	.	.	.	.	.
Lychnocanium conicum	.	.	.	.	.	.	.	.	.	.
Gorgospyris hemisphaerica	.	.	.	.	.	.	.	.	.	.
Podocyrtis mitrella	.	.	.	.	.	.	.	.	.	.
Eusyringium striata striata	.	.	.	.	.	.	.	.	.	.
Eusyringium striata exquisita	.	.	.	.	.	.	.	.	.	.
Phormocyrtis embolum	.	.	.	.	.	.	.	.	.	.
Spongurus bilobatus	.	.	.	.	.	.	.	.	.	.
Stichocapsa sp.	.	.	.	.	.	.	.	.	.	.
Stylatractus ostracion	.	.	.	.	R	.	.	R	.	.
Stylosphaera coronata	.	.	.	.	.	.	.	.	R	.
Stylosphaera liostylus	.	.	.	.	.	.	.	.	.	.
Stylosphaera minor	.	.	.	.	.	.	.	.	.	.
Theocyrtis litos	.	.	.	.	.	.	R	.	.	.

Note: See Table 1 for abbreviations.

Occurrences: Eocene.

Genus *SPONGODISCUS* Ehrenberg, 1854
Spongodiscus osculosus (Dreyer)

Spongopyle osculose Dreyer, 1889, p. 213, pl. 11, figs. 99, 1000.

Occurrences: upper Oligocene.

Family LITHELIIDAE Haeckel, 1862
Genus *LITHOCARPIUM* Stohr, 1880 emend.
Petrushevskaya, 1975.

Lithocarpium titan Campbell and Clark

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: upper Oligocene.

Order NASSELLARIA Ehrenberg, 1875
Family SETHOPHORMIDIDAE Haeckel, 1881
Genus *CHLATHROCYCLAS* Haeckel, 1881, emend.
Foreman, 1968.

Clathrocyclas extensa Clark and Campbell
(Pl. 3, Fig. 4)

Calocyclas extensa Clark and Campbell, 1942, p. 85, pl. 8, figs. 10, 11; Petrushevskaya and Kozlova, 1979, p. 131, figs. 386, 504.

Occurrences: Eocene–Oligocene.

Clathrocyclas universa Clark and Campbell group
(Pl. 4, Figs. 1a–1b)

Clathrocyclas universa Clark and Campbell gr., 1942, p. 86, pl. 7, figs. 16–18.

Family STICHOCAPSIDAE Haeckel, 1881
Genus *STICHOCAPSA* Haeckel, 1881, emend.
Petrushevskaya and Kozlova, 1972
Stichocapsa spp.

Remarks: This is an impression. Shell droplike. Number of segments, six-eight. Segments clearly separated. Maximum shell length, 150–200 µm, width, 66–100 µm.

Occurrences: Samples 145-883B-85X-CC and 145-883B-86X-CC. Early–middle Eocene.

Genus *DICTYOMITRA* Zittel, 1876
Dictyomitra amygdala n. sp.
(Pl. 1, Figs. 4—holotype, 5a–5b—paratype, 6a–6b)

Theoperid gen. et sp. indet. Johnson, 1974, pl. 3, fig. 12;
Archaeodictyomitra? sp. Takemura, 1992, p. 744, pl. 3, figs. 1–2.

Description: "Cigar-shaped" shell, 5–6 segments. Cephalis rounded, with 5–7 μm length and 10–15 μm width, with small pores visible. Thorax cone-shaped, with pores of a smaller diameter than those on other segments (d = 2.5–3 μm). Pores form transverse and longitudinal rows (3 transverse rows on a segment), separated by ribs, passing over the entire shell. Length of thorax, 22–25 μm, width 32–38 μm. The rest of segments have a cylindrical shape and the same character of pore distribution. Pores are rounded (d = 4–5 μm). The broadest segment is the fourth one (W = 52–75 μm). Length of shell, 98–150 μm, width 52–75 μm. Measurements based on 20 specimens from Samples 145-883B-81X-CC and 145-883E-13R-CC.
Name: *Amygdala* (lat.) = almond.
Occurrences: middle Eocene.

Family EUCYRTIDIIDAE Ehrenberg, 1847
Genus *AXOCORYS* Haeckel, 1881
Axocorys sp.?
(Pl. 1, Figs. 1a–1b)

Description: Shell composed of two segments. Cephalis cone-shaped, connected with thorax by a gradual transition, contains single pores. Height of cephalis 20 μm, width, 40 μm. Thorax domelike, strongly convex, small spines diverge from it to the sides. Height of thorax 120 μm, width 140 μm. Pores of thorax rounded, regularly arranged longitudinally and hexagonally, about 20 on a semicircumference. Diameter of pores 1–1.5 μm.
Occurrences: Sample 145-883E-15R-CC. Middle Eocene.

Genus *CALOCYCLAS* Ehrenberg, 1847
Calocyclas asperum (Ehrenberg)

Eucyrtidium asperum Ehrenberg, 1873, p. 226; 1875, pl. 8, fig. 15.
Calocyclas asperum (Ehrenberg) Petrushevskaya and Kozlova, 1972, p. 548, pl. 28, fig. 16; Petrushevskaya and Kozlova, 1979, p. 144, figs. 389, 505–508.

Occurrences: Oligocene.

Genus *EUSYRINGIUM* Haeckel, 1881
Eusyringium striata Brandt
(Pl. 2, Figs. 3a–3b)

Phormocyrtis striata striata (Brandt) Foreman, 1973, p. 438, figs. 5, 6, 9; Westberg-Smith and Riedel, 1984, pl. 6, fig. 12; Blome, 1992, pl. 2, fig. 6.

Occurrences: Eocene.

Eusyringium striata exquisita (Kozlova)
(Pl. 1, Fig. 2)

Phormocyrtis striata exquisita (Kozlova) Foreman, 1973, p. 438, pl. 7, figs. 1–4, 7, 8; Blome, 1992, pl. 3, figs. 6, 7; Nishimura, 1992, p. 344, pl. 9, figs. 4, 5.

Occurrences: Eocene.

Family LYCHNOCANIIDAE Haeckel, 1881
Genus *RHOPALOCANIUM* Ehrenberg, 1847
Rhopalocanium ornatum Ehrenberg

Phopalocanium ornatum Ehrenberg, 1875, p. 82, pl. 17, fig. 8; Foreman, 1973, p. 439, pl. 2, figs. 8–10, pl. 12, fig. 3.

Occurrences: middle Eocene.

Genus *LYCHNOCANIUM* Ehrenberg, 1847
Lychnocanium conicum Clark and Campbell
(Pl. 2, Fig. 1)

Lychnocanium conicum Clark and Campbell, 1942, p. 71, pl. 9, fig. 38;
Lychnocanoma conica (Clark and Campbell) Takemura, 1992, p. 747, pl. 2, figs. 13, 14.

Occurrences: Oligocene.

Genus *LYCHNOCANELLA* Haeckel, 1887 emend.
Petrushevskaya, 1981
Lychnocanella babylonis Clark and Campbell

Dictyophimus babylonis Clark and Campbell, 1942, p. 67, pl. 9, figs. 32, 36; *Dictyophimus* cf. *D.babylonis* Clark and Campbell, 1945, p. 38, pl. 6, fig. 2.
Sethochyrtis babylonis (Clark and Campbell) group, Riedel and Sanfilippo, 1970, p. 528, pl. 9, figs. 1–3.
Lithochyrtis sp. aff. *L. tripodium* (Ehrenberg) Petrushevskaya and Kozlova, 1972, p. 552, pl. 27, fig. 5.
Lychnocanoma babylonis group (Campbell and Clark) Johnson, 1974, pl. 2, fig. 13.

Occurrences: Eocene.

Family ARTOSTROBIIDAE Riedel, 1967
Genus *Buryella* Foreman, 1973
Buryella tetradica Foreman

Buryella tetradica Foreman, 1973, p. 433, figs. 4, 5, pl. 9, figs. 13, 14; Kozlova, 1984, pl. 12, fig. 16; Blome, 1992, pl. 1, figs. 7, 8.

Occurrences: lower?–middle Eocene.

Genus *DICTYOPRORA* Haeckel, 1881
emend. Nigrini, 1977

Dictyoprora mongolfieri (Ehrenberg)
(Pl. 2, Fig. 6)

Eucyrtidium mongolfieri Ehrenberg, 1854; 1875, p. 72, pl. 10, fig. 3.
Dictyoprora mongolfieri (Ehrenberg) Nigrini, 1977, p. 250, pl. 4, fig. 7.

Occurrences: middle Eocene.

Dictyoprora urceolus (Haeckel)

Dictyoprora urceolus (Haeckel) Nigrini, 1977, p. 251, pl. 4, figs. 9, 10.
Theocampe urceolus (Haeckel) Foreman, 1973, p. 432, pl. 8, figs. 14–17, pl. 9, figs. 6, 7.

Occurrences: Eocene.

Dictyoprora amphora (Haeckel)
(Pl.2, Figs. 7–8)

Dictyocephalus amphora Haeckel, 1887, pl. 62, fig. 4.
Theocampe amphora (Haeckel) group Foreman, 1973, p. 431, pl. 8, figs. 7, 9–13; Johnson, 1975, pl. 2, fig. 4.
Lithomitra sp. aff. *L.lineata* (Ehrenberg) group Riedel and Sanfilippo, 1971, pl. 3E, fig. 18.
Dictyoprora amphora (Haeckel) group Nigrini, 1977, p. 250, pl. 4, figs. 1, 2.

Occurrences: middle Eocene.

Genus *LITHOMITRA* Butschli, 1882
Lithomitra micropore n. sp.
(Pl. 1, Figs. 9—holotype, 10—paratype)

Description: "Cigar-shaped" shell. Cephalis spherical (length, 2 μm; width, 4 μm). Closely connected with thorax; transition between them not distinctly expressed. Thorax conical thick-walled, containing small rounded pores 1–1.5 μm across in the upper part. They are abundant and densely arranged, with cove one-fifth the size of shell. Length of this part of shell is 20 μm, width 35 μm. Abdomen cylindrical, 70–78 μm long, and 35–55 μm wide. Pores on (abdomen) are less dense, their diameter is 2.5–3 μm, spacing between them exceeds their diameter.

Number of transverse rows is 11, number of longitudinal rows is 6. Length of shell, 100 μm, width 37–55 μm. Measurements based on 20 specimens from Samples 145-883B-81X-CC, 145-883E-13R-CC, and 145-883E-12R-CC.

This species differs from *Siphocampe acefala* (Ehrenberg) Nigrini (1977) by the form of the thorax and by dimensions.

Name: Micropore (lat.) = microporous.

Occurrences: middle Eocene–Oligocene.

Genus *LITHOMITRELLA* Haeckel, 1887, emend. Petrushevskaya and Kozlova, 1979.

Lithomitrella minuta Clark and Campbell
(Pl. 2, Fig. 5)

Lithocampe minuta Clark and Campbell, 1942, p. 93, fig. 17.
Theocampe minuta (Clark and Campbell) Petrushevskaya, 1975, p. 578, pl. 26, figs. 5, 6.
Lithomitrella minuta (Clark and Campbell) Petrushevskaya and Kozlova, 1979, p. 154, figs. 412, 413, 478.

Occurrences: Eocene.

Lithomitrella elizabethae Clark and Campbell

Lithomitra elizabethae Clark and Campbell, 1942, p. 92, fig. 18.
Lithomitrella elizabethae (Clark and Campbell) Petrushevskaya and Kozlova, 1979, p. 153, figs. 418, 419, 483–486, 540–544.

Occurrences: Eocene.

Family PTEROCORYIDAE Haeckel, 1881
Genus *PHORMOCYRTIS* Haeckel, 1887

Phormocyrtis embolum (Ehrenberg) group?
(Pl. 4, Figs. 2, 3a–3b)

Eucyrtidium embolum Ehrenberg, 1873, p. 228; 1875, pl. 10, fig. 5.
Phormocyrtis embolum (Ehrenberg) Johnson, 1975, pl. 4, fig. 5; group Petrushevskaya and Kozlova, 1972, p. 537, pl. 22, figs. 8, 9.
?*Phromocyrtis proxima* Clark and Campbell, 1942, p. 82, pl. 7, figs. 24–26.
?*Phromocyrtis ligulata* (Clark and Campbell) Blueford, 1988, p. 246, pl. 2, figs. 7–9.

Remarks: Cephalis is slightly submerged into thorax, and abdomen commonly broken off. Width of shell, 88–90 μm.

Occurrences: Eocene.

Genus *PODOCYRTIS* Ehrenberg, 1847
Podocyrtis mitrella Ehrenberg
(Pl. 1, Fig. 3)

Podocyrtis mitrella Ehrenberg, 1875, pl. 15, fig. 3.
?*Podocyrtis papalis* (Ehrenberg) Sanfilippo and Riedel, 1973, pl. 20, fig. 12 (only)?

Remarks: Shell composed of three segments. Cephalis cone-shaped with single minor pores. Length of cephalis, 25–33 μm, width, 38–40 μm. Thorax domelike with length, 100 μm and width 120–125 μm. Pores on thorax form 11–12 longitudinal rows; pore diameter 5 μm. Abdomen cylindrical with length 50 μm and width, 100 μm. Apical spine small; its length is 20 μm.

The species was frequently assigned to the group of *Podocyrtis papalis* Ehrenberg, but it can be distinguished by the shape and size of thorax (i.e., it is more rounded than that of *Podocyrtis papalis* as well as by the size of abdomen, which is commonly longer in *P. mitrella.*

Occurrences: Six species from Sample 145-883B-81X-CC. Middle Eocene.

Genus *THEOCYRTIS* Haeckel, 1887
Theocyrtis litos Clark and Campbell
(Pl. 4, Figs. 5a–b)

Calocyclas litos Campbell and Clark, 1945, p. 44, pl. 6, figs. 13, 20.

Occurrences: Eocene.

Family TRIOSPYRIDIDAE Haeckel, 1881
Genus *GORGOSPYRIS* Haeckel, 1881

Gorgospyris hemisphaerica Clark and Campbell
(Pl. 1, Figs. 7, 8)

Gorgospyris hemisphaerica Clark and Campbell, 1942, p. 61, pl. 9, fig. 6.

Occurrences: middle Eocene.

Family CANNOBOTRYIDAE Haeckel, 1881
Genus *Artobotrys* Petrushevskaya, 1971

Artobotrys auriculaleporis (Clark and Campbell)
(Pl. 4, Figs. 4a–4b)

Lophophaena auriculaleporis Clark and Campbell, 1942, p. 76, pl. 8, figs. 20, 27–29.
Artobotrys auriculaleporis (Clark and Campbell) Petrushevskaya and Kozlova, 1979, p. 137, figs. 397, 515.

Occurrences: Eocene.

Artobotrys titanotriceros (Clark and Campbell)

Lophoconus titanotriceros Clark and Campbell, 1942, p. 89, pl. 8, figs. 30–37 (only).

Occurrences: Eocene.

Artobotrys bicorne (Ehrenberg)

Eucyrtidium bicorne Ehrenberg, 1875, pl. 11, fig. 7.

Occurrences: Eocene.

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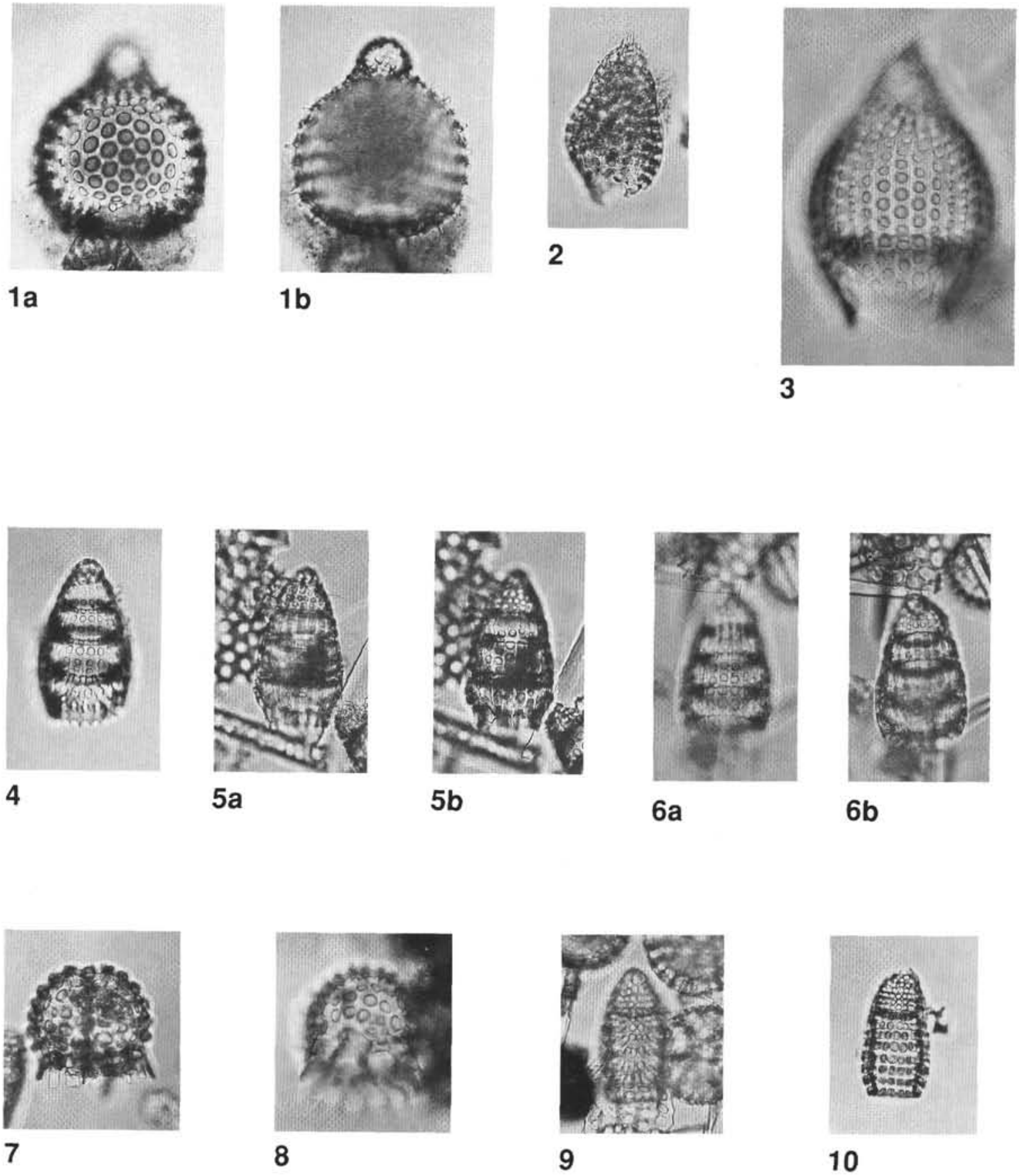

Plate 1. **1a and b.** *Axocorys* (?) sp., Sample 145-883E-15R-CC. **2.** *Eusysingium striata exquisita* Dozlova, Sample 145-883E-15R-CC. **3.** *Podocyrtis mitrella* Ehrengerf; Sample 145-883B-81X-CC. **4.** *Dictyomitra amygdala* n. sp. (holotype), Sample 145-883E-13R-CC. **5a and b.** *Dictyomitra amygdal*a n. sp. (paratype), Sample 145-E-13R-CC. **6a and b.** *Dictyomitra amygdala*, Sample 145-883E-13R-CC. **7 and 8.** *Gorgospypris hemisphaerica* Clark and Campbell, Sample 145-883E-13R-CC. **9.** *Lithomitra micropore* n. sp. (holotype), Sample 145-883E-13R-CC. **10.** *Lithomitra micropore* n. sp. (paratype), Sample 145-883E-13R-CC. All ×200.

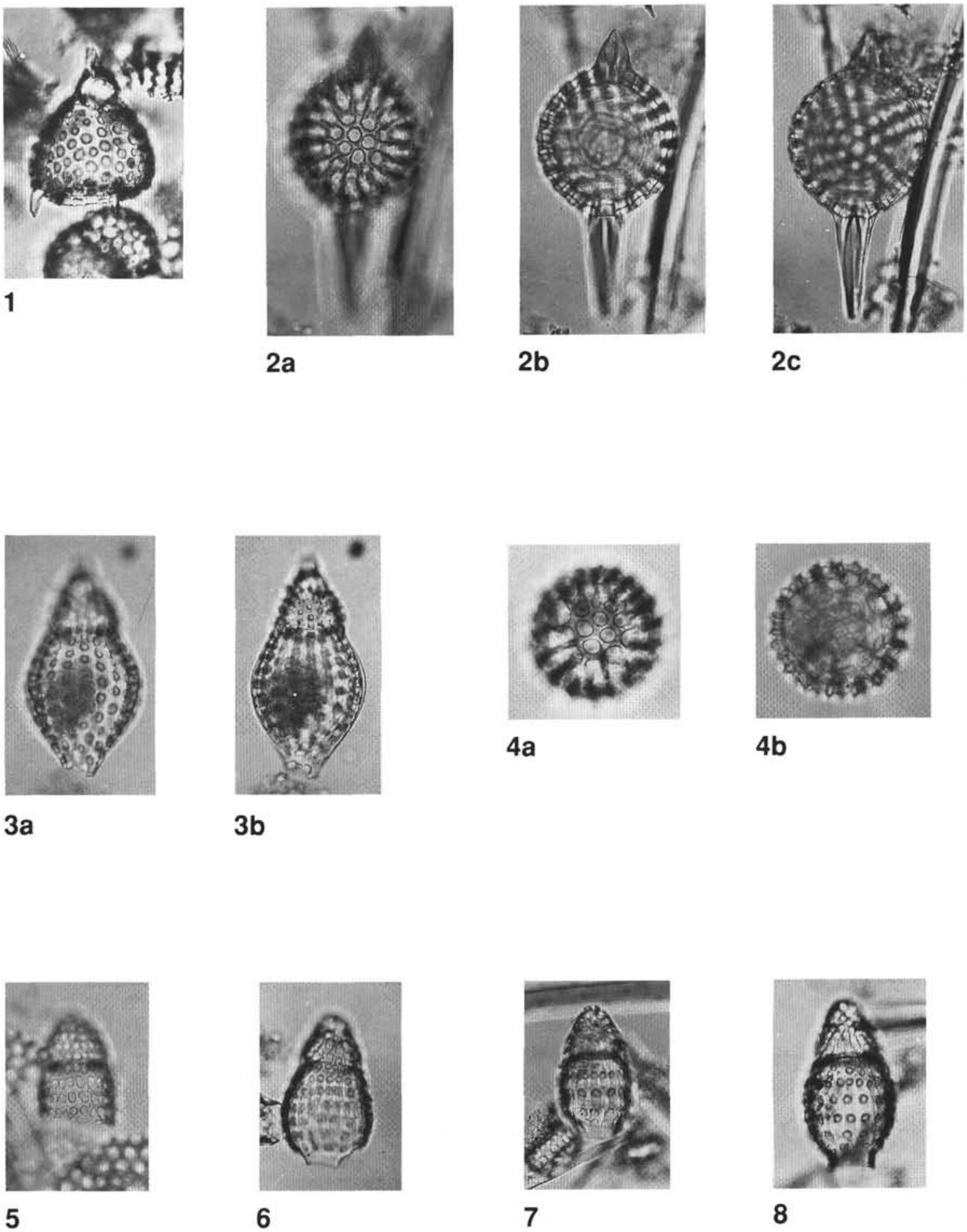

Plate 2. **1.** *Lychnocanium conicum* Clark and Campbell, Sample 145-883B-75X-4, 90–91 cm. **2a–c.** *Stylosphaera coronata* Ehrenberg; Sample 145-883B-76X-4, 90–91 cm. **3a and b.** *Eusyringium striata* Brandt, Sample 145-883B-79X-CC. **4a and b.** *Carposphaera magnoporulosa* Clark and Campbell, Sample 145-884B-71X-CC. **5.** *Lithomitrella minuta* Clark and Campbell, Sample 145-883B-77X-3, 90–91 cm. **6.** *Dictyoprora mongolfieri* Ehrenberg, Sample 145-883B-10R-CC. **7 and 8.** *Dictyoprora amphora* Haeckel, Sample 145-883B-13R-CC. All ×200.

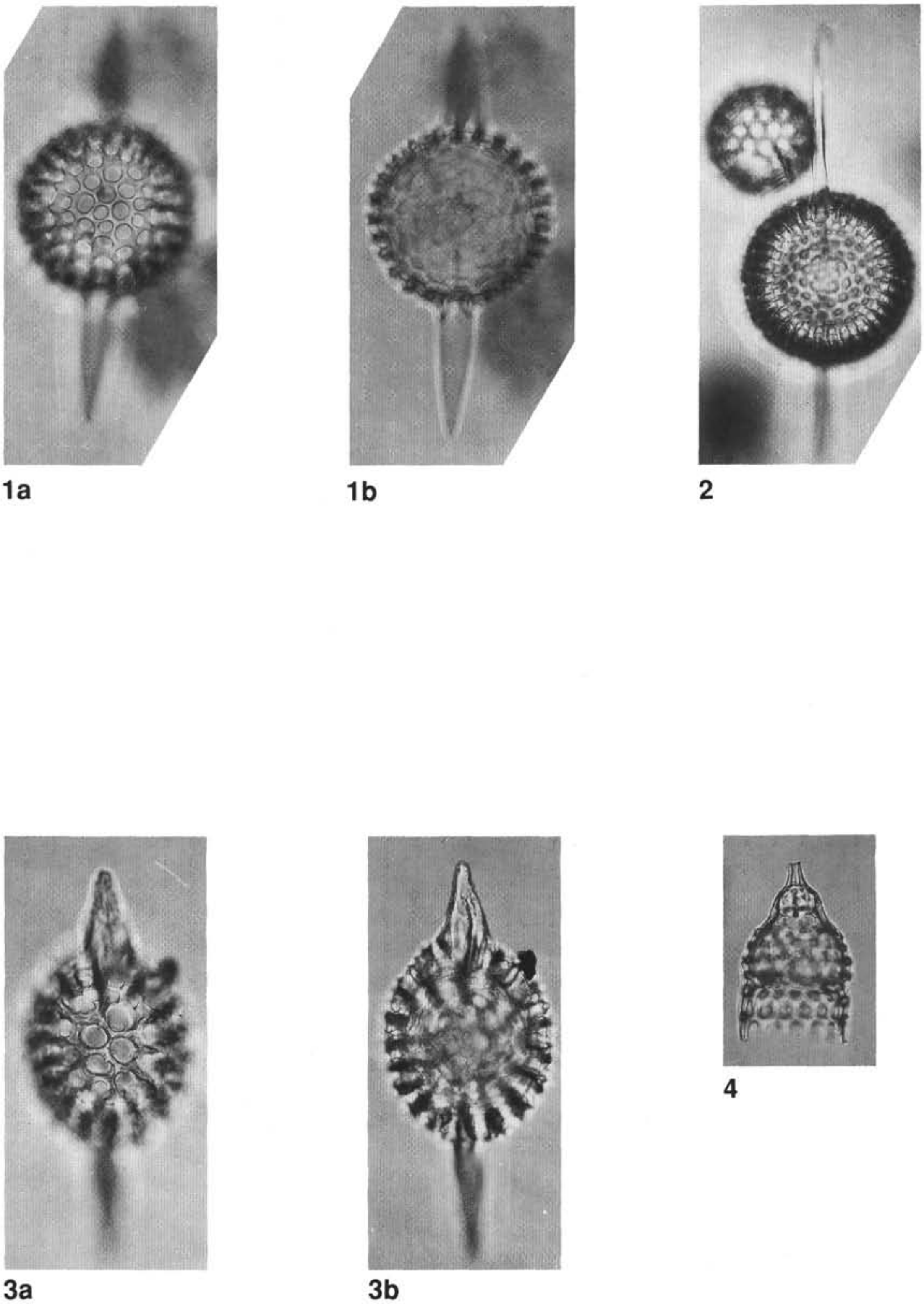

Plate 3. **1a and b.** *Axoprunum losbanosensis* Clark and Campbell, Sample 145-883B-71X-5, 90–91 cm. **2.** *Stylosphaera minor* Clark and Campbell, Sample 145-883B-76X-3, 90–91 cm. **3a and b.** *Stylatractus ostracion* Haeckel, Sample 145-884B-76X-CC. **4.** *Clathrocyclas extensa* Clark and Campbell, Sample 145-883E-9R-CC. All ×200.

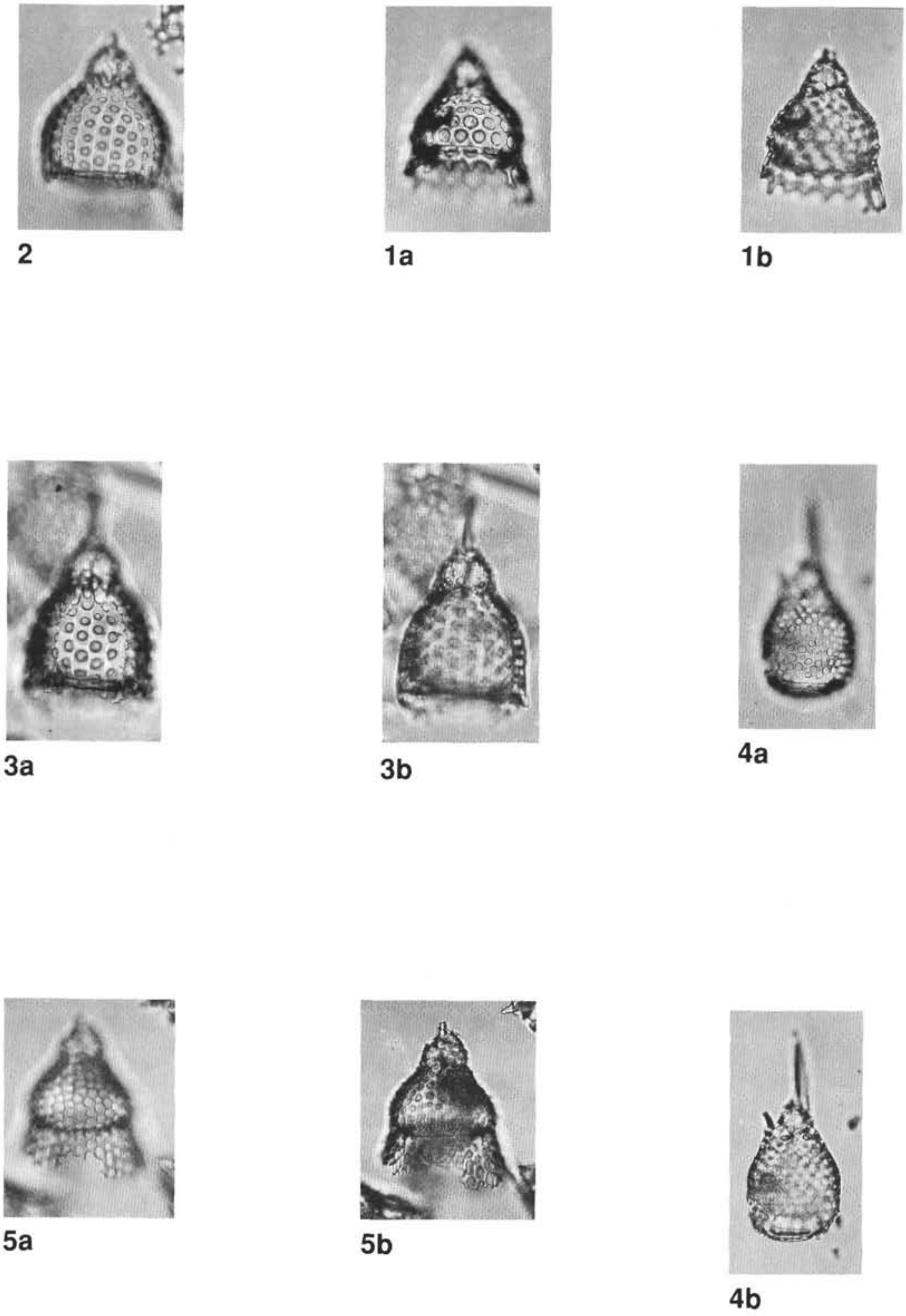

Plate 4. **1a and b.** *Clathrocyclas universa* Clark and Campbell, Sample 145-883E-9R-CC. **2.** *Phormocyrtis embolum* ?Ehrenberg group, Sample 145-883B-76X-4, 90–91 cm. **3a and b.** *Phormocyrtis embolum* ?Ehrenberg group, Sample 145-883B-76X-4, 90–91 cm. **4a and b.** *Artobotrus auriculaleporis* Clark and Campbell, Sample 145-883E-10R-CC. **5a and b.** *Theocyrtis litos* Clark and Campbell, Sample 145-883-12R-2, 70–72 cm. All ×200.