20. CENOZOIC RADIOLARIA IN THE WESTERN NORTH ATLANTIC, SITE 603, LEG 93 OF THE DEEP SEA DRILLING PROJECT[1]

Akiko Nishimura, Institute of Geological Sciences, Osaka University[2]

ABSTRACT

Eight Cenozoic radiolarian zones were recognized in samples from two holes at Site 603, drilled on the lower continental rise off North America during Leg 93 of the Deep Sea Drilling Project. Paleocene to early Eocene radiolarian zones (*Bekoma bidartensis, Buryella clinata*, and *Phormocyrtis striata striata* zones) and early to late Miocene radiolarian zones (*Calocycletta costata, Dorcadospyris alata, Diartus petterssoni*, and *Didymocyrtis antepenultima* zones) were recognized in sediments from Holes 603 and 603B. In addition, a new Paleocene *Bekoma campechensis* radiolarian Zone is defined by the interval between the first morphotypic appearance of *B. campechensis* and the *B. campechensis–B. bidartensis* evolutionary transition. This zone is immediately below the *B. bidartensis* Zone of Foreman (1973), and has previously been discussed as a Paleocene "unnamed zone" by other investigators. A hiatus between Neogene and Paleogene sequences was also recognized in the radiolarian faunas.

INTRODUCTION

Prior to Leg 93 drilling, *Glomar Challenger* had occupied about 20 sites in the North American Basin of the western North Atlantic Ocean during Legs 1, 2, 11, 43, 44, and 76 of the Deep Sea Drilling Project. Five of these sites were drilled on the continental rise: Sites 8, 105, 106, 387, and 388. In all these sites radiolarians have been reported to be sparse or absent.

During Leg 93, three holes at Site 603 (Fig. 1) were drilled on the lower continental rise off Cape Hatteras, in the North American Basin. Radiolarian-bearing samples from Site 603 range in age from Cretaceous to Neogene. Cenozoic faunas are discussed in the present paper, and Mesozoic ones in the Site 603 chapter.

The object of this study is to investigate the occurrence of radiolarians at Site 603, and to discuss the Cenozoic radiolarian biostratigraphy of these samples. Two holes, 603 and 603B, yielded Cenozoic radiolarians, but all samples examined from Hole 603C were barren. Neogene faunas were recovered from the samples of the lower part of Hole 603 and the upper part of Hole 603B. Paleogene faunas were found only in cores from Hole 603B. A hiatus between Neogene and Paleogene sequences was also recognized in the radiolarian faunas.

In order to investigate the Paleocene radiolarian assemblage, Paleocene samples from DSDP Site 384 were examined. The age of these samples was previously determined using calcareous nannofossils (Okada and Thierstein, 1979), which only rarely co-occurred with Cenozoic radiolarians at Site 603.

METHOD OF INVESTIGATION

All samples examined in this study were treated in the following manner: about 5 cm^3 of each sample was placed in a 300 ml beaker in about 50 ml of 10% H_2O_2 solution until the effervescence ceased, then a 4% solution of $(NaPO_3)_6$ was added. After 24 hr. the sample was treated in an ultrasonic cleaner for 5–7 s, and then was washed through a 250-mesh (39 μm) sieve. Calcareous components in the residue were dissolved by adding HCl.

In addition to the preceding treatment, indurated Paleogene samples were immersed in a solution of approximately 1–3% HF for 1–20 min. and wet-sieved through the same 39-μm sieve.

The dried materials were examined under a binocular microscope, mounted on an SEM stub using a thin brush, coated with gold, observed, and photographed by using a scanning electron microscope. Strewn slides were also mounted on a 24 × 32 mm cover glass using Entellan New (n = 1.4905), and observed under a transmitted-light microscope.

The estimates of abundance of radiolarians in each sample were made by both binocular and transmitted-light microscopes, the former being used for Paleogene radiolarians and the latter for Neogene radiolarians. Total abundances of radiolarians in each sample are indicated by A (abundant) = >200 specimens; C (common) = 100–200; F (few) = 50–100; R (rare) = 10–50; VR (very rare) = <10. Preservation is indicated by: G (good) = most specimens are well preserved; M (moderate) = patterns on the surface of specimens are partly unclear; P (poor) = most specimens are corroded or broken. Abundances of each species in a sample are indicated as follows: C = 20–30 specimens; F = 10–20; R = 3–10; and VR = 1–2. A blank indicates that the species was looked for and not found.

BIOSTRATIGRAPHY

Occurrence of Radiolarians

Hole 603: 35°29.66′N: 70°01.70′W; Water Depth 4634 m (Table 1)

No radiolarians were present in samples from Cores 1 to 24. Samples from 603-24,CC to 603-30-1 contained few radiolarians, with poor to moderate preservation, but no zone-diagnostic species were identified. Sections 603-30-3 through 603-40,CC contained no radiolarians. Sections 603-41-1 to 603-54-1 contained rare to common radiolarian assemblages, with poor to moderate preservation. Samples from Sections 603-46-4, 603-49-1, 603-50-1, 603-50-3 and 603-52-1 contained abundant, well-preserved radiolarians.

[1] van Hinte, J. E., Wise, S. W., Jr., et al., *Init. Repts. DSDP*, 93: Washington (U.S. Govt. Printing Office).

[2] Address: Institute of Geological Sciences, College of General Education, Osaka University, Toyonaka, Osaka 560, Japan.

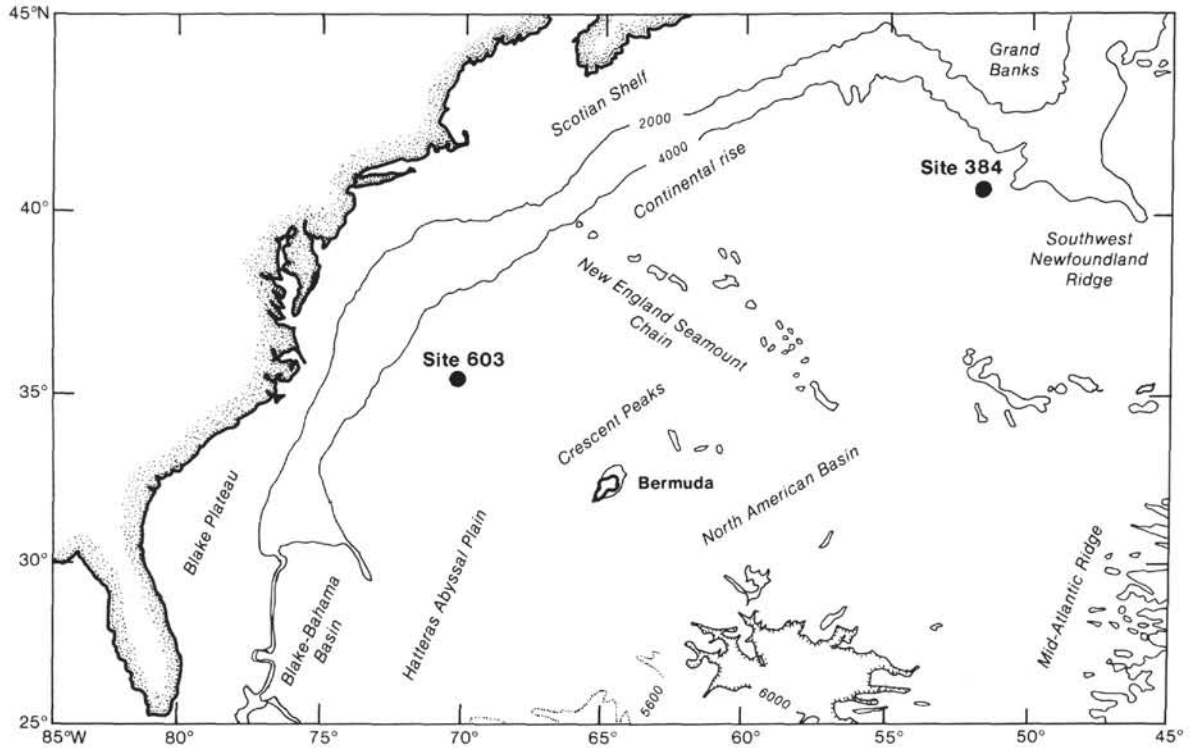

Figure 1. Location map of Sites 603 and 384 in the western North Atlantic Ocean.

Sections 603-42-1 through 603-52-1 contained middle Miocene radiolarians from the *Diartus petterssoni* Zone, as indicated by the presence of *D. petterssoni*, along with *Didymocyrtis laticonus, Stichocorys delmontensis, Cyrtocapsella japonica, Stylosphaera angelina, S.* cf. *santaeannae*, and *Acrosphaera spinosa* group. The samples from Sections 603-42-1, 603-43,CC, 603-46-2, 603-46-4, 603-50-3, and 603-52-1 contained a few, probably reworked, middle Eocene forms.

Sections 603-52-3, and 603-54-1 contained rare to very rare assemblages of moderately preserved radiolarians, but it was impossible to identify a zone because zonal marker species were absent.

Hole 603B: 35°29.71′N: 70°01.71′W; Water Depth 4633 m (Tables 2 and 3)

The Cenozoic radiolarian assemblages of this hole were divided into two parts: late early to late Miocene, and Paleocene to early Eocene assemblages.

Cores 603B-1 to -3 were barren of radiolarians. Sample 603B-4,CC contained well-preserved, common radiolarians. Species present in this sample include *Diartus hughesi, Heliodiscus asteriscus, Cyrtocapsella japonica, Stichocorys peregrina*, and *S. delmontensis*, and it is assigned to the *Didymocyrtis antepenultima* Zone of late Miocene age. Section 603B-5-1 through Sample 603B-6,CC contained rare radiolarians with moderate preservation. The dominant species were *C. japonica, S. delmontensis*, and *Stylodictya validispina*. This assemblage was questionably assigned to the *Diartus petterssoni* Zone of middle Miocene age. Sections 603B-7-2 through 603B-10,CC were also of middle Miocene age, and contained radiolarians from the *D. alata* Zone, including *C. tetrapera, C. cornuta, C. japonica, Stichocorys delmontensis, Acrocubus octopylus, Amphymenium* sp. cf. *A. splendiarmatum*, and *Didymocyrtis laticonus*. Samples from Section 603B-11-2 to 603B-12,CC contained rare radiolarians with moderate preservation. The dominant species were *Calocycletta virginis, Cyrtocapsella tetrapera, S. delmontensis*, and *Dorcadospyris alata*, and these samples were assigned to the *D. alata* Zone of middle Miocene age. The *Calocycletta costata* Zone of late early Miocene age was recognized in two samples from Core 13, which contained specimens of *C. costata, C. virginis, Stichocorys delmontensis, Cyrtocapsella tetrapera*, and *Amphisphaera minor*. No radiolarians were found in samples from Sections 603B-14-2 to 603B-15-2.

Paleogene Radiolarians

Paleogene radiolarians at Hole 603B were subdivided into two assemblages. Sections 603B-15-4 through 603B-17-3 consisted of radiolarian claystone, where moderately to well-preserved radiolarians were recovered by the use of weak HF solution. Sample 603B-17,CC through Section 603B-22-1 contained authigenic zeolite-filled radiolarians, upon which the chemicals had no effect. Specimens of the radiolarian genus *Bekoma* were found only in these last cores.

Section 603B-15-4 contained *Spongodiscus phrix, Pseudostaurosphaera*(?) sp., *Dictyoprora amphora*, and *Theocotyle*(?) *ficus*. Sample 603B-15,CC to Section 603B-16-6 contained early Eocene radiolarians from the *Phormocyrtis striata striata* Zone, as characterized by the presence of *P. striata striata, Buryella clinata, Podocyrtis papalis, Calocycloma ampulla, Theocotyle*(?) *ficus, Dictyospyris gigas, Dorcadospyris pentas*, and *Cerato-*

spyris articulata. Sample 603B-16,CC through Section 603B-17-3 contained *Amphicraspedum murrayanum, Amphymenium splendiarmatum, Phormocyrtis striata striata, B. clinata*, and *Calocycloma castum*. Therefore Sections 603B-15-4 to 603B-17-3 were assigned to the *P. striata striata* Zone of early Eocene age. The early Eocene *Buryella clinata* Zone was recognized in the interval from Sample 603B-17,CC to Section 603B-18-3, as indicated by the co-occurrence of *B. clinata* and *Bekoma bidartensis*. These samples also contained *Theocotyle cryptocephala* cf. *nigriniae, P. cubensis*, and *P. striata exquisita*. The last occurrence of *P. turgida* occurred between Samples 603B-17-3, 120–121 cm and 603B-17,CC. Samples 603B-18,CC to 603B-19,CC were assigned to the *B. bidartensis* Zone by the presence of *B. bidartensis, P. turgida, P. striata exquisita, P. cubensis*, and *T. cryptocephala* cf. *nigriniae*.

Samples from Section 603B-20-1 to 603B-21,CC contained common to rare radiolarians, with poor to moderate preservation. These samples included *Bekoma campechensis, Stylosphaera goruna, Hexacontium palaeocenicum*, and *Phormocyrtis turgida*. A new Paleocene *Bekoma campechensis* radiolarian Zone is tentatively defined here, by the total range of the nominate species. Samples 603B-18,CC to 603B-19,CC were assigned to the *B. bidartensis* Zone and are late Paleocene to early Eocene in age. Samples from Section 603B-20-1 to 603B-21,CC were assigned to the *B. campechensis* Zone and are middle to late Paleocene in age. Rare radiolarians were present in samples from Core 22, but no specimens of *B. campechensis* were present, so these samples were not assigned to the *B. campechensis* Zone.

RADIOLARIAN ZONATION

The zones used in this report are those of Riedel and Sanfilippo (1970, 1971, 1978) and Foreman (1973).

Four Paleogene and four Neogene zones were recognized in the samples from two holes at Site 603. These eight zones, in order from the oldest to the youngest, are as follows:

Paleogene

Bekoma campechensis Zone (new zone)

The base of this zone is defined by the first appearance of *Bekoma campechensis*, which is approximately synchronous with the first occurrence of *Stylosphaera goruna*. The interval from Section 603B-20-1 through Sample 603B-21,CC belongs to this zone, in which the radiolarian assemblage includes *B. campechensis, S. goruna*, and their associated species, such as *Stylotrochus nitidus, Buryella pentadica, B. tetradica*, and *Phormocyrtis turgida*. This zone was established as an "unnamed zone" by Foreman (1973), Sanfilippo and Riedel (1973), and Riedel and Sanfilippo (1978).

In order to investigate the Paleocene radiolarian assemblage of the western North Atlantic Ocean, samples of Paleocene age from Site 384 were examined. The age of these samples had been previously determined using calcareous nannofossils (Okada and Thierstein, 1979). Abundant to common, remarkably well preserved radiolarians were recovered from 33 samples of Paleocene age at Site 384. *Bekoma campechensis*, considered one of the most characteristic species of Paleocene sediments, occurs in most of the cores. Therefore, Sections 603B-20-1 through 603B-22-1 are regarded as being Paleocene in age, and the *B. campechensis* Zone is tentatively established. A more extensive taxonomic and biostratigraphic investigation of Paleocene radiolarians at Site 384 is continuing and will be presented in another publication (Nishimura, unpublished data).

Bekoma bidartensis Zone (Foreman, 1973)

The base is defined by the earliest morphotypic appearance of *Bekoma bidartensis*.

Samples 603B-18,CC through 603B-19,CC were assigned to the *B. bidartensis* Zone by the first morphotypic appearance of *B. bidartensis* and *Theocotyle cryptocephala* cf. *nigriniae*, along with specimens of *B. divaricata, Buryella tetradica, Phormocyrtis cubensis*, and *P. turgida*.

Buryella clinata Zone (Foreman, 1973, emend. Riedel and Sanfilippo, 1978)

The base is defined by the evolutionary transition of *Buryella clinata* from *B. tetradica*.

The interval from Sample 603B-17,CC through Section 603B-18-3 was assigned to the *B. clinata* Zone by the earliest evolutionary appearance of *B. clinata* and the last morphotypic occurrence of *Bekoma bidartensis*. Within this zone are the last morphotypic occurrences of *Phormocyrtis turgida, P. striata exquisita*, and *P. cubensis*.

Phormocyrtis striata striata Zone (Foreman, 1973, emend. Riedel and Sanfilippo, 1978)

Section 603B-15-4 through 603B-17-3 were assigned to the *Phormocyrtis striata striata* Zone by the presence of *Calocycloma ampulla, Dictyospyris gigas, Theocotyle* (?) *ficus, Buryella clinata, Phormocyrtis striata striata*, and *Stylotrochus nitidus*. According to Riedel and Sanfilippo (1978), the boundary between the *Buryella clinata* and *Phormocyrtis striata striata* zones is fixed by the earliest morphotypic appearance of *Theocorys anaclasta*. However, no specimen of *T. anaclasta* was found in these cores at Site 603.

The *Phormocyrtis striata striata* Zone recognized at Site 603 was subdivided between Section 603B-16-6 and Sample 603B-16,CC, and between Section 603B-15-4 and Sample 603B-15,CC by slight differences in the radiolarian assemblage.

The radiolarian assemblage from Section 603B-16-6 showed a slight change in that specimens of *Theocotyle* (?) *ficus, Ceratospyris articulata and Dorcadospyris pentas* appeared and *Calocycloma castum* disappeared. I have not established a subzone in this report, because it is unknown whether the faunal change was due to environmental or to biostratigraphic effects.

Between Section 603B-15-4 and Sample 603B-15,CC, specimens of *Buryella clinata, Phormocyrtis striata striata*, and *Stylotrochus nitidus* disappeared and *Pseudostaurosphaera*(?) sp. appeared. Cita et al. (1970) have reported that *Pseudostaurosphaera*(?) sp. occurred only

Table 1. Radiolarians from Hole 603.

Radiolarian zones	Core-Section (interval in cm)	Abundance	Preservation	*Botryostrobus miralestensis*	*Stichocorys delmontensis*	*Lithopera bacca*	*Stylosphaera angelina*	*Stylosphaera* cf. *santaeannae*	*Didymocyrtis laticonus*	*Stylatractus* sp. aff. *S. neptunus*	*Dorcadospyris alata*	*Lithopera baueri*	*Lithopera neotera*	*Lithopera thornburgi*	*Zygocircus productus*	*Tholospyris kantiana*	*Cyrtocapsella cornuta*	*Acrosphaera murrayana*	*Eucyrtidium calvertense*	*Phorticium pylonium*	*Tricolospyris leibnitziana*	*Cladococcus* cf. *pinetum*	*Cyrtocapsella tetraperta*	*Cannartus* sp. D *in* Sakai	*Eucyrtidium hexagonatum*	*Rhopalastrum angulatum*	*Prunopyle titan*	*Siphostichartus corona*
		VR	P																									
	25-1, 120–122	VR	M							VR																		
	25-3, 120–122	VR	M																									
	25-5, 120–122	VR	M																									
	25,CC	VR	M																									
	27,CC	R	M																									
	28-1, 45–47	R	M																									
	42-1, 120–122	F	M				VR		VR	R																		
	42-3, 120–122	R	M				VR	R																				
	42,CC	R	M				VR	VR																				
	43-1, 120–122	R	P				VR																					
	43,CC	VR	M		VR	VR	VR																					
	44-1, 120–122	C	M		VR	R			VR	R																		
	44-3, 120–122	R	G																									
	44,CC	VR	G							VR																		
	45-4, 120–122	R	P		VR																							
Diartus petterssoni	45,CC	VR	G				VR																					
	46-2, 110–112	F	G	VR				VR		R															VR		VR	VR
	46-4, 120–122	A	G	R	R	R	R	R		R						?					R	R	VR	VR	VR	R		VR
	47,CC	C	M		R			VR		R																		
	48-1, 112–113	F	M		R				VR											VR					R			
	48,CC	R	M					VR										VR										
	49-1, 120–122	C	G	VR	F				R	R									VR							?		
	50-1, 120–122	C	G	R	F		R	R	R	R									VR					VR		?	VR	
	50-3, 120–122	A	G	R	F		R		F	R								R	VR	R			VR				R	
	51-1, 120–122	R	G		VR		R	VR	VR																			
	52-1, 120–122	C	G	R	R	R	R	R	R		R	VR	VR	VR	VR	VR	VR	VR	VR	R	VR	R	VR	VR	VR	VR	R	VR
	52-3, 120–122	R	M	VR	VR	VR	R	VR	VR	R																		
	54-1, 120–122	VR	P																									

Note: Listed here are samples in which the species in this table were not present; radiolarian abundances and preservation for each sample given in parentheses: 603-24,CC (VR, P); 603-26-1, 120–122 cm (R, P); 603-26-3, 120–122 cm (R, P); 603-29-1, 120–122 cm (R, P), 603-29-3, 120–122 cm (R, P); 603-29-5, 120–122 cm (R, P); 603-29,CC (—, —); 603-30-1, 118–120 cm (R, P); 603-41-1, 120–122 cm (R, P); 603-41-3, 120–122 cm (R, P); 603-41-5, 120–122 cm (R, P); 603-41,CC (R, P). For abundances, VR = very rare, R = rare, F = few, C = common, A = abundant. For preservation, G = good, M = moderate, P = poor. For quantitative estimates see text.

in cores of late middle Eocene age from Hole 8A of Deep Sea Drilling Project Leg 2. It may be that Section 603B-15-4 should be assigned a younger age than the *Phormocyrtis striata striata* Zone; however, the radiolarian assemblage from this core is generally similar to those of the *P. striata striata* Zone.

Neogene

Calocycletta costata Zone (Riedel and Sanfilippo, 1970)

The base is defined by the earliest morphotypic appearance of *Calocycletta costata*.

Core 603B-13 was assigned to the *C. costata* Zone by the occurrence of *C. costata, C. virginis, Stichocorys delmontensis, S. wolffii*, and *Cyrtocapsella cornuta*.

Dorcadospyris alata Zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo, 1971)

The base is defined by the evolutionary transition of *Dorcadospyris alata* from *D. dentata*.

The interval from Section 603B-7-6 through Sample 603B-12,CC was assigned to the *D. alata* Zone by the presence of *D. alata, Stichocorys wolffii, S. delmontensis, Cyrtocapsella tetrapera, C. cornuta, C. japonica, Acrocubus octopylus*, and *Amphymenium* sp. cf. *A. splendiarmatum*. This zone was subdivided into two radiolarian assemblages between Core 603B-10-4 and 603B-10,CC. In the lower part rare radiolarians occurred and *D. alata* was present; in the upper part specimens of *Didymocyrtis laticonus, Spongodiscus* cf. *osculosus*, and *Cyrtocapsella japonica* occurred in the absence of *D. alata*.

Diartus petterssoni Zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo, 1978)

The base is defined by the earliest morphotypic appearance of *Diartus petterssoni*.

Cores 603-42-1 through 603-52-1 were assigned to the *D. petterssoni* Zone by the presence of *D. petterssoni*, along with specimens of *Stichocorys delmontensis, Cyrtocapsella japonica, Larcospira moschkovskii, Didymocyrtis laticonus, Stylodictya validispina*, and *Druppatractus acquilonius*. This zone in Hole 603 was subdivided into three parts on the basis of differences in the radiolarian assemblage mentioned above.

Table 1 (continued).

Eucyrtidium punctatum	*Stichocorys* sp.	*Eucyrtidium cienkowskii*	*Diartus petterssoni*	*Stylodictya validispina*	*Stylochlamidium asteriscus*	*Anthocyrtidium ehrenbergi*	*Cyrtocapsella japonica*	*Heliodiscus* (?) spp.	*Acrosphaera spinosa* group	*Otosphaera auriculata* group	*Euchitonia* spp.	*Diplocyclas* (?) sp. aff. *D. davisiana*	*Acrocubus octopylus*	*Cyrtocapsella elongata*	*Lychnodictyum audax*	*Larcospira moschkovskii*	*Spongodiscus* cf. *osculosus*	*Cyrtolagena* (?) sp.	*Botryostrobus auritus*	*Carpocanistrum* spp.	*Stichocorys peregrina*	*Heliodiscus* sp.	*Druppatractus aquilonius*	*Tholospyris* sp. aff. *T. infericosta*	*Heliodiscus asteriscus*	*Amphymenium* sp. cf. *A. splendiarmatum*	*Didymocyrtis antepenultima*	*Pterocanium trilobum*	*Eucyrtidium yatsuoensis*	*Lychnocanoma* cf. *grande*	Fragments of Orosphaerids	Included Eocene species
																							VR								VR		
																							VR								VR		
																							VR								VR		
									VR		VR											VR	R								R	+	
																							R								R	+	
		VR	?	VR	R	VR	F	R	R	R											VR	VR	R	+	+
								VR																VR		VR						VR	+	+
			VR					VR	R	R														VR								VR	+	
			VR				VR		R																						VR	+	
																								VR									+
R	R		VR	R				R	R	R						VR	VR	VR		R		R							VR		+	
							VR		R	R										R		R									VR		
								R	VR								VR			R		R									VR	+	
							VR		R														R									+	
							VR		R														VR										
		VR	VR		R		R		F						R					R		R	R								R	+	+
	VR	VR	VR	R	R	VR	R	R	F						R	R				F	R	F	R	VR	R	VR	VR	VR	VR	R	R	+	+
	R		VR				F	R	R	VR	R					R					R		R	R									
	R			VR	VR		R	R	R												R		R	VR									
R				VR	VR		R	R	R		R													VR									
R			VR	R	R		F	F	VR	R	R		R	R			VR						F	R		R						+	
	R		VR	R	R	R	F	F	R			VR	R	R		VR		VR	VR	R			F	R	VR	R						+	
	R		R	R	R	R	R	R	R		R	VR	R	R	VR	VR	VR	VR	VR	R	VR	F	R									+	+
							R	VR	VR																							+	
VR	R	VR	VR	R	R	R	R	R	C	R	R																					+	+
																																+	
																																+	

Didymocyrtis antepenultima Zone (Riedel and Sanfilippo, 1970, emend. Riedel and Sanfilippo 1978)

The base is defined by the evolutionary transition of *Diartus hughesi* from *D. petterssoni*.

The *Didymocyrtis antepenultima* Zone of late Miocene age was recognized only in Sample 603B-4,CC, which contained *Diartus hughesi, Stichocorys peregrina*, and *Cyrtocapsella japonica*.

RANGES AND CORRELATION

Eight Cenozoic radiolarian zones were recognized at Site 603. These include four Paleocene to early Eocene zones and four early to late Miocene zones. The ranges of selected radiolarian species are shown in Figures 2 to 4.

In comparison with equatorial or tropical radiolarian assemblages (Foreman, 1973; Riedel and Sanfilippo, 1978) there are differences in the ranges of several species studies in this report. For example, the earliest evolutionary appearance of *Theocotyle cryptocephala* (?) *conica* was reported to occur in the *Dictyoprora mongolfieri* Zone by Foreman (1973). However, this species at Site 603 had its first appearance in the *Phormocyrtis striata striata* Zone. The last morphotypic occurrence of *T. alpha* was reported from the *Buryella clinata* Zone and those of *Lamptonium* (?) *incohatum* and *L.* (?) *colymbus* were reported from the *Bekoma campechensis* Zone by Foreman (1973), whereas specimens of these species occurred in the *Phormocyrtis striata striata* Zone at Site 603. Moreover, the earliest evolutionary appearance of *Stichocorys peregrina* was reported at the base of the *S. peregrina* Zone by Riedel and Sanfilippo (1978), but specimens of this species were present in the *Diartus petterssoni* Zone in both Holes 603 (Table 1) and 603B (Table 2).

The faunal composition and biostratigraphic ranges of radiolarians of Site 603 closely parallel those of nearby Hole 390A (Weaver and Dinkelman, 1978), drilled on the Blake Plateau during DSDP Leg 44. The same three early Eocene zones found in Hole 603B were also described on the Blake Plateau, and the Neogene stratigraphic succession of Hole 603 closely parallels that of Hole 390A.

Calcareous microfossils were nearly absent in most of the radiolarian-containing samples of Site 603, except for several cores. The biostratigraphic age based upon radiolarians in Neogene sediments differed little from that indicated by foraminifers (Ma'Alouleh and Moullade, this volume) and by calcareous nannofossils (Muza et al., this volume). The "radiolarian middle/late Miocene boundary" of Site 603 corresponds to the lithologic Unit IB/IC boundary (Site 603 chapter, this volume). Paleogene samples from Hole 603B contained few to no calcareous microfossils, so correlation of the radi-

Table 2. Neogene radiolarians from Hole 603B.

Radiolarian zones	Core-Section (interval in cm)	Abundance	Preservation	*Calocycletta costata*	*Calocycletta virginis*	*Stichocorys wolffii*	*Eucyrtidium diaphanes*	*Cyrtocapsella tetrapera*	*Cyrtocapsella cornuta*	*Lamprocyclas maritalis*	*Carpocanistrum* spp.	*Stylodictya validispina*	*Stichocorys delmontensis*	*Amphisphaera minor*	*Stylosphaera* cf. *santaeannae*	*Dorcadospyris alata*	*Acrocubus octopylus*	*Calocycletta* sp.	*Cornutella* sp.	*Eucyrtidium hexagonatum*	*Phorticium pylonium*	*Amphymenium* sp. cf. *A. splendiarmatum*
Didymocyrtis antepenultima	4,CC	C	G							VR	R	R	R	R	R							
Diartus petterssoni ?	5-1, 120–121	F	M									R	R		R		R	VR				
	5-2, 120–121	R	M					VR	VR	VR	R		VR					VR				
	5-3, 120–121	VR	P																			
	5-4, 120–121	R	M								VR											
	5-5, 120–121	R	M					VR														
	5,CC	R	M						VR			R			R		VR					
	6-2, 120–121	R	M					VR														
	6-4, 120–121	VR	M																			
	6,CC	VR	P									VR										
---?---																						
Dorcadospyris alata	7-2, 120–121	R	M					R									VR					
	7-4, 120–121	R	M						VR			R					VR					
	7-6, 120–121	R	M					R	R				R									
	7,CC	R	M					VR	R				VR							VR		
	8-2, 120–121	F	M						VR	VR	VR	R	VR		VR		VR					
	8-4, 120–121	R	M					R				VR		VR	R							VR
	8-6, 120–121	F	M				VR					VR	R	R						VR	R	VR
	8,CC	R	M			VR		R			R		VR	R	VR		VR		VR			
	9,CC	C	M			R		F	VR		R	R	F				R	R		VR		VR
	10-2, 120–121	C	M		VR	VR		F	VR		VR	R	F	VR			R	R				
	10-4, 120–122	F	M					F	R			R	R	VR			VR		VR			VR
	10,CC	F	M		VR	R		R	VR			VR	R		VR	VR		VR	VR			VR
	11-2, 120–121	R	M								VR										R	
	11-4, 120–121	R	M					VR			VR	R	R		R							
	11-6, 120–121	R	M					VR					VR								VR	VR
	11,CC	R	M		VR			R	VR						VR			R	VR	VR		
	12-2, 120–121	R	M										R		R							
	12-4, 120–121	R	M		R			R					R		VR							
	12,CC	R	M	VR	R			VR	R		VR		R			VR	R	R				
Calocycletta costata	13-2, 120–122	R	M		R	VR		VR	VR				R	VR								
	13,CC	F	M	R	R	R	R	VR	R	VR	VR	R	F	R	R							

Note: Listed here are samples in which the species in this table were not present; radiolarian abundances and preservation for each sample that was not barren given in parentheses. 603B-1,CC; 603B-2,CC: 603B-3,CC; 603B-14-2, 120–122 cm; 603B-14-4, 120–121 cm; 603B-14-6, 120–121 cm (VR, VP); 603B-14,CC (VR, VP); 603B-15-2, 120–121 cm. Symbols as in Table 1.

olarian biostratigraphy to that of other microfossil groups was not possible.

The *Bekoma campechensis* Zone was established in Site 603 sediments based on a comparison to the Paleocene radiolarians in Site 384 (Nishimura, unpublished data). As mentioned above, this zone should be considered to be tentative until Paleocene radiolarians are more widely studied.

SPECIES LIST

The references cited herein are restricted to the original description and some changes in generic name, and those which conform to the concept of the author for the limit of species. Most stratigraphic marker species are illustrated by scanning electron micrographs. In addition, some Neogene species are illustrated by photographs using an optical microscope in order to correspond to the photos by SEM.

The occurrences given here apply only to Site 603.

Acrocubus octopylus Haeckel
(Plate 5, Fig. 24)

Acrocubus octopylus Haeckel, 1887, p. 993, pl. 82, fig. 9; Goll, 1972, p. 961, pl. 37, figs. 1–3.

Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Acrosphaera murrayana (Haeckel)

Choenisphaera murrayana Haeckel, 1887, p. 102, pl. 8, fig. 4.

Acrosphaera murrayana (Haeckel), Strelkov and Reshetnyak, 1971, p. 347, fig. 25.

Occurrence. *Diartus petterssoni* Zone.

Acrosphaera spinosa (Haeckel) group
(Plate 4, Fig. 1)

Collosphaera spinosa Haeckel, 1862, p. 536.

Polysolenia spinosa (Haeckel), Nigrini, 1967, pp. 14–15, pl. 1, fig. 1.

Polysolenia spinosa (Haeckel) group, Ling, 1975, p. 717, pl. 1, figs. 2, 3.

Table 2 (continued).

Stylochlamidium asteriscus	*Stylatractus* sp. aff. *S. neptunus*	*Carpocanopsis cristata*	*Cyrtocapsella elongata*	*Didymocyrtis laticonus*	*Eucyrtidium punctatum*	*Giraffospyris toxaria*	*Stichocorys* sp.	*Rhopalastrum angulatum*	*Spongodiscus* cf. *osculosus*	*Cyrtocapsella japonica*	*Botryostrobus miralestensis*	*Liriospyris elevata*	*Tholospyris kantiana*	*Prunopyle titan*	*Zygocircus productus*	*Eucyrtidium cienkowskii*	*Lithopera neotera*	*Phormostichoartus corbula*	*Lithopera baueri*	*Dendrospyris stabilis*	*Druppatractus acquilonius*	*Heliodiscus asteriscus*	*Acrosphaera spinosa* group	*Otosphaera auriculata* group	*Stichocorys peregrina*	*Diartus hughesi*
	R								R	C					VR	VR					R	F	F	R	R	R
								R		R				VR			VR									
									R			VR	VR													
										R				VR												
R										R																
				VR					R																		
										VR																	
								VR				VR															
	VR			R					R	VR																	
										VR			VR														
	R			R					R	VR					VR	VR							VR			
									R	VR												VR					
VR			R	R			R		R	R			VR				VR	VR	VR	VR							
	R		R	VR			R		R					VR				VR									
R			R	R			R	VR	R	R		VR		VR			VR										
R			R	R	VR	VR		VR		R	R	R	VR	VR	VR	VR											
R			R	R				R	R	VR																	
	VR	VR	R		VR	VR	R	VR																			
	VR	VR	VR	VR																							
	VR																										
R																											

Acrosphaera spinosa (Haeckel), Johnson and Nigrini, 1980, p. 119, pl. I, fig. 3.

Remarks. The form illustrated herein differs from the original species in the morphology of the radial spines. However, it seems that the Miocene forms possess rather longer radial spines, so that various kinds of specimens are included under this species name.

Occurrence. *Diartus petterssoni* Zone to *Didymocyrtis antepenultima* Zone.

Amphicraspedum murrayanum Haeckel
(Plate 1, Figs. 14, 18)

Amphicraspedum murrayanum Haeckel, 1887, p. 523, pl. 44, fig. 10; Sanfilippo and Riedel, 1973, p. 524, pl. 10, figs. 3–6; pl. 28, fig. 1.

Occurrence. Top of *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Amphicraspedum sp. cf. *A. murrayanum* Haeckel
(Plate 1, Fig. 19)

Amphicraspedum sp. cf. *A. murrayanum* Haeckel, Sanfilippo and Riedel, 1973, pl. 28, fig. 2.

Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Amphicraspedum prolixum Sanfilippo and Riedel

Amphicraspedum prolixum Sanfilippo and Riedel, 1973, p. 524, pl. 10, figs. 7–11; pl. 28, figs. 3, 4.

Occurrence. *Buryella clinata* Zone to *Phormocyrtis striata striata* Zone.

Amphisphaera minor (Clark and Campbell)
(Plate 1, Fig. 5)

Stylosphaera minor Clark and Campbell, 1942, p. 27, pl. 5, figs. 1, 2, 12.

Amphisphaera minor (Clark and Campbell), Sanfilippo and Riedel, 1973, p. 486, pl. 1, figs. 1–5; pl. 22, fig. 4.

Occurrence. *Phormocyrtis striata striata* Zone and *Calocycletta costata* Zone to *Didymocyrtis antepenultima* Zone.

Amphymenium splendiarmatum Clark and Campbell
(Plate 1, Fig. 20)

Amphymenium splendiarmatum Clark and Campbell, 1942, p. 46, pl. 1, figs. 12, 14; Sanfilippo and Riedel, 1973, p. 524, pl. 11, figs. 6–8; pl. 28, figs. 6–8.

Occurrence. *Bekoma bidartensis* Zone to *Phormocyrtis striata striata* Zone.

Table 3. Paleogene radiolarians from Hole 603B.

Radiolarian zones	Core-Section (interval in cm)	Abundance	Preservation	*Dorcadospyris platyacantha*	*Stylosphaera goruna*	*Xiphospira* cf. *circularis*	*Spongodiscus americanus*	*Spongodiscus pulcher*	*Hexacontium palaeoceticum*	*Stylosphaera coronata coronata*	*Buryella pentadica*	*Bekoma campechensis*	*Lychnocanoma auxilla*	*Spongodiscus rhabdostylus*	*Buryella tetradica*	*Spongurus* (?) spp.	*Bekoma divaricata*	*Phormocyrtis turgida*	*Phormocyrtis striata exquisita*	*Stylotrochus nitidus*	*Amphicraspedum* cf. *murrayanum*	*Spongodiscus cruciferus*	*Lychnocanium* (?) *carinatum*	*Lychnocanoma* sp. aff. *L. babylonis*	*Amphipyndax* (?) sp.	*Lithochytris tripodium*	*Lamptonium pennatum*	*Phormocyrtis cubensis*	*Amphicraspedum murrayanum*	*Axoprunum pierinae*	*Buryella* sp.	*Theocotyle cryptocephala* cf. *nigriniae*	*Amphymenium splendiarmatum*	*Bekoma bidartensis*
Phormocyrtis striata striata	15-4, 120-121	C	G						VR	VR													R	R					VR	R			
	15,CC	C	G							VR										R			R											
	16-2, 120-121	C	G							R										R	R	VR	R	R						R	R			
	16-4, 120-121	C	G							R										R			R	R							R		VR	
	16-6, 120-121	C	G						VR	R										VR		VR	R			VR						VR	R	
	16,CC	C	P							VR										R									VR					
	17-2, 120-121	R	G							VR										R										VR				
	17-3, 120-121	C	G						VR	VR					VR					VR		R									R	R		
Buryella clinata	17,CC	C	M							VR					R			VR	R	R	VR		R	VR					R			R	R	R
	18-1, 118-120	R	P/M			VR	VR	VR								VR													R	VR				VR
	18-3, 119-121	R	P/M				R			VR					VR	R						VR	R							VR				VR
Bekoma bidartensis	18,CC	C	P/M											VR		VR					R								R				R	
	19-1, 118-120	C	P/M				R	R					VR		R	R		VR	R	VR			R				VR	R					R	
	19-3, 119-121	C	P/M				R	R		VR					VR	R				VR		VR	VR								VR			VR
	19,CC	C	P/M		R		R		R			?				R	VR	VR	R			R							VR		VR	VR	VR	
Bekoma campechensis	20-1, 121-123	C	M		R	VR	R		VR	R		R			R	R	R	VR	R	R				R	R	VR	R	R	R	VR				
	20-3, 115-117	R	P						VR	VR					VR					VR			VR	VR										
	20,CC	R	P													VR					VR	VR	VR											
	21-1, 130-131	VR	P																															
	21-3, 118-119	R	P		VR					VR								VR		VR														
	21-5, 116-117	R	P/M		R		R		VR	VR										VR														
	21,CC	C	M	R	R		R		R	R	R	R	VR	R	R	R	R	R	R															
	22-1, 113-135	R	P/M	VR	VR	VR	R	R	R	VR																								

Note: Symbols as in Table 1.

Amphymenium sp. cf. *A. splendiarmatum* Clark and Campbell
(Plate 4, Fig. 8)

Amphymenium splendiarmatum Clark and Campbell, 1942, p. 46, pl. 1, figs. 12, 14.
Ommatocampe spp. aff. *Amphymenium amphistylium* Haeckel, Petrushevskaya and Kozlova, 1972, p. 527, pl. 20, figs. 1, 2.
Amphymenium sp. cf. *A. splendiarmatum* Clark and Campbell, Riedel and Sanfilippo, 1977, pl. 18, fig. 14.
Occurrence. Middle of *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Anthocyrtidium ehrenbergii (Stöhr)

Anthocyrtis ehrenbergii Stöhr, 1880, p. 100, pl. 3, figs. 21a, b.
Anthocyrtidium ehrenbergii (Stöhr), Riedel et al., 1974, p. 712, pl. 60, fig. 10; pl. 61, fig. 1.
Occurrence. *Diartus petterssoni* Zone.

Axoprunum pierinae (Clark and Campbell)
(Plate 1, Fig. 6)

Lithatractus pierinae Clark and Campbell, 1942, p. 34, pl. 5, fig. 25.
Axoprunum pierinae (Clark and Campbell) group, Sanfilippo and Riedel, 1973, p. 488, pl. 1, figs. 6–12; pl. 23, fig. 3.
Occurrence. Top of *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Bekoma bidartensis Riedel and Sanfilippo
(Plate 3, Fig. 15)

Bekoma bidartensis Riedel and Sanfilippo, 1971, p. 1592, pl. 7, figs. 1, 2, 5–7 (not 3, 4); Foreman, 1973, p. 432, pl. 3, figs. 20, 21.
Occurrence. *Bekoma bidartensis* Zone to *Buryella clinata* Zone.

Bekoma campechensis Foreman
(Plate 3, Fig. 13)

Bekoma campechensis Foreman, 1973, p. 432, pl. 3, fig. 24; pl. 10, figs. 1, 2.
Occurrence. *Bekoma campechensis* Zone.

Bekoma divaricata Foreman
(Plate 3, Fig. 14)

Bekoma sp. *in* Riedel and Sanfilippo, 1971, pl. 6, fig. 8.
Bekoma divaricata Foreman, 1973, p. 433, pl. 10, figs. 3, 4.
Occurrence. *Bekoma campechensis* Zone to *B. bidartensis* Zone.

Botryostrobus bramlettei (Campbell and Clark)

Lithomitra bramlettei Campbell and Clark, 1944a, p. 53, pl. 7, figs. 10–14.
Botryostrobus bramlettei (Campbell and Clark), Nigrini, 1977, p. 248, pl. 1, figs. 7, 8.
Occurrence. *Diartus petterssoni* Zone.

Botryostrobus miralestensis (Campbell and Clark)
(Plate 5, Fig. 18)

Dictyocephalus miralestensis Campbell and Clark, 1944a, p. 45, pl. 6, figs. 12–14.
Artostrobium miralestense (Campbell and Clark), Riedel and Sanfilippo, 1971, p. 1599, pl. 1H, figs. 14–17; pl. 21, figs. 9, 10.
Botryostrobus miralestensis (Campbell and Clark), Petrushevskaya and Kozlova, 1972, p. 539, pl. 24, fig. 31; Nigrini, 1977, p. 249, pl. 1, fig. 9.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Buryella clinata Foreman
(Plate 2, Figs. 5, 6)

Buryella clinata Foreman, 1973, p. 433, pl. 8, figs. 1–3; pl. 9, fig. 19.
Occurrence. *Buryella clinata* Zone to *Phormocyrtis striata striata* Zone.

Buryella pentadica Foreman
(Plate 2, Fig. 9)

Buryella pentadica Foreman, 1973, p. 433, pl. 8, fig. 8; pl. 9, figs. 15, 16.
Occurrence. *Bekoma campechensis* Zone.

Table 3 (continued).

Theocotyle auctor	*Heliostylas* spp.	*Podocyrtis papalis*	*Buryella clinata*	*Amphicraspedum prolixum*	*Spongomelissa aduncа*	*Phormocyrtis striata striata*	*Theocotyle alpha*	*Dendrospyris fragoides*	*Orbula* cf. *comitata*	*Lamptonium* (?) *colymbus*	*Lamptonium* (?) *incohatum*	*Calocycloma castum*	*Lithapium* (?) cf. *plegmacantha*	*Dorcadospyris confluens*	*Spongaractus balbis*	*Calocycloma ampulla*	*Stylosphaera coronata sabaca*	*Dictyospyris gigas*	*Lamptonium* (?) *fabaeforme fabaeforme*	*Rhopalocanium* sp. aff. *R. ornatum*	*Lithochytris archaea*	*Thyrsocyrtis hirsuta hirsuta*	*Dorcadospyris pentas*	*Theocotyle* (?) *ficus*	*Lithelius* sp.	*Ceratospyris articulata*	*Histiastrum quaternarium*	*Coccolarcus* (?) *oviformis* (?)	*Theocotyle cryptocephala* (?) *conica*	*Spongodiscus phrix*	*Thecosphaera larnacium*	*Spongodiscus quartus bosoculus*	*Lychnocanoma bellum*	*Dictyoprora urceolus*	*Dictyoprora amphora*	*Lamptonium fabaeforme* (?) *constrictum*	*Podocyrtis sinuosa*	*Pseudostaurosphaera* (?) sp.
		R		VR		R										R			VR					VR	R	R						VR					
		VR	R	F		R										R								R	R	VR			VR	VR		R		R			
	R			R		R																		R		R			R	R							
			R	R		R						VR	VR	R	VR									R													
				VR																																	
	VR	VR	VR	VR																																	
VR	R	R		VR		R	VR	VR	VR	R	VR	R	R	R	VR	VR	VR	VR	VR	VR	VR	VR	VR	R	VR	VR											
	VR	R		VR	R	R																															
			VR	R																																	
VR	R																																				
VR	R	R																																			

***Buryella tetradica* Foreman**
(Plate 2, Fig. 8)

Lithocampium sp. A in Riedel and Sanfilippo, 1971, pl. 7, fig. 12.
Buryella tetradica Foreman, 1973, p. 433, pl. 8, figs. 4, 5; pl. 9, figs. 13, 14.
Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

***Buryella* sp.**
(Plate 2, Fig. 4)

Remarks. This form is distinguished from *Buryella clinata* by thorax with pores arranged irregularly.
Occurrence. *Bekoma bidartensis* Zone to *Phormocyrtis striata striata* Zone.

***Calocycletta costata* (Riedel)**
(Plate 5, Fig. 15)

Calocyclas costata Riedel, 1959, p. 296, pl. 2, fig. 9.
Calocycletta costata (Riedel), Riedel and Sanfilippo, 1970, p. 535, pl. 14, fig. 12.
Occurrence. *Calocycletta costata* Zone to lower part of *Dorcadospyris alata* Zone.

***Calocycletta virginis* Haeckel**
(Plate 5, Fig. 16)

Calocyclas virginis Haeckel, 1887, p. 1381; Riedel, 1957, p. 90, pl. 4, figs. 3, 4.
Calocycletta virginis (Haeckel), Moore, 1972, p. 147, pl. 1, fig. 7.
Occurrence. *Calocycletta costata* Zone to *Dorcadospyris alata* Zone.

***Calocycletta* sp.**

Remarks. This form differs from *C. virginis* in having a roundish thorax.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone (?).

***Calocycloma ampulla* (Ehrenberg)**
(Plate 3, Fig. 2)

Eucyrtidium ampulla Ehrenberg, 1854, pl. 36, figs. 15a–c; 1873, p. 225.
Calocycloma ampulla (Ehrenberg), Foreman, 1973, p. 434, pl. 1, figs. 1–5; pl. 9, fig. 20.
Occurrence. Upper part of *Phormocyrtis striata striata* Zone.

***Calocycloma castum* (Haeckel)**
(Plate 3, Fig. 1)

Calocyclas casta Haeckel, 1887, p. 1384, pl. 73, fig. 10.
Calocycloma castum (Haeckel), Foreman, 1973, p. 434, pl. 1, figs. 9, 10.
Occurrence. Upper part of *Phormocyrtis striata striata* Zone.

***Cannartus* sp. D *in* Sakai**
(Plate 4, Figs. 18, 19; Plate 6, Fig. 14)

Cannartus sp. D in Sakai, 1980, p. 708, pl. 5, figs. 2, 5, 6.
Occurrence. *Diartus petterssoni* Zone to *Didymocyrtis antepenultima* Zone.

***Carpocanistrum* spp.**

Carpocanium spp., Nigrini, 1970, p. 171, pl. 4, figs. 4–6.
Carpocanistrum spp., Riedel and Sanfilippo, 1971, p. 1596, pl. 1G, figs. 1–6, 8–13; pl. 2F, figs. 5–6; pl. 3D, figs. 1, 2, 6, 7, 9.
Occurrence. *Calocycletta costata* Zone to *Didymocyrtis antepenultima* Zone.

***Carpocanopsis cristata* (Carnevale)?**

?*Sethocorys cristata* Carnevale, 1908, p. 31, pl. 4, fig. 18.
Carpocanopsis cristatum (Carnevale)?, Riedel and Sanfilippo, 1971, p. 1597, pl. 1G, fig. 16; pl. 2G, figs. 1–7.
Carpocanopsis cristata (Carnevale)?, Sanfilippo and Riedel, 1973, p. 531.
Occurrence. *Dorcadospyris alata* Zone.

***Ceratospyris articulata* Ehrenberg**
(Plate 3, Fig. 16)

Ceratospyris articulata Ehrenberg, 1873, p. 218; 1875, pl. 20, fig. 4; Sanfilippo and Riedel, 1973, p. 526, pl. 15, figs. 8, 9.
Occurrence. *Phormocyrtis striata striata* Zone.

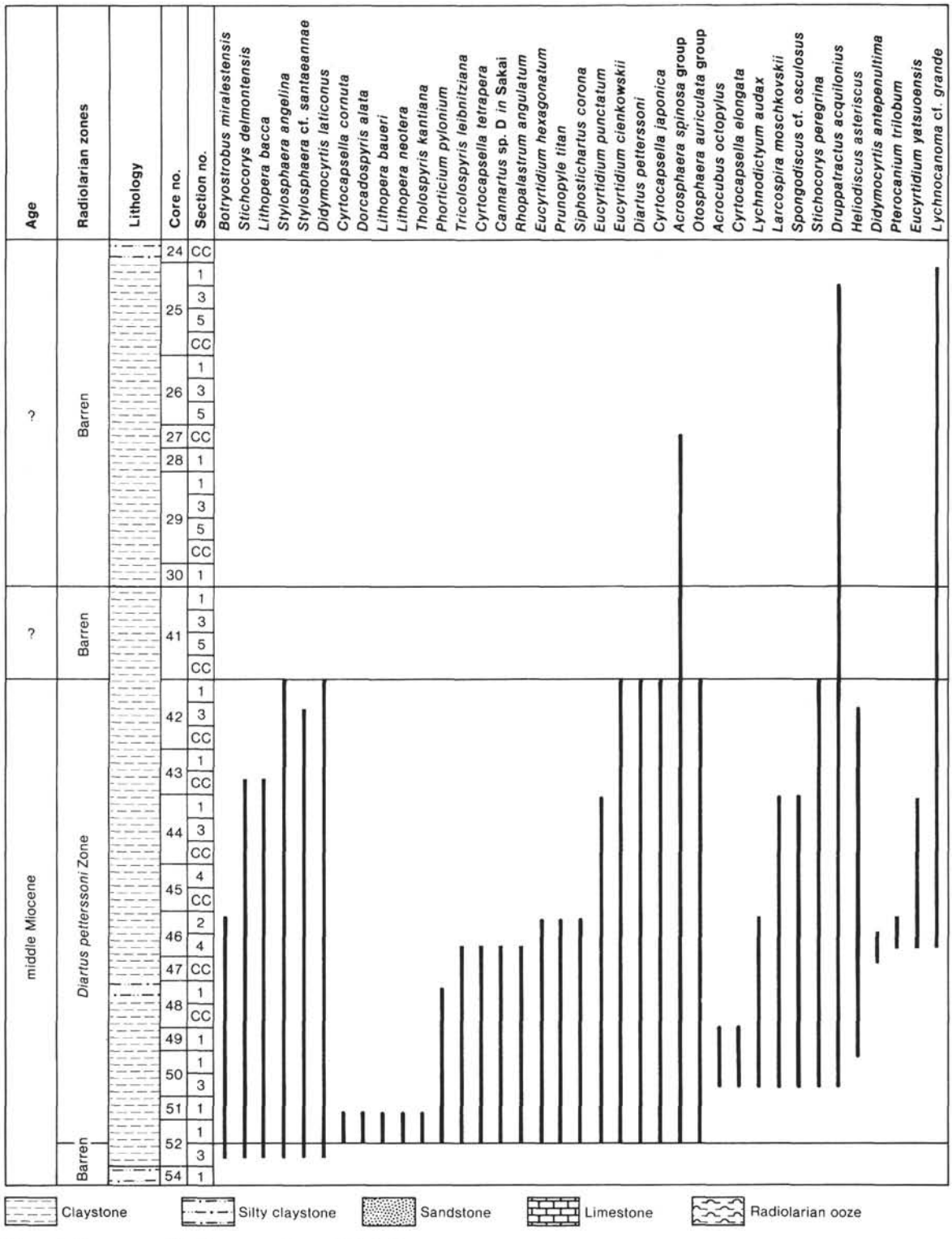

Figure 2. Neogene radiolarian range chart of Hole 603.

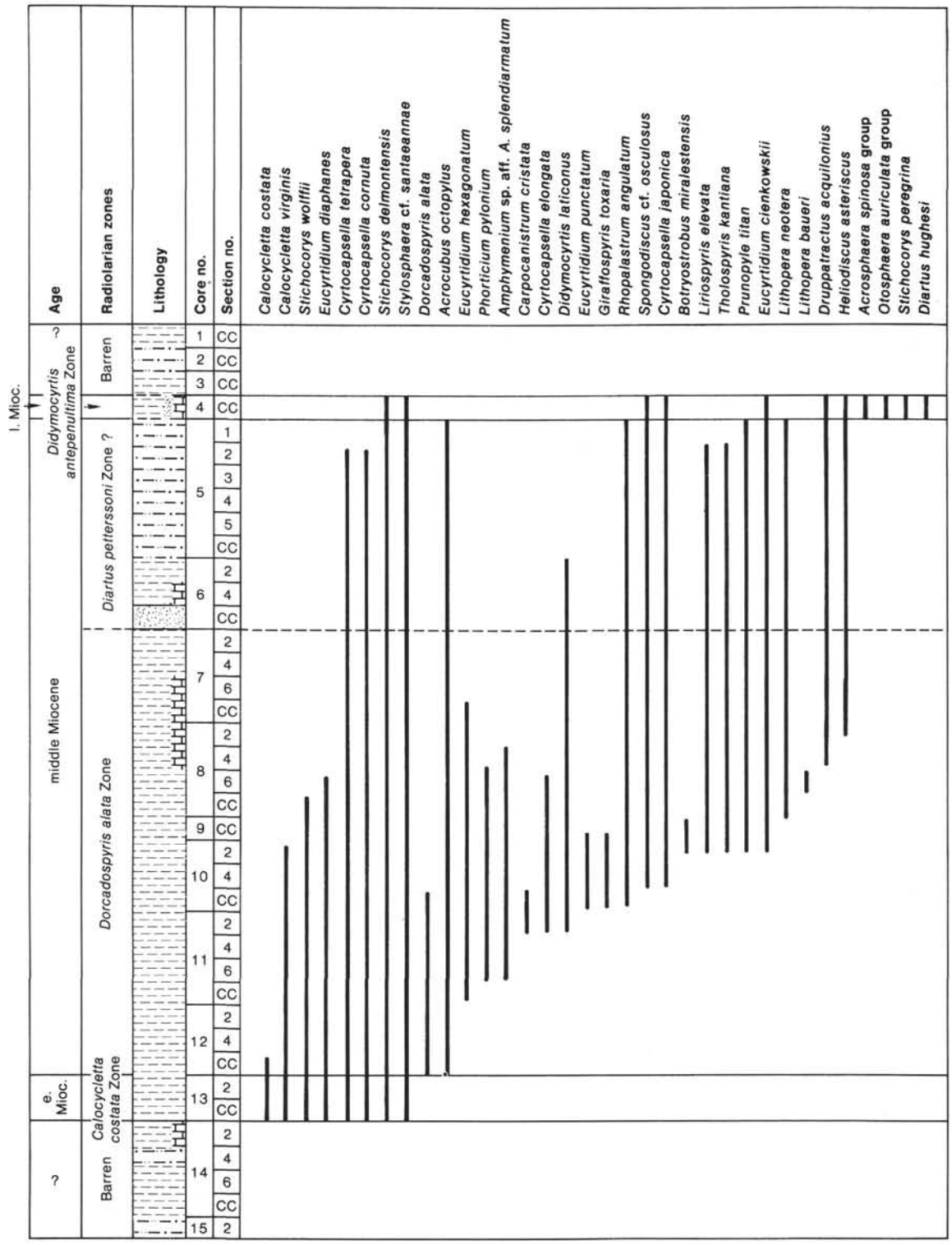

Figure 3. Neogene radiolarian range chart of Hole 603B.

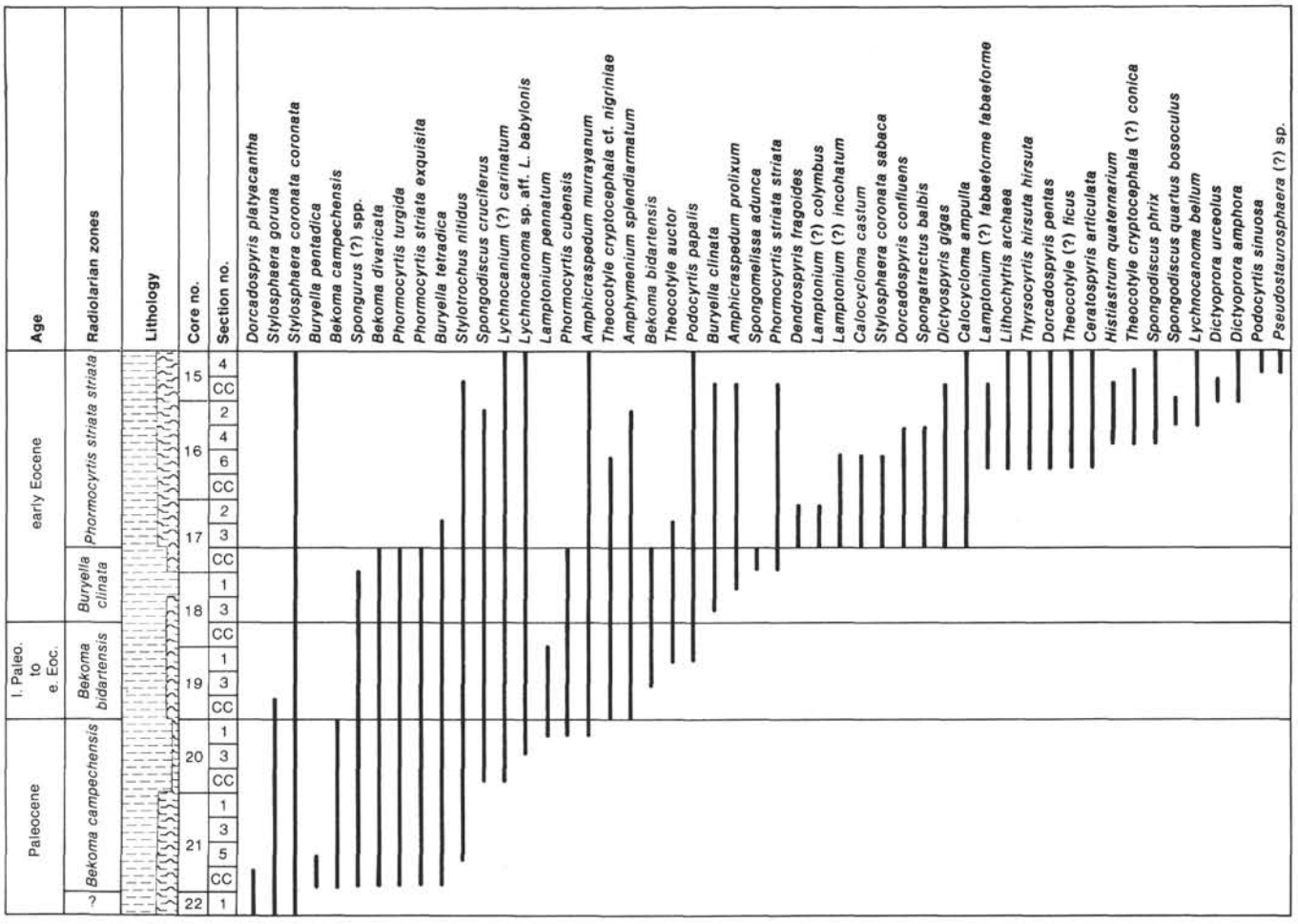

Figure 4. Paleogene radiolarian range chart of Hole 603B.

Cladococcus cf. *pinetum* Haeckel

Cladococcus pinetum Haeckel, 1887, p. 226, pl. 27, fig. 1.
Heteracantha dentata Mast, 1910, p. 157.
Anomalacantha dentata (Mast), Nigrini and Moore, 1979, p. S37, pl. 4, fig. 4.

Occurrence. *Diartus petterssoni* Zone.

Coccolarcus (?) *oviformis* Clark and Campbell

Coccolarcus (?) *oviformis* Clark and Campbell, 1945, p. 28, pl. 4, fig. 12.

Occurrence. *Phormocyrtis striata striata* Zone.

Cornutella sp.

Remarks. The outline of this form is fairly uneven in the lower part of the shell. It seems to be similar to *Cornutella californica* Campbell and Clark (1944b, p. 22, pl. 7, fig. 42) reported from the Upper Cretaceous of central California.

Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Cyrtocapsella cornuta (Haeckel)

(Plate 5, Fig. 6)

Cyrtocapsa (*Cyrtocapsella*) *cornuta* Haeckel, 1887, p. 1513, pl. 78, fig. 9.
Cyrtocapsella cornuta (Haeckel), Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 19, 20.

Occurrence. *Calocycletta costata* Zone to *Diartus petterssoni* Zone.

Cyrtocapsella elongata (Nakaseko)

(Plate 5, Fig. 1)

Theocampe elongata Nakaseko, 1963, p. 185, pl. 3, figs. 4, 5.
Cyrtocapsella elongata (Nakaseko), Sanfilippo and Riedel, 1970, p. 452, pl. 1, figs. 11, 12.

Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Cyrtocapsella japonica (Nakaseko)

(Plate 5, Figs. 3–5)

Eusyringium japonicum Nakaseko, 1963, p. 193, pl. 4, figs. 1–3.
Cyrtocapsella japonica (Nakaseko), Sanfilippo and Riedel, 1970, p. 452, pl. 1, figs. 13–15.

Occurrence. Middle part of *Dorcadospyris alata* Zone to *Didymocyrtis antepenultima* Zone.

Cyrtocapsella tetrapera Haeckel

(Plate 5, Fig. 2)

Cyrtocapsa tetrapera Haeckel, 1887, p. 1512, pl. 78, fig. 5.
Cyrtocapsella tetrapera Haeckel, Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 16–18.

Occurrence. *Calocycletta costata* Zone to *Diartus petterssoni* Zone.

Dendrospyris fragoides Sanfilippo and Riedel

Dendrospyris fragoides Sanfilippo and Riedel, 1973, p. 526, pl. 15, figs. 8–13; pl. 31, figs. 13, 14.

Occurrence. *Phormocyrtis striata striata* Zone.

***Dendrospyris stabilis* Goll**

Dendrospyris stabilis Goll, 1968, p. 1422, pl. 173, figs. 16–18, 20.
Occurrence. *Dorcadospyris alata* Zone.

***Diartus hughesi* (Campbell and Clark)**
(Plate 6, Fig. 1)

Ommatocampe hughesi Campbell and Clark, 1944a, p. 23, pl. 3, fig. 12.
Ommatartus hughesi (Campbell and Clark), Riedel and Sanfilippo, 1970, p. 521.
Diartus hughesi (Campbell and Clark), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, i.
Occurrence. *Didymocyrtis antepenultima* Zone.

***Diartus petterssoni* (Riedel and Sanfilippo)**
(Plate 4, Figs. 10–13; Plate 6, Figs. 2–6)

Cannartus (?) *petterssoni* Riedel and Sanfilippo, 1970, p. 520, pl. 14, fig. 3.
Diartus petterssoni (Riedel and Sanfilippo), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, h.
Occurrence. *Diartus petterssoni* Zone.

***Dictyoprora amphora* (Haeckel)**
(Plate 2, Fig. 3)

Dictyocephalus amphora Haeckel, 1887, p. 1305, pl. 62, fig. 4.
Theocampe amphora (Haeckel), Foreman, 1973, p. 431, pl. 8, figs. 7, 9–13; pl. 9, figs. 8, 9.
Dictyoprora amphora (Haeckel), Nigrini, 1977, p. 250, pl. 4, figs. 1, 2.
Occurrence. *Phormocyrtis striata striata* Zone.

***Dictyoprora urceolus* (Haeckel)**
(Plate 2, Figs. 1, 2)

Dictyocephalus urceolus Haeckel, 1887, p. 1305.
Theocampe urceolus (Haeckel), Foreman, 1973, p. 432, pl. 8, figs. 14–17; pl. 9, figs. 6, 7.
Dictyoprora urceolus (Haeckel), Nigrini, 1977, p. 251, pl. 4, figs. 9, 10.
Occurrence. *Phormocyrtis striata striata* Zone.

***Dictyospyris gigas* Ehrenberg**
(Plate 3, Fig. 20)

Dictyospyris gigas Ehrenberg, 1873, p. 224; 1875, pl. 19, fig. 6; Sanfilippo and Riedel, 1973, p. 527, pl. 16, figs. 9, 10; pl. 32, figs. 10, 11.
Occurrence. *Phormocyrtis striata striata* Zone.

***Didymocyrtis antepenultima* (Riedel and Sanfilippo)**
(Plate 4, Fig. 9)

Ommatartus antepenultimus Riedel and Sanfilippo, 1970, p. 521, pl. 14, fig. 4.
Didymocyrtis antepenultima (Riedel and Sanfilippo), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, f.
Occurrence. *Diartus petterssoni* Zone.

***Didymocyrtis laticonus* (Riedel)**
(Plate 4, Figs. 14–17; Plate 6, Figs. 7–10)

Cannartus laticonus Riedel, 1959, p. 291, pl. 1, fig. 5.
Didymocyrtis laticonus (Riedel), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, e.
Occurrence. Middle part of *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Didymocyrtis mammifera* (Haeckel)**
(Plate 4, Fig. 21; Plate 6, Figs. 11–13)

Cannartidium mammiferum Haeckel, 1887, p. 375, pl. 39, fig. 16.
Cannartus mammiferus (Riedel), Riedel, 1959, p. 291, pl. 1, fig. 4.
Didymocyrtis mammifera (Riedel), Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, d.
Occurrence. *Diartus petterssoni* Zone.

***Diprocyclas* (?) sp. aff. *D. davisiana* (Ehrenberg)**

Cycladophora (?) *davisiana* Ehrenberg, 1861, p. 297; 1873, pl. 2, fig. 11.
Diprocyclas davisiana (Ehrenberg), Petrushevskaya, 1975, p. 587.
Remarks. This form possesses three (?) slender, cylindrical, terminally tapered feet which are extended from the ribs of the abdomen.
Occurrence. *Diartus petterssoni* Zone.

***Dorcadospyris alata* (Riedel)**
(Plate 5, Fig. 20)

Brachiospyris alata Riedel, 1959, p. 293, pl. 1, figs. 11, 12.
Dorcadospyris alata (Riedel), Riedel and Sanfilippo, 1971, p. 1590, pl. 2D, fig. 1.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Dorcadospyris confluens* (Ehrenberg)**
(Plate 3, Figs. 18, 19)

Petalospyris confluens Ehrenberg, 1873, p. 246; 1875, pl. 22, fig. 5.
Dorcadospyris confluens (Ehrenberg), Goll, 1969, p. 337, pl. 58, figs. 9–12.
Occurrence. *Phormocyrtis striata striata* Zone.

***Dorcadospyris pentas* Ehrenberg**
(Plate 3, Fig. 17)

Dorcadospyris pentas Ehrenberg, 1873, p. 247; 1875, pl. 22, figs. 11a–b.
Occurrence. *Phormocyrtis striata striata* Zone.

***Dorcadospyris platyacantha* Ehrenberg**

Petalospyris platyacantha Ehrenberg, 1873, p. 247; 1875, pl. 22, fig. 8.
Dorcadospyris platyacantha Ehrenberg, Sanfilippo and Riedel, 1973, p. 528, pl. 17, figs. 11–15; pl. 33, fig. 2.
Occurrence. *Bekoma campechensis* Zone.

***Druppatractus acquilonius* Hays**

Druppatractus acquilonius Hays, 1970, p. 217, pl. 1, figs. 4, 5; Ling, 1975, p. 717, pl. 1, figs. 17, 18; Nigrini and Lombari, 1984, p. S23, pl. 4, figs. 1a, b.
Stylacontarium acquilonium (Hays) Kling, 1973, p. 634, pl. 1, figs. 17–20; pl. 14, figs. 1–4.
Occurrence. *Diartus petterssoni* Zone to *Didymocyrtis antepenultima* Zone.

***Entapium regulare* Sanfilippo and Riedel (?)**
(Plate 1, Fig. 9)

Entapium regulare Sanfilippo and Riedel, 1973, p. 492, pl. 1, figs. 10–19; pl. 24, figs. 1–3.

***Euchitonia* spp.**

Remarks. These forms are variable in size and angle of arms. Some of them are similar to *Euchitonia furcata*.
Occurrence. *Diartus petterssoni* Zone.

***Eucyrtidium calvertense* Martin**

Eucyrtidium calvertense Martin, 1904, p. 450, pl. 130, fig. 5.
Occurrence. *Diartus petterssoni* Zone.

***Eucyrtidium cienkowskii* Haeckel**
(Plate 5, Fig. 13; Plate 6, Fig. 20)

Eucyrtidium cienkowskii Haeckel, 1887, p. 1493, pl. 80, fig. 9; Nigrini and Lombari, 1984, p. N111, pl. 23. fig. 6.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Eucyrtidium diaphanes* Sanfilippo and Riedel**

Eucyrtidium diaphanes Sanfilippo and Riedel, Sanfilippo et al., 1973, p. 221, pl. 5, figs. 12–14.
Occurrence. *Calocycletta costata* Zone to *Dorcadospyris alata* Zone.

***Eucyrtidium hexagonatum* Haeckel**
(Plate 5, Fig. 14; Plate 6, Fig. 21)

Eucyrtidium hexagonatum Haeckel, 1887, p. 1489, pl. 80, fig. 11.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Eucyrtidium punctatum* (Ehrenberg)**
(Plate 5, Fig. 17)

cf. *Lithocampe punctata* Ehrenberg, 1844, p. 84.
cf. *Eucyrtidium punctatum* (Ehrenberg), Ehrenberg, 1847a, p. 43; 1854, pl. 2, fig. 24.
Eucyrtidium punctatum (Ehrenberg), Sanfilippo et al., 1973, p. 221, pl. 5, figs. 15, 16.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Eucyrtidium yatsuoensis* Nakaseko**

Eucyrtidium yatsuoensis Nakaseko, 1955, p. 110, pl. 10, figs. 1a, b.
Occurrence. *Diartus petterssoni* Zone.

***Giraffospyris toxaria* (Haeckel)**
(Plate 5, Fig. 26)

Podocoronis (Dipocoronis) toxarium Haeckel, 1877, p. 980, p. 83, fig. 7.
Giraffospyris toxaria (Haeckel), Goll, 1969, p. 335, pl. 56, figs. 1, 2, 4, 7.
Occurrence. *Dorcadospyris alata* Zone.

***Heliodiscus asteriscus* Haeckel**

Heliodiscus asteriscus Haeckel, 1887, p. 445, pl. 33, fig. 8.
Occurrence. Upper part of *Dorcadospyris alata* Zone to *Didymocyrtis antepenultima* Zone.

***Heliodiscus* sp.**

Remarks. This form is similar to *H. asteriscus*, but is distinguished from the latter by spines that are markedly shorter or are sometimes absent.
Occurrences. *Diartus petterssoni* Zone to upper unzoned interval.

***Heliodiscus* (?) sp.**

Remarks. Most forms are broken except for the central part, which consists of two shells, a lenticular outer shell and a subspherical inner shell, which are connected by a number of beams. The pores of the inner shell are larger than those of *Heliodiscus* sp. It is difficult to identify the genus *Heliodiscus* when the marginal part is absent.
Occurrence. *Diartus petterssoni* Zone.

***Heliostylus* spp.**
(Plate 1, Fig. 10)

Heliostylus spp. Sanfilippo and Riedel, 1973, pl. 8, figs. 1–7.
Occurrence. *Bekoma bidartensis* Zone to *Buryella clinata* Zone.

***Hexacontium palaeocenicum* Sanfilippo and Riedel**
(Plate 1, Figs. 8, 11)

Hexacontium palaeocenicum Sanfilippo and Riedel, 1973, p. 492, pl. 4, fig. 4.
Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

***Histiastrum quaternarium* Ehrenberg**
(Plate 1, Fig. 16)

Histiastrum quaternarium Ehrenberg, 1875, p. 74, pl. 24, figs. 3, 4.
Occurrence. *Phormocyrtis striata striata* Zone.

***Lamprocyclas maritalis* Haeckel group**

Lamprocyclas maritalis Haeckel, 1887, p. 1390, pl. 74, figs. 13, 14.
Lamprocyclas maritalis Haeckel group, Nigrini and Lombari, 1984, p. N163, pl. 30, figs. 1a, b.
Occurrence. *Calocycletta costata* Zone to *Didymocyrtis antepenultima* Zone.

***Lamptonium* (?) *colymbus* Foreman**

Lamptonium (?) *colymbus* Foreman, 1973, p. 435, pl. 6, fig. 2; pl. 11, figs. 15, 19.
Occurrence. Lower part of *Phormocyrtis striata striata* Zone.

***Lamptonium fabaeforme* (?) *constrictum* Riedel and Sanfilippo**
(Plate 2, Fig. 21)

Lamptonium (?) *fabaeforme* (?) *constrictum* Riedel and Sanfilippo, 1970, p. 523, pl. 5, fig. 7. *Lamptonium fabaeforme* (?) *constrictum* Riedel and Sanfilippo, Foreman, 1973, p. 436, pl. 6, figs. 13, 14.
Occurrence. *Phormocyrtis striata striata* Zone.

***Lamptonium* (?) *fabaeforme fabaeforme* (Krasheninnikov)**
(Plate 2, Fig. 20)

(?)*Cyrtocalpis fabaeforme* Krasheninnikov, 1960, p. 296, pl. 3, fig. 11.
Lamptonium (?) *fabaeforme fabaeforme* (Krasheninnikov) (?), Riedel and Sanfilippo, 1970, p. 523, pl. 5, fig. 6.
Occurrence. *Phormocyrtis striata striata* Zone.

***Lamptonium* (?) *incohatum* Foreman**
(Plate 2, Fig. 24)

Lamptonium (?) *incohatum* Foreman, 1973, p. 436, pl. 6, fig. 1; pl. 11, fig. 18.
Occurrence. Lower part of *Phormocyrtis striata striata* Zone.

***Lamptonium pennatum* Foreman**

Lamptonium pennatum Foreman, 1973, p. 436, pl. 6, figs. 3–5; pl. 11, fig. 13.
Occurrence. Top of *Bekoma campechensis* Zone to *B. bidartensis* Zone.

***Larcospira moschkovskii* Kruglikova**
(Plate 6, Fig. 17)

Larcospira moschkovskii Kruglikova, 1978, p. 88, pl. 27, figs. 3–6; Nigrini and Lombari, 1984, p. S91, pl. 13, figs. 2a, b.
Occurrence. *Diartus petterssoni* Zone.

***Liriospyris elevata* Goll**
(Plate 5, Fig. 23)

Liriospyris elevata Goll, 1968, p. 1426, pl. 175, figs. 4, 5, 8, 9. text-fig. 9.
Occurrence. Middle part of *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Lithapium* (?) cf. *plegmacantha* Sanfilippo and Riedel**

Lithapium plegmacantha Sanfilippo and Riedel, 1973, p. 516, pl. 3, figs. 1, 2; pl. 24, figs. 8, 9.
Occurrence. Lower part of *Phormocyrtis striata striata* Zone.

***Lithelius* sp.**

Remarks. This form is similar to *L. foremanae* Sanfilippo and Riedel, 1973, p. 522, pl. 7, figs. 1–6; pl. 26, figs. 4, 5. It differs from the latter in that radial spines are thorny and scarcely extend outward.
Occurrence. *Phormocyrtis striata striata* Zone.

***Lithochytris archaea* Riedel and Sanfilippo**
(Plate 3, Fig. 9)

Lithochytris archaea Riedel and Sanfilippo, 1970, pl. 9, fig. 8; 1971, p. 1594, pl. 7, fig. 13; Foreman, 1973, p. 436, pl. 2, figs. 4, 5.
Occurrence. *Phormocyrtis striata striata* Zone.

***Lithochytris tripodium* Ehrenberg**
(Plate 3, Fig. 10)

Lithochytris tripodium Ehrenberg, 1875, p. 76, pl. 4, fig. 11.
Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Lithopera bacca Ehrenberg

Lithopera bacca Ehrenberg, 1872a, p. 314; 1872b, p. 297, pl. 8, fig. 1; Nigrini, 1967, p. 54, pl. 6, fig. 2.
Occurrence. *Diartus petterssoni* Zone.

Lithopera baueri Sanfilippo and Riedel

Lithopera baueri Sanfilippo and Riedel, 1970, p. 455, pl. 2, figs. 1–2.
Occurrence. Middle part of *Dorcadospyris alata* Zone to base of *Diartus petterssoni* Zone.

Lithopera neotera Sanfilippo and Riedel
(Plate 6, Fig. 18)

Lithopera neotera Riedel and Sanfilippo, 1971, p. 1594, pl. 1F, figs. 14–15; pl. 2E, fig. 19.
Occurrence. Middle part of *Dorcadospyris alata* Zone to base of *Diartus petterssoni* Zone.

Lithopera thornburgi Sanfilippo and Riedel

Lithopera thornburgi Sanfilippo and Riedel, 1970, p. 455, pl. 2, figs. 4–6.
Occurrence. *Diartus petterssoni* Zone.

Lychnocanium (?) *carinatum* Ehrenberg
(Plate 3, Figs. 6, 11)

Lychnocanium carinatum Ehrenberg, 1875, p. 78, pl. 8, fig. 5.
Remarks. All specimens which have distinct ribs on the thorax are included in this species.
Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Lychnocanium pyriforme Haeckel
(Plate 3, Fig. 7)

Lychnocanium pyriforme Haeckel, 1887, p. 1225, pl. 61, fig. 11.
Occurrence. *Phormocyrtis striata striata* Zone.

Lychnocanoma auxilla Foreman

Lychnocanoma auxilla Foreman, 1973, p. 437, pl. 2, fig. 6; pl. 11, figs. 1, 2.
Occurrence. *Bekoma campechensis* Zone to *B. bidartensis* Zone.

Lychnocanoma sp. aff. *L. babylonis* (Clark and Campbell)
(Plate 3, Figs. 3–5)

Dictyophimus babylonis Clark and Campbell, 1942, p. 67, pl. 9, figs. 32, 36.
Sethochytris babylonis (Clark and Campbell) group, Riedel and Sanfilippo, 1970, p. 528, pl. 9, figs. 1–3.
Lychnocanoma babylonis (Clark and Campbell) group, Foreman, 1973, p. 437, pl. 2, fig. 1.
Remarks. This species differs from *Lychnocanoma babylonis* in that the apical horn and three terminal feet are three-bladed.
Occurrence. Upper part of *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Lychnocanoma bellum (Clark and Campbell)
(Plate 3, Fig. 8)

Lychnocanium bellum Clark and Campbell, 1942, p. 72, pl. 9, figs. 35, 39.
Lychnocanoma bellum (Clark and Campbell), Foreman, 1973, p. 437, pl. 1, fig. 17; pl. 11, fig. 9.
Occurrence. *Phormocyrtis striata striata* Zone.

Lychnocanoma cf. *grande* (Campbell and Clark)

Lychnocanium grande Campbell and Clark, 1944a, p. 42, pl. 6, figs. 3–6.
Lychnocanoma grande (Campbell and Clark), Kling, 1973, p. 637, pl. 10, figs. 10–14.
Occurrence. Middle part of *Diartus petterssoni* Zone to upper unzoned interval.

Lychnodictyum audax Riedel

Lychnodictyum audax Riedel, 1953, p. 810, pl. 85, fig. 9.
Occurrence. *Diartus petterssoni* Zone.

Orbula cf. *comitata* Foreman

Orbula comitata Foreman, 1973, p. 437, pl. 3, fig. 11; pl. 10, figs. 7, 8.
Occurrence. Lower part of *Phormocyrtis striata striata* Zone.

Otosphaera auriculata Haeckel group

Otosphaera auriculata Haeckel, 1887, p. 116, pl. 7, fig. 5.
Otosphaera auriculata Haeckel group, Ling, 1975, p. 717, pl. 1, figs. 5, 6.
Remarks. Forms with two to three spines are included under the name of this species. One of them is similar to *Otosphaera annikae* Petrushevskaya and Kozlova (1972, pl. 9, fig. 1), who have reported that this species is characteristic of the early *Dorcadospyris alata* Zone; however, at Site 603 it appeared in the *Diartus petterssoni* to *Didymocyrtis antepenultima* zones.
Occurrence. *Diartus petterssoni* Zone to *Didymocyrtis antepenultima* Zone.

Phormocyrtis cubensis (Riedel and Sanfilippo)
(Plate 2, Fig. 14)

Eucyrtidium cubensis Riedel and Sanfilippo, 1971, p. 1594, pl. 7, figs. 10, 11.
Phormocyrtis cubensis (Riedel and Sanfilippo), Foreman, 1973, p. 438, pl. 7, figs. 11, 12, 14.
Occurrence. Top of *Bekoma campechensis* Zone to *Buryella clinata* Zone.

Phormocyrtis striata exquisita (Kozlova)
(Plate 2, Fig. 13)

Podocyrtis exquisita Kozlova, Kozlova and Gorbovetz, 1966, p. 106, pl. 17, fig. 2.
Phormocyrtis striata exquisita (Kozlova), Foreman, 1973, p. 438, pl. 7, figs. 1–4, 7, 8; pl. 12, fig. 5.
Occurrence. *Bekoma campechensis* Zone to *Buryella clinata* Zone.

Phormocyrtis striata striata Brandt
(Plate 2, Figs. 10, 11)

Phormocyrtis striata Brandt, Riedel and Sanfilippo, 1970, p. 532, pl. 10, fig. 7.
Phormocyrtis striata striata Brandt, Foreman, 1973, p. 438, pl. 7, figs. 5, 6, 9.
Occurrence. Top of *Buryella clinata* Zone to *Phormocyrtis striata striata* Zone.

Phormocyrtis turgida (Krasheninnikov)
(Plate 2, Fig. 12)

Lithocampe turgida Krasheninnikov, 1960, p. 301, pl. 3, fig. 17.
Phormocyrtis turgida (Krasheninnikov), Foreman, 1973, p. 438, pl. 7, fig. 10; pl. 12, fig. 6.
Occurrence. *Bekoma campechensis* Zone to *Buryella clinata* Zone.

Phormostichoartus corbula (Harting)

Lithocampe corbula Harting, 1863, p. 12, pl. 1, fig. 21.
Phormostichoartus corbula (Harting), Nigrini, 1977, p. 252, pl. 1, fig. 10.
Occurrence. *Dorcadospyris alata* Zone.

Phorticium pylonium Haeckel

Phorticium pylonium Haeckel, 1887, p. 709, pl. 49, fig. 10; Nigrini and Lombari, 1984, p. S85, pl. 12, figs. 2a, b.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Podocyrtis papalis Ehrenberg
(Plate 2, Fig. 17)

Podocyrtis papalis Ehrenberg, 1847b, fig. 2; 1854, pl. 36, fig. 23; 1873, p. 251; Riedel and Sanfilippo, 1970, p. 533, pl. 11, fig. 1;

Sanfilippo and Riedel, 1973, p. 531, pl. 20, figs. 11–14; pl. 36, figs. 2, 3.
Occurrence. *Bekoma bidartensis* Zone to *Buryella clinata* Zone.

***Podocyrtis sinuosa* Ehrenberg**
(Plate 2, Fig. 18)

(?)*Podocyrtis sinuosa* Ehrenberg, 1873, p. 253; 1875, pl. 15, fig. 5.
Podocyrtis (Lampterium) sinuosa Ehrenberg, Riedel and Sanfilippo, 1970, p. 534, pl. 11, figs. 3, 4; Sanfilippo and Riedel, 1973, p. 532, pl. 21, figs. 4, 5.
Occurrence. *Phormocyrtis striata striata* Zone.

***Prunopyle titan* Campbell and Clark**
(Plate 4, Fig. 6)

Prunopyle titan Campbell and Clark, 1944a, p. 20, pl. 3, figs. 1–3.
Remarks. This species was described from the Miocene samples of California by Campbell and Clark (1944a); in the Antarctic sea it has been reported in Pliocene samples by Hays (1965) and Chen (1975).
Occurrence. Middle part of *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Pseudostaurosphaera* (?) sp.**
(Plate 1, Fig. 7)

(?)*Pseudostaurosphaera* sp., Cita, Nigrini and Gartner, 1970, p. 401, pl. 1, fig. A.
Remarks. It has been reported that this species had a very restricted range and was found in an upper middle Eocene sample from Hole 8A during Leg 2. This specimen appeared in a sample from the *Phormocyrtis striata striata* Zone of late early Eocene age at Site 603.
Occurrence. *Phormocyrtis striata striata* Zone.

***Pterocanium trilobum* (Haeckel)**

Dictyopodium trilobum Haeckel, 1860, p. 839.
Pterocanium trilobum (Haeckel), Nigrini and Moore, 1979, p. N45, pl. 23, figs. 1a–c; Nigrini and Lombari, 1984, p. N127, pl. 25, fig. 3.
Occurrence. *Diartus petterssoni* Zone.

***Rhopalastrum angulatum* (Ehrenberg)**
(Plate 4, Fig. 7)

Dictyastrum angulatum Ehrenberg, 1872a, p. 306; 1872b, pl. 8, fig. 18.
Rhopalastrum angulatum (Ehrenberg) group, Petrushevskaya and Kozlova, 1972, p. 529, pl. 17, figs. 7, 8.
Occurrence. Middle part of *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

***Rhopalocanium* sp. aff. *R. ornatum* Ehrenberg**
(Plate 3, Fig. 12)

Rhopalocanium ornatum Ehrenberg, 1847b, fig. 3; 1854, pl. 36, fig. 9.
Occurrence. *Phormocyrtis striata striata* Zone.

***Siphostichartus corona* (Haeckel)**
(Plate 5, Fig. 19)

Cyrtophormis (Acanthocyrtis) corona, Haeckel, 1887, p. 1426, pl. 77, fig. 5.
Siphostichartus corona (Haeckel), Nigrini, 1977, p. 257, pl. 2, figs. 5–7.
Occurrence. *Diartus petterssoni* Zone.

***Spongatractus balbis* Sanfilippo and Riedel**
(Plate 1, Fig. 4)

Spongatractus balbis Sanfilippo and Riedel, 1973, p. 518, pl. 2, figs. 1–3; pl. 25, figs. 1, 2.
Occurrence. *Phormocyrtis striata striata* Zone.

***Spongodiscus americanus* Kozlova**
(Plate 1, Fig. 15)

Spongodiscus americanus Kozlova, Kozlova and Gorbovetz, 1966, p. 88, pl. 14, figs. 1, 2; Sanfilippo and Riedel, 1973, p. 524, pl. 11, figs. 9–13; pl. 27, fig. 11; pl. 28, fig. 9.
Occurrence. *Bekoma campechensis* Zone to *Buryella clinata* Zone.

***Spongodiscus cruciferus* Clark and Campbell**

Spongodiscus cruciferus Clark and Campbell, 1942, p. 50, pl. 1, figs. 1–6, 8, 10, 11, 16, 18; Sanfilippo and Riedel, 1973, p. 524, pl. 11, figs. 14–17; pl. 28, figs. 10, 11.
Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

***Spongodiscus phrix* Sanfilippo and Riedel**
(Plate 1, Fig. 13)

Spongodiscus phrix Sanfilippo and Riedel, 1973, p. 525, pl. 12, figs. 1, 2; pl. 29, figs. 3, 4.
Occurrence. *Phormocyrtis striata striata* Zone.

***Spongodiscus* cf. *osculosus* (Dreyer)**
(Plate 4, Fig. 5)

Spongopyle osculosa Dreyer, 1889, p. 42, pl. 6, figs. 99, 100.
Spongodiscus resurgens osculosus (Dreyer), Petrushevskaya, 1975, p. 574, pl. 5, fig. 11, pl. 36, figs. 1–4.
Remarks. This form is distinguished from *S. osculosus* by having a girdle on the margin.
Occurrence. Middle part of *Dorcadospyris alata* Zone to *Didymocyrtis antepenultima* Zone.

***Spongodiscus quartus bosoculus* Sanfilippo and Riedel**

Spongodiscus quartus bosoculus Sanfilippo and Riedel, 1973, p. 525, pl. 12, figs. 8–10; pl. 29, fig. 7.
Occurrence. *Phormocyrtis striata striata* Zone.

***Spongodiscus pulcher* Clark and Campbell**

Spongodiscus pulcher Clark and Campbell, 1945, p. 26, pl. 4, fig. 5; Sanfilippo and Riedel, 1973, p. 525, pl. 12, figs. 3–5; pl. 29, figs. 4, 5.
Occurrence. *Bekoma campechensis* Zone to *Buryella clinata* Zone.

***Spongodiscus rhabdostylus* (Ehrenberg)**

Spongosphaera rhabdostyla Ehrenberg, 1873, p. 256; 1875, pl. 26, figs. 1, 2.
Stylotrochus rhabdostylus (Ehrenberg), Haeckel, 1887, p. 584.
Spongodiscus rhabdostylus (Ehrenberg), Sanfilippo and Riedel, 1973, p. 525, pl. 13, figs. 1–3; pl. 30, figs. 1, 2.
Remarks. This species as encountered at Site 603 has four rodlike radial spines.
Occurrence. *Bekoma campechensis* Zone to *B. bidartensis* Zone.

***Spongomelissa adunca* Sanfilippo and Riedel**

Spongomelissa adunca Sanfilippo and Riedel, 1973, p. 529, pl. 19, figs. 3, 4; pl. 34, figs. 1–6.
Occurrence. *Buryella clinata* Zone.

***Spongurus* (?) spp.**
(Plate 1, Fig. 17)

Remarks. There are at least two kinds of forms under this name. One of them is similar to the illustration which was shown by Sanfilippo and Riedel, 1973, pl. 27, fig. 10.
Occurrence. *Bekoma campechensis* Zone to *Buryella clinata* Zone.

***Stichocorys delmontensis* (Campbell and Clark)**
(Plate 5, Figs. 10, 11; Plate 6, Fig. 19)

Eucyrtidium delmontense Campbell and Clark, 1944a, p. 56, pl. 7, figs. 19, 20.
Stichocorys delmontensis (Campbell and Clark), Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 9.
Occurrence. *Calocycletta costata* Zone to *Didymocyrtis antepenultima* Zone.

***Stichocorys peregrina* (Riedel)**
(Plate 5, Figs. 8, 9)

Eucyrtidium elongatum peregrinum Riedel, 1953, p. 812, pl. 85, fig. 2.
Stichocorys peregrina (Riedel), Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 10.

Occurrence. *Diartus petterssoni* Zone to *Didymocyrtis antepenultima* Zone.

Stichocorys wolffii Haeckel
(Plate 5, Figs. 7, 12)

Stichocorys wolffii Haeckel, 1887, p. 1479, pl. 80, fig. 10; Riedel, 1957, pp. 92–93, pl. 4, figs. 6, 7.
Occurrence. *Calocycletta costata* Zone to *Diartus petterssoni* Zone.

Stichocorys sp.

Remarks. This form is quite slender and cylindrical in shell outline.
Occurrence. *Calocycletta costata* Zone to *Diartus petterssoni* Zone.

Stylatractus sp. aff. *S. neptunus* Haeckel

Stylatractus neptunus Haeckel, 1887, p. 328, pl. 17, fig. 6.
Occurrence. Middle part of *Dorcadospyris alata* Zone to *Didymocyrtis antepenultima* Zone.

Stylochlamidium asteriscus Haeckel

Stylochlamidium asteriscus Haeckel, 1887, p. 514, pl. 41, fig. 10; Nigrini and Lombari, 1984, p. S75, pl. 10, fig. 4.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Stylodictya validispina Jørgensen

Stylodictya validispina Jørgensen, 1905, p. 119, pl. 10, fig. 40; Petrushevskaya, 1967, p. 33, fig. 17, IV–V; Nigrini and Lombari, 1984, p. S71, pl. 10, fig. 2.
Occurrence. *Calocycletta costata* Zone to *Didymocyrtis antepenultima* Zone.

Stylosphaera angelina Campbell and Clark
(Plate 4, Fig. 2)

Stylosphaera angelina Campbell and Clark, 1944a, p. 12, pl. 1, figs. 14–20.
Occurrence. Base of *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Stylosphaera coronata coronata Ehrenberg
(Plate 1, Figs. 1, 2)

Stylosphaera coronata Ehrenberg, 1873, p. 258; 1875, pl. 25, fig. 4.
Stylosphaera coronata coronata Ehrenberg, Sanfilippo and Riedel, 1973, p. 520, pl. 1, figs. 13–17; pl. 25, fig. 4.
Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Stylosphaera coronata sabaca Sanfilippo and Riedel

Stylosphaera coronata sabaca Sanfilippo and Riedel, 1973, p. 521, pl. 1, fig. 18; pl. 25, figs. 7, 8.
Occurrence. *Phormocyrtis striata striata* Zone.

Stylosphaera goruna Sanfilippo and Riedel
(Plate 1, Fig. 3)

Stylosphaera goruna Sanfilippo and Riedel, 1973, p. 521, pl. 1, figs. 20, 21; pl. 25, figs. 9, 10.
Remarks. This species is similar to *Stylosphaera spinulosa* Ehrenberg (1875, pl. 25, fig. 8) and *Druppatractus* cf. *coronatus* (Squinabol) by Dumitrică (1973, pl. 6, figs. 4, 6; pl. 12, fig. 1). It is assigned to *S. goruna*, however, as there is a possibility that all these three species may be a single species. Further study is necessary to resolve this taxonomic problem.
Occurrence. *Bekoma campechensis* Zone to base of *B. bidartensis* Zone.

Stylosphaera cf. *santaeannae* Campbell and Clark
(Plate 4, Fig. 3)

Stylosphaera santaeannae Campbell and Clark, 1944a, p. 19, pl. 2, figs. 20–22.
Occurrence. *Calocycletta costata* Zone to *Didymocyrtis antepenultima* Zone.

Stylotrochus nitidus Sanfilippo and Riedel
(Plate 1, Fig. 12)

Stylotrochus nitidus Sanfilippo and Riedel, 1973, p. 525, pl. 13, figs. 9–14; pl. 30, figs. 7–10.
Occurrence. *Bekoma campechensis* Zone to *Phormocyrtis striata striata* Zone.

Thecosphaera larnacium Sanfilippo and Riedel

Thecosphaera larnacium Sanfilippo and Riedel, 1973, p. 521, pl. 3, figs. 4–6; pl. 25, figs. 13, 14.
Occurrence. *Phormocyrtis striata striata* Zone.

Theocotyle auctor Foreman

Theocotyle (*Theocotylissa*) *auctor* Foreman, 1973, p. 441, pl. 4, figs. 8–10; pl. 12, fig. 13.
Occurrence. *Bekoma bidartensis* Zone to base of *Phormocyrtis striata striata* Zone.

Theocotyle alpha Foreman
(Plate 2, Fig. 16)

Theocotyle (*Theocotylissa*) *alpha* Foreman, 1973, p. 441, pl. 4, figs. 13–15; pl. 12, fig. 16.
Occurrence. *Phormocyrtis striata striata* Zone.

Theocotyle cryptocephala (?) *conica* Foreman
(Plate 2, Fig. 22)

Theocotyle cryptocephala (?) *conica* Foreman, 1973, p. 440, pl. 4, fig. 11.
Occurrence. *Phormocyrtis striata striata* Zone.

Theocotyle cryptocephala cf. *nigriniae* Riedel and Sanfilippo
(Plate 2, Fig. 15)

Theocotyle cryptocephala nigriniae Riedel and Sanfilippo, 1970, p. 525, pl. 6, figs. 5, 6; Foreman, 1973, p. 440, pl. 4, figs. 1–5; pl. 12, fig. 17.
Remarks. This species is distinguished from *Theocotyle cryptocephala nigriniae* by irregularly well developed ribs and small pores on the abdomen.
Occurrence. *Bekoma bidartensis* Zone to *Phormocyrtis striata striata* Zone.

Theocotyle (?) *ficus* (Ehrenberg)
(Plate 2, Fig. 23)

Eucyrtidium ficus Ehrenberg, 1873, p. 228; 1875, pl. 11, fig. 19.
Theocotyle (?) *ficus* (Ehrenberg), Riedel and Sanfilippo, 1970, p. 525, pl. 7, figs. 3–5; Foreman, 1973, p. 441, pl. 4, figs. 16–20.
Occurrence. *Phormocyrtis striata striata* Zone.

Tholospyris sp. aff. *T. infericosta* Goll
(Plate 5, Fig. 21)

Tholospyris infericosta Goll, 1969, p. 326, pl. 55, figs. 7, 10–12.
Remarks. This species is similar to form T4 illustrated by Goll (1969, p. 323, text-fig. 1).
Occurrence. *Diartus petterssoni* Zone.

Tholospyris kantiana (Haeckel)
(Plate 5, Fig. 25)

Tricolospyris kantiana Haeckel, 1887, p. 1098, pl. 88, fig. 10.
Tholospyris kantiana (Haeckel), Goll, 1969, p. 327, pl. 58, figs. 17–19, 23, text-fig. 1.
Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

Tricolospyris leibnitziana Haeckel
(Plate 5, Fig. 22)

Tricolospyris leibnitziana Haeckel, 1887, p. 1098, pl. 88, fig. 9; Goll, 1972, p. 969, pl. 84, figs. 1–4; pl. 85, figs. 1–3.
Occurrence. *Diartus petterssoni* Zone.

Thyrsocyrtis hirsuta hirsuta (Krasheninnikov)

Podocyrtis hirsuta Krasheninnikov, 1960, p. 300, pl. 3, fig. 16.

Thyrsocyrtis hirsuta hirsuta (Krasheninnikov) Riedel and Sanfilippo, 1970, p. 526, pl. 7, fig. 9; Foreman, 1973, p. 441, pl. 3, figs. 3–8; pl. 12, fig. 15.

Occurrence. *Phormocyrtis striata striata* Zone.

Xiphospira cf. *circularis* (Clark and Campbell)

Porodiscus circularis Clark and Campbell, 1942, p. 42, pl. 2, figs. 2, 6, 10.

Xiphospira circularis (Clark and Campbell), Sanfilippo and Riedel, 1973, p. 526, pl. 14, figs. 5–12; pl. 31, figs. 4–7.

Occurrence. *Bekoma campechensis* Zone to *Bekoma bidartensis* Zone.

Zygocircus productus (Hertwig)

Lithocircus productus Hertwig, 1879, p. 69, pl. 7, fig. 4.

Zygocircus productus (Hertwig), Bütschli, 1882, p. 496.

Occurrence. *Dorcadospyris alata* Zone to *Diartus petterssoni* Zone.

ACKNOWLEDGMENTS

The samples at Site 603 were supplied through the shipboard scientists of Leg 93 of the Deep Sea Drilling Project. The samples at Site 384 were supplied through the assistance of the National Science Foundation. I wish to thank Dr. Makoto Okamura for arranging for the shipboard sampling, and the Scripps Institution and Lamont-Doherty DSDP curatorial staffs for immediately filling sample requests. I wish to express my sincere thanks to Prof. Kojiro Nakaseko of the Institute of Geological Sciences, College of General Education, Osaka University, for his assistance and valuable advice. I am also greatly indebted to Dr. Itaru Koizumi of the same Institute, for his kind advice and to Mr. Moriyoshi Yamauchi of the Department of Earth Sciences, Nara University of Education, for his kind help in printing photographs and useful discussion. I am also most grateful to Drs. Catherine A. Nigrini, Dean A. Dunn, and Amanda Palmer, all of whom reviewed the manuscript.

REFERENCES

Bütschli, O., 1882. Beitrage zur Kenntnis der Radiolarienskelette insbesondere der Cyrtida. *Z. Wiss. Zool.*, 36:485–540.

Campbell, A. S., and Clark, B. L., 1944a. *Miocene Radiolarian Faunas from Southern California.* Geol. Soc. Am., Spec. Pap., 51.

_____, 1944b. *Radiolaria from Upper Cretaceous of Middle California.* Geol. Soc. Am. Spec. Pap., 57.

Carnevale, P., 1980. Radiolarie e silicoflagellati di Bergonzano (Reggio Emilia). *R. Ist. Veneto Sci. Lett. Arti, Mem.* 28(3).

Chen, P. H., 1975. Antarctic Radiolaria. *In* Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 437–513.

Cita, M. B., Nigrini, C., and Gartner, S., 1970. Biostratigraphy. *In* Peterson, M. N. A., Edgar, N. T., et al., *Init. Repts. DSDP*, 2: Washington (U.S. Govt. Printing Office), 391–411.

Clark, B. L., and Campbell, A. S., 1942. *Eocene Radiolarian Faunas from the Mt. Diablo Area, California.* Geol. Soc. Am. Spec. Pap., 39.

_____, 1945. *Radiolaria from the Kreyenhagen Formation near Los Banos, California.* Geol. Soc. Am. Mem., 10.

Dreyer, F., 1889. Morphologische Radiolarienstudien. 1. Die Pylombildungen in vergleichend-anatomischer und entwicklungsgeschichtlicher Beziehung bei Radiolarien und bei Protisten überhaupt, nebst System und Beschreibung neuer und der bis jetzt bekannten pylomatischen Spumellarien. *Jenaischen Z. Naturw.* 23, n. ser., 16.

Dumitrică, P., 1973. Paleocene radiolaria, DSDP, Leg 21. *In* Burns, R. E., Andrews, J. E., et al., *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office), 787–817.

Ehrenberg, C. G., 1844. Über 2 neue Lager von Gebirgsmassen aus Infusorien als Meeres-Absatz in Nord-Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europa und Afrika. *Monatsber. K. Preuss. Akad. Wiss. Berlin, Jahrg.*, pp. 57–97.

_____, 1847a. Über eine halibiolithische, von Herrn R. Schomburgk entdeckte, vorherrschend aus mikroskopischen Polycystinen gebildete, Gebirgsmasse von Barbados. *Monatsber. K. Preuss. Akad. Wiss. Berlin, Jahrg.*, pp. 382–385.

_____, 1847b. Über die mikroskopischen keiselschaligen Polycystinen aus mächtige Gebirgsmasse von Barbados und über das Verhältinis der aus mehr als 300 neuen Arten bestehehenden ganz eigenthümlichen Formengruppe jener Felsmasse zu den lebenden Thieren und zur Kreidebildung. Eine neue Anregung zur Erforschung des Erdlebens. *Monatsber. K. Preuss. Akad. Wiss. Berlin, Jahrg.*, pp. 40–60.

_____, 1854. *Mikrogeologie.* Leipzig.

_____, 1861. Über die Tiefgrund-Verhältnisse des Ozeans am Eingange der Daviastrasse und bei Island. *Monatsber. K. Preuss. Akad. Wiss. Berlin, Jahrg.*, pp. 275–315.

_____, 1872a. Mikrogeologischen Studien als Zusammenfassung seiner Beobachtungen des kleinsten Lebens der Meeres-Tiefgrunde aller Zonen und dessen geologischen Einfluss. *Monatsber. K. Preuss. Akad. Wiss. Berlin, Jahrg.*, pp. 265–322.

_____, 1872b. Mikrogeologischen Studien über das kleinste Leben der Meeres-Tiefgrunde aller Zonen und dessen geologischen Einfluss. *Abh. K. Akad. Wiss. Berlin, Jahrg.*, pp. 131–399, pls. 1–12.

_____, 1873. Grossere Felsproben des Polycystinen-Mergels von Barbados mit weiteren Erlauterungen. *Monatsber. K. Preuss. Akad. Wiss., Berlin, Jahrg.*, pp. 213–263.

_____, 1875. Fortsetzung der mikrogeologischen Studien als Gesammt-Übersicht der mikroskopipschen Paläontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rücksicht auf den Polycystinen-Mergel von Barbados. *Abh. K. Akad. Wiss., Berlin*, pp. 1–226.

Foreman, H. P., 1973. Radiolaria of Leg 10 with systematics and ranges for the families Amphipyndacidae, Artostrobiidae, and Theoperidae. *In* Worzel, J. L., Bryant, W., et al., *Init. Repts. DSDP*, 10: Washington (U.S. Govt. Printing Office), 407–474.

Goll, R. M., 1968. Classification and phylogeny of Cenozoic Trissocyclidae (Radiolaria) in the Pacific and Caribbean basins. Part I. *J. Paleontol.*, 42(no. 6):1409–1432.

_____, 1969. Classification and phylogeny of Cenozoic Trissocyclidae (Radiolaria) in the Pacific and Caribbean basins. Part II. *J. Paleontol.* 43(no. 2):322–339.

_____, 1972. Leg 9 synthesis, Radiolaria. *In* Hays, J. D., et al. *Init. Repts. DSDP*, 9: Washington (U.S. Govt. Printing Office), 947–1058.

Haeckel, E., 1860. Uber neue, lenende Radiolarien des Mittelmeeres. *Monatsber. K. Preuss. Akad. Wiss. Berlin, Jahrg.*, pp. 835–845.

_____, 1862. *Die Radiolarien (Rhizopoda Radiolaria): Eine Monographie:* Berlin (Reimer).

_____, 1887. *Report on the Scientific Results of the Voyage of H.M.S.* Challenger *during the years 1873-76. Zool.*, Vol. 18. *Report on the Radiolaria:* London (Eyre and Spottiswood).

Harting, P., 1863. Bijdrage tot de kennis der mikroskopische fauna en flora van de Banda-Zee. *Verh. Koninkl. Akad. Wetensch. Amsterdam*, 10:1–34.

Hays, J. D., 1965. Radiolaria and Late Tertiary and Quaternary history of Antarctic seas. Am. Geophys. Un., *Antarctic Res. Ser., Biol. Antarctic Seas* (Vol. 2), 125–184.

_____, 1970. Stratigraphy and evolutionary trends of Radiolaria in North Pacific deep-sea sediments. *In* Hays, J. D. (Ed.), *Geological Investigations of the North Pacific.* Geol. Soc. Am. Mem., 126: 185–218.

Hertwig, R., 1879. *Der Organismus der Radiolarien:* Jena (G. Fischer).

Johnson, D. A., and Nigrini, C., 1980. Radiolarian biogeography in surface sediments of the western Indian Ocean. *Mar. Micropaleontol.*, 5:111–151.

Jørgensen, E., 1905. The Protist plankton and the diatoms in bottom samples. *Bergens Mus. Skr.*, pp. 49–151, 195–225.

Kling, S. A., 1973. Radiolaria from the eastern North Pacific, Deep Sea Drilling Project, Leg 18. *In* Kulm, L. D., von Huene, R., et al. *Init. Repts. DSDP*, 18: Washington (U.S. Govt. Printing Office), 617–671.

Kozlova, G. E., and Gorbovetz, A. N., 1966. Radiolaria of the Upper Cretaceous and upper Eocene deposits of the West Siberian Lowland. *Tr. Vses. Nauch.-Issled. Geol.-Razv. Inst.*, 248(1):1–119.

Krasheninnikov, V. A., 1960. Nekotorye radiolyari nizhnego i srednego eotsena zapadnogo predkavkazya. *Min. Geol. i Okhr. Nedr SSSR., Vses. Nauch.-Issled. Geol. Neft. Inst.*, No. 16:271–301.

Kruglikova, S. B., 1978. Novye vidy radiolyarii miotsena–golotsena ekvatorialnoi zony Tikhogo okean. *In* Zhuze, A. P. (Ed.), *Morskaya Mikropaleontogiya (diatomei, radiolyarii, silikoflyagellyaty,*

foraminifery i izvestkovyi nannoplankton): Moscow (Nauka), pp. 87–90.

Ling, H. Y., 1975. Radiolaria: Leg 31 of the Deep Sea Drilling Project. *In* Karig, D. E., Ingle, J. C., Jr., et al., *Init. Repts. DSDP*, 31: Washington (U.S. Govt. Printing Office), 703–761.

Martin, G. C., 1904. *Radiolaria.* Maryland Geol. Surv. (Miocene), 447.

Mast, H., 1910. Die Astrosphaeriden. *Wiss. Ergebn. D. Tiefsee-Exped. "Valdivia"*, 19:123–190.

Moore, T. C., Jr., 1972. Mid-Tertiary evolution of the radiolarian genus *Calocycletta. Micropaleontology*, 18(2):144–152.

Nakaseko, K., 1955. Miocene radiolarian fossil assemblage from the southern Toyama Prefecture in Japan. *Osaka Univ., South and North Coll., Sci. Rept.*, 12:165–198.

_____, 1963. Neogene Cyrtoidea (Radiolaria) from the Isozaki Formation in Ibaraki Prefecture, Japan. *Osaka Univ. Sci. Repts.*, 12(2): 165–198.

Nigrini, C. A., 1967. Radiolaria in pelagic sediments from the Indian and Atlantic oceans. *Bull. Scripps Inst. Ocean.*, 11:1–125.

_____, 1970. Radiolarian assemblages in the North Pacific and their application to a study of Quaternary sediments in core v20-130. *Geol. Soc. Am. Mem.*, 126:139–183.

_____, 1977. Tropical Cenozoic Artostrobiidae (Radiolaria). *Micropaleontology*, 23(3):241–269.

Nigrini, C. A., and Lombari, C., 1984. *A Guide to Miocene Radiolaria.* Cushman Found. Foram. Res. Spec. Publ., 22.

Nigrini, C. A., and Moore, T. C., Jr., 1979. *A Guide to Modern Radiolaria.* Cushman Found. Foram. Res. Spec. Publ., 16.

Okada, H., and Thierstein, H. R., 1979. Calcareous nannoplankton—Leg 43, Deep Sea Drilling Project. *In* Tucholke, B. E., Vogt, P. R., et al., *Init. Repts. DSDP*, 43: Washington (U.S. Govt. Printing Office), 507–573.

Petrushevskaya, M. G., 1967. Radiolarii otryadov Spumellaria i Nassellaria Antarcticheskoi oblasti (po materialam Sovetsko, Antarkticheskoi ekspeditsii). *Issed. Fauny mori*, l.IV(XII). *Resultaty Biol. Issed. Sovetskoi Antarctic. Exped.* (1950–58), 3:5–186.

_____, 1975. Cenozoic radiolarians of the Antarctic, Leg 29, DSDP. *In* Kennett, J. P., Houtz, R. E., et al. *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 541–675.

Petrushevskaya, M. G., and Kozlova, G. E., 1972. Radiolaria, Leg 14, Deep Sea Drilling Project. *In* Hayes, D. E., Pimm, A. C., et al., *Init. Repts. DSDP*, 14: Washington (U.S. Govt. Printing Office), 495–648.

Riedel, W. R., 1953. Mesozoic and late Tertiary Radiolaria of Rotti. *J. Paleontol.*, 27:805–813.

_____, 1957. Radiolaria: a preliminary stratigraphy. *Repts. Swedish Deep-Sea Exped.* 6:59–96.

_____, 1959. Oligocene and lower Miocene Radiolaria in tropical Pacific sediments. *Micropaleontology*, 5(3):285–302.

Riedel, W. R., and Sanfilippo, A., 1970. Radiolaria, Leg 4, Deep Sea Drilling Project. *In* Bader, R. G., Gerard, R. D., et al., *Init. Repts. DSDP*, 4: Washington (U.S. Govt. Printing Office), 503–575.

_____, 1971. Cenozoic Radiolaria from the Western tropical Pacific, Leg 7. *In* Winterer, E. L., Riedel, W. R., et al., *Init. Repts. DSDP*, 7, Pt. 2: Washington (U.S. Govt. Printing Office), 1529–1672.

_____, 1977. Cainozoic Radiolaria. *In* A. T. S. Ramsay (Ed.), *Oceanic Micropaleontology* (Vol. 2): London (Academic Press), 847–912.

_____, 1978. Stratigraphy and evolution of tropical Cenozoic radiolarians. *Micropaleontology*, 24(1):61–96.

Riedel, W. R., Sanfilippo, A., and Cita, M. B., 1974. Radiolarians from the stratotype Zanclean (lower Pliocene, Sicily). *Riv. Ital. Paleont. Stratigr.*, 80(no. 4):699–734.

Sakai, T., 1980. Radiolarians from Sites 434, 435, and 436, Northwest Pacific Leg 56, Deep Sea Drilling Project. *In* Scientific Party, et al., *Init. Repts. DSDP*, 56, 57, Pt. 2: Washington (U.S. Govt. Printing Office), 695–733.

Sanfilippo, A., Burckle, L. H., Martini, E., and Riedel, W. R., 1973. Radiolarians, diatoms, silicoflagellates and calcareous nannofossils in the Mediterranean Neogene. *Micropaleontology*, 19(2):209–234.

Sanfilippo, A., and Riedel, W. R., 1970. Post-Eocene "closed" Theoperid radiolarians. *Micropaleontology*, 16(4):446–462.

_____, 1973. Cenozoic radiolaria (exclusive of Theoperids, Artostrobiids and Amphipyndacids) from the Gulf of Mexico, Deep Sea Drilling Project Leg 10. *In* Worzel, J. L., Bryant, W., et al., *Init. Repts. DSDP*, 10: Washington (U.S. Govt. Printing Office), 475–611.

_____, 1980. A revised generic and suprageneric classification of the Artiscins (Radiolaria). *J. Paleontol.*, 54(5):1008–1012.

Stöhr, E., 1880. Die Radiolarienfauna der Tripoli von Grotte, Provinz Girgenti in Sicilien. *Palaeontographica*, 26(3–2):69–124.

Strelkov, A. A., and Reshetnyak, V. V., 1971. Colonialinie radiolarii Spumellaria Mirovogo Okeana. *V. Kn. Issed. faunui Morei, L.*, pp. 295–373.

Weaver, F. M., and Dinkelman, M. G., 1978. Cenozoic radiolarians from the Blake Plateau and the Blake-Bahama Basin, DSDP Leg 44. *In* Benson, W. E., Sheridan, R. E., et al., *Init. Repts. DSDP*, 44: Washington (U.S. Govt. Printing Office), 865–885.

Date of Initial Receipt: 4 December 1984
Date of Acceptance: 5 June 1985

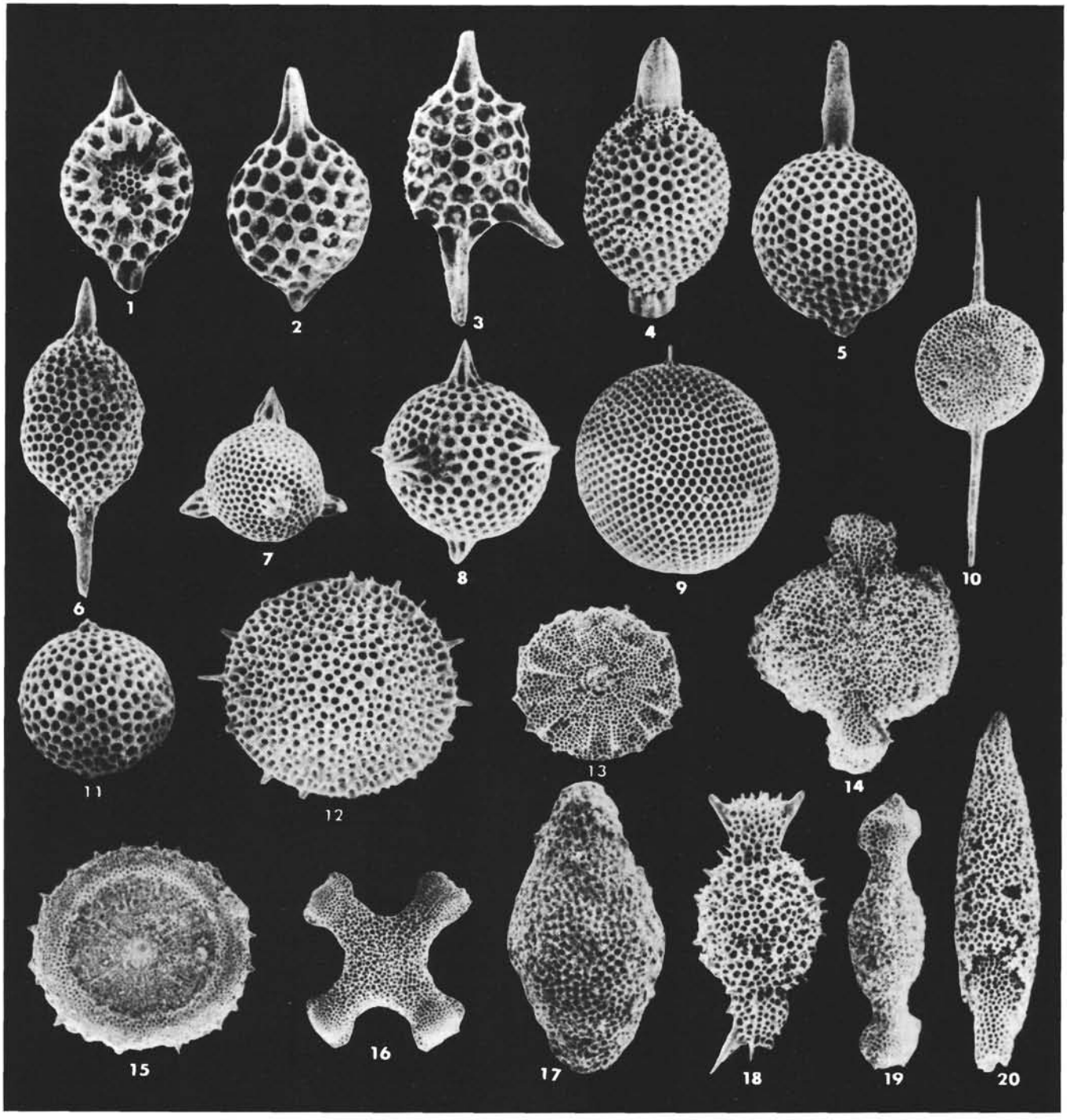

Plate 1. Scanning electron micrographs of Paleogene radiolarians from Hole 603B. (Magnification ×200, except for Figs. 1, 2, 3, ×270; Figs. 7, 10, 14, 15, 19, 20, ×135; Figs. 13, 16, ×70.) **1, 2.** *Stylosphaera coronata coronata* Ehrenberg, (1) Sample 603B-15,CC; (2) Sample 603B-16-4, 120–121 cm. **3.** *Stylosphaera goruna* Sanfilippo and Riedel, Sample 603B-21,CC. **4.** *Spongatractus balbis* Sanfilippo and Riedel, Sample 603B-16-6, 120–121 cm. **5.** *Amphisphaera minor* (Clark and Campbell), Sample 603B-15-4, 120–121 cm. **6.** *Axoprunum pierinae* (Clark and Campbell), Sample 603B-17,CC. **7.** *Pseudostaurosphaera*? sp., Sample 603B-15-4, 120–121 cm. **8, 11.** *Hexacontium palaeocenicum* Sanfilippo and Riedel, (8) sample 603B-20-1, 130–131 cm; (?) (11) Sample 603B-15-4, 120–121 cm. **9.** *Entapium regulare* Sanfilippo and Riedel (?), Sample 603B-16-6, 120–121 cm. **10.** *Heliostylus* sp., Sample 603B-19-1, 118–120 cm. **12.** *Stylotrochus nitidus* Clark and Campbell, Sample 603B-16-6, 120–121 cm. **13.** *Spongodiscus phrix* Sanfilippo and Riedel, Sample 603B-15-4, 120–121 cm. **14, 18.** *Amphicraspedum murrayanum* Haeckel, (14) Sample 603B-17-3, 120–121 cm; (18) Sample 603B-18,CC. **15.** *Spongodiscus americanus* Kozlova, Sample 603B-20-1, 121–123 cm. **16.** *Histiastrum quaternarium* Ehrenberg, Sample 603B-16-2, 120–121 cm. **17.** *Spongurus* (?) sp., Sample 603B-20-1, 121–123 cm. **19.** *Amphicraspedum* sp. cf. *A. murrayanum* Haeckel, Sample 603B-19-1, 118–120 cm. **20.** *Amphymenium splendiarmatum* Clark and Campbell, Sample 603B-17-3, 120–121 cm.

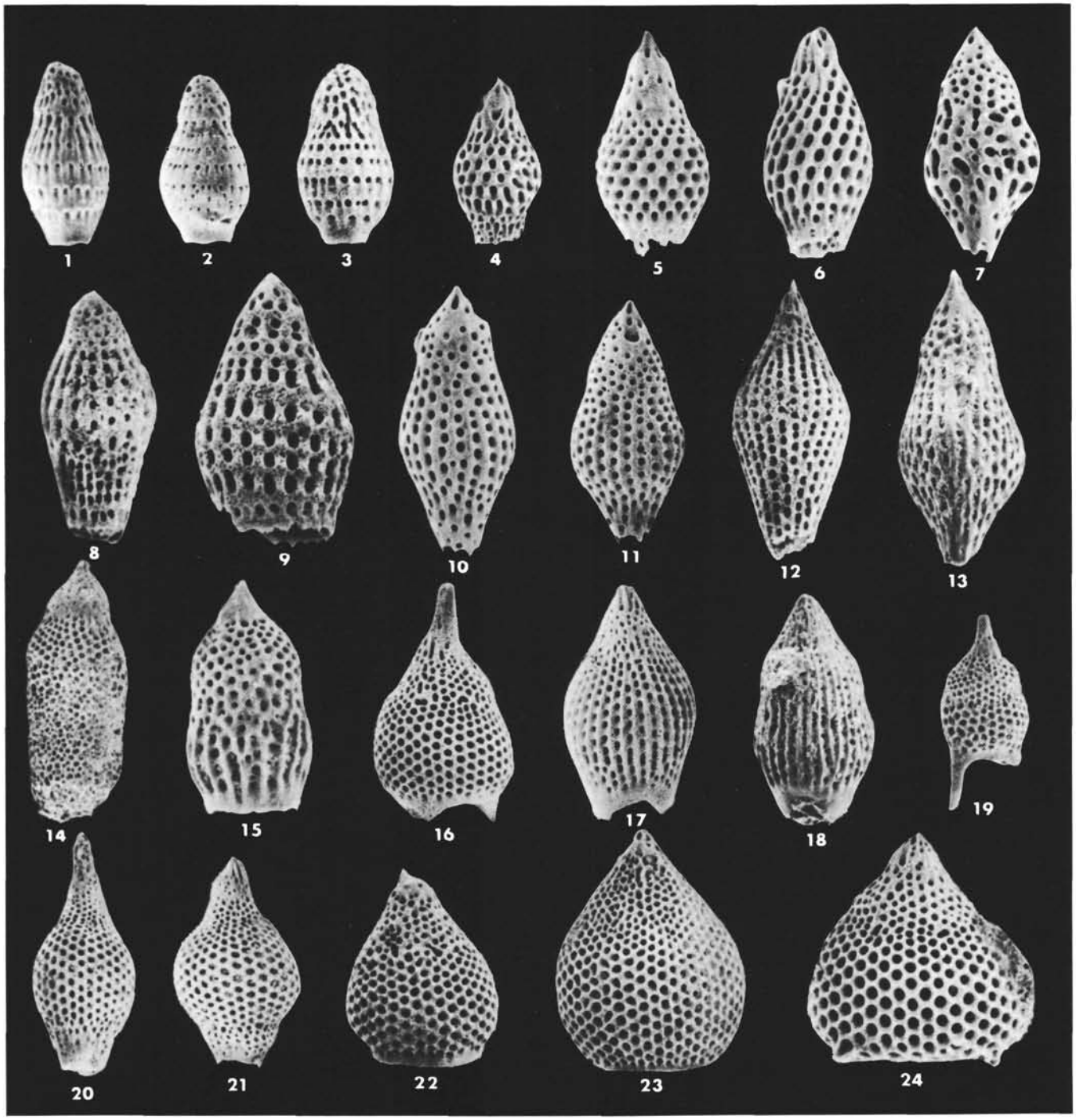

Plate 2. Scanning electron micrographs of Paleogene radiolarians from Hole 603B. (Magnification ×270, except for Fig. 9, ×405; Figs. 4, 12, 16–18, 22–24, ×200; Figs. 14, 19–21, ×135.) **1, 2.** *Dictyoprora urceolus* (Haeckel), Sample 603B-15,CC. **3.** *Dictyoprora amphora* (Haeckel), Sample 603B-15,CC. **4.** *Buryella* sp., Sample 603B-15,CC. **5, 6.** *Buryella clinata* Foreman, (5) Sample 603B-15,CC; (6) Sample 603B-16-6, 120–121 cm. **7.** *Phormocyrtis* sp., Sample 603B-16-6, 120–121 cm. **8.** *Buryella tetradica* Foreman, Sample 603B-17,CC. **9.** *Buryella pentadica* Foreman, Sample 603B-21,CC. **10, 11.** *Phormocyrtis striata striata* Brandt, Sample 603B-16-6, 120–121 cm. **12.** *Phormocyrtis turgida* (Krasheninnikov), Sample 603B-17,CC. **13.** *Phormocyrtis striata exquisita* (Kozlova), Sample 603B-17,CC. **14.** *Phormocyrtis cubensis* (Riedel and Sanfilippo), Sample 603B-17,CC. **15.** *Theocotyle cryptocephala* cf. *nigriniae* (Riedel and Sanfilippo), Sample 603B-17-3, 120–121 cm. **16.** *Theocotyle alpha* Foreman. Sample 603B-17-3, 120–121 cm. **17.** *Podocyrtis papalis* Ehrenberg, Sample 603B-17-3, 120–121 cm. **18.** *Podocyrtis sinuosa* Ehrenberg, Sample 603B-15-4, 120–121 cm. **19.** *Thyrsocyrtis hirsuta hirsuta* (Krasheninnikov), Sample 603B-15-4, 120–121 cm. **20.** *Lamptonium* (?) *fabaeforme fabaeforme* (Krasheninnikov), Sample 603B-15-4, 120–121 cm. **21.** *Lamptonium fabaeforme* (?) *constrictum* Riedel and Sanfilippo, Sample 603B-15-4, 120–121 cm. **22.** *Theocotyle cryptocephala* (?) *conica* Foreman, Sample 603B-16-4, 120–121 cm. **23.** *Theocotyle* (?) *ficus* (Ehrenberg), Sample 603B-15-4, 120–121 cm. **24.** *Lamptonium* (?) *incohatum* Foreman, Sample 603B-17-3, 120–121 cm.

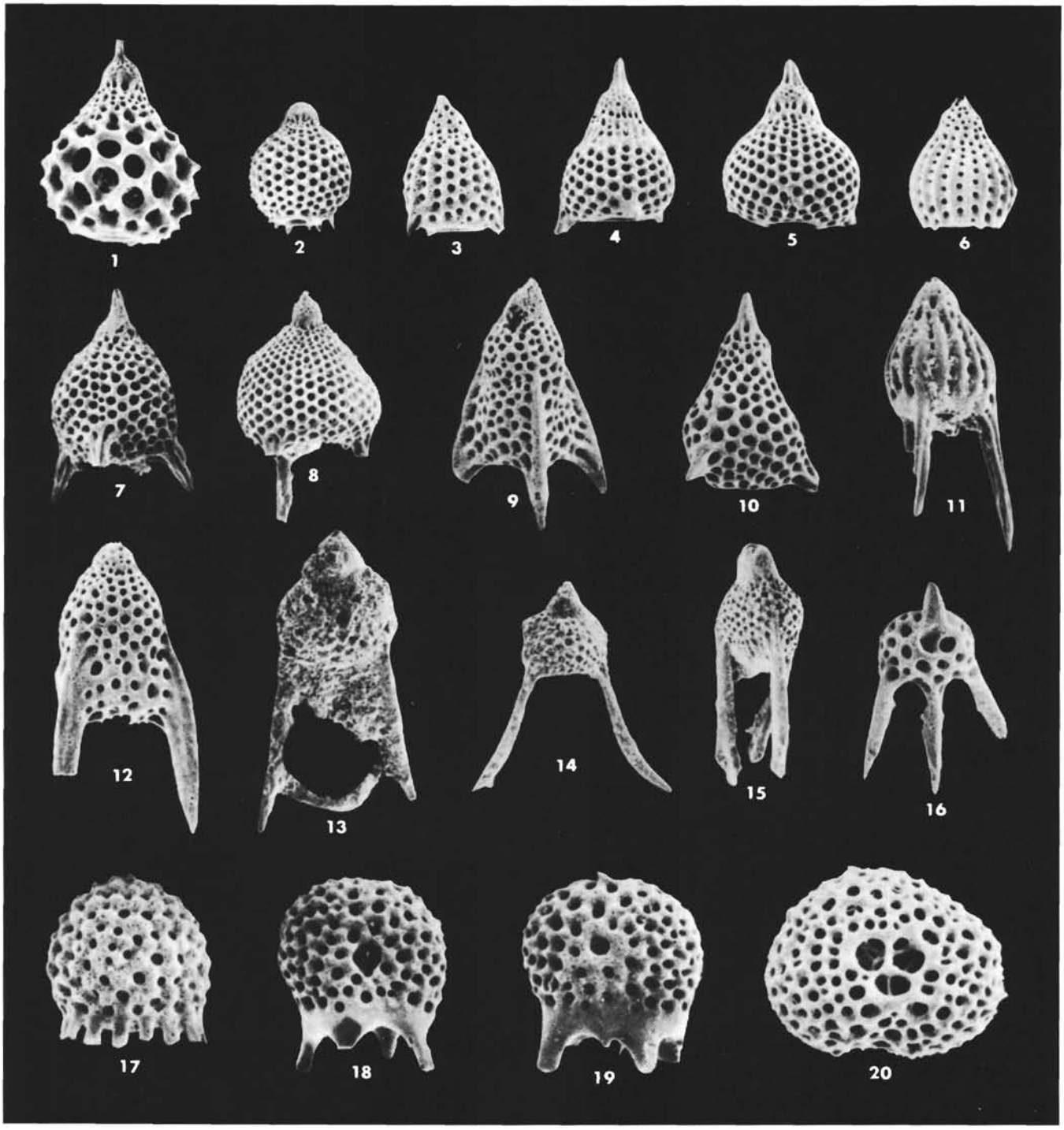

Plate 3. Scanning electron micrographs of Paleogene radiolarians from Hole 603B. (Magnification ×270, except for Figs 17–20, ×405; Figs. 1, 7–9, 13, ×200; Figs. 2, 14, 15, ×135.) **1.** *Calocycloma castum* (Haeckel), Sample 603B-16-6, 120–121 cm. **2.** *Calocycloma ampulla* (Ehrenberg), Sample 603B-15-4, 120–121 cm. **3–5.** *Lychnocanoma* sp. aff. *L. babylonis* (Clark and Campbell), (3, 4) Sample 603B-16-2, 120–121 cm; (5) Sample 603B-16-4, 120–121 cm. **6, 11.** *Lychnocanium* (?) *carinatum* Ehrenberg, (6) Sample 603B-16-2, 120–121 cm; (11) 603B-15-4, 120–121 cm. **7.** *Lychnocanium pyriforme* Haeckel, Sample 603B-15-4, 120–121 cm. **8.** *Lychnocanoma bellum* (Clark and Campbell), Sample 603B-15-4, 120–121 cm. **9.** *Lithochytris archaea* Riedel and Sanfilippo, Sample 603B-16-6, 120–121 cm. **10.** *Lithochytris tripodium* Ehrenberg, Sample 603B-16-6, 120–121 cm. **12.** *Rhopalocanium* sp. aff. *R. ornatum* Ehrenberg, Sample 603B-16-6, 120–121 cm. **13.** *Bekoma campechensis* Foreman, Sample 603B-21,CC. **14.** *Bekoma divaricata* Foreman, Sample 603B-20-1, 121–123 cm. **15.** *Bekoma bidartensis* Riedel and Sanfilippo, Sample 603B-18,CC. **16.** *Ceratospyris articulata* Ehrenberg, Sample 603B-15,CC. **17.** *Dorcadospyris pentas* Ehrenberg, Sample 603B-15-4, 120–121 cm. **18, 19.** *Dorcadospyris confluens* (Ehrenberg), Sample 603B-16-4, 120–121 cm. **20.** *Dictyospyris gigas* Ehrenberg, Sample 603B-16-6, 120–121 cm.

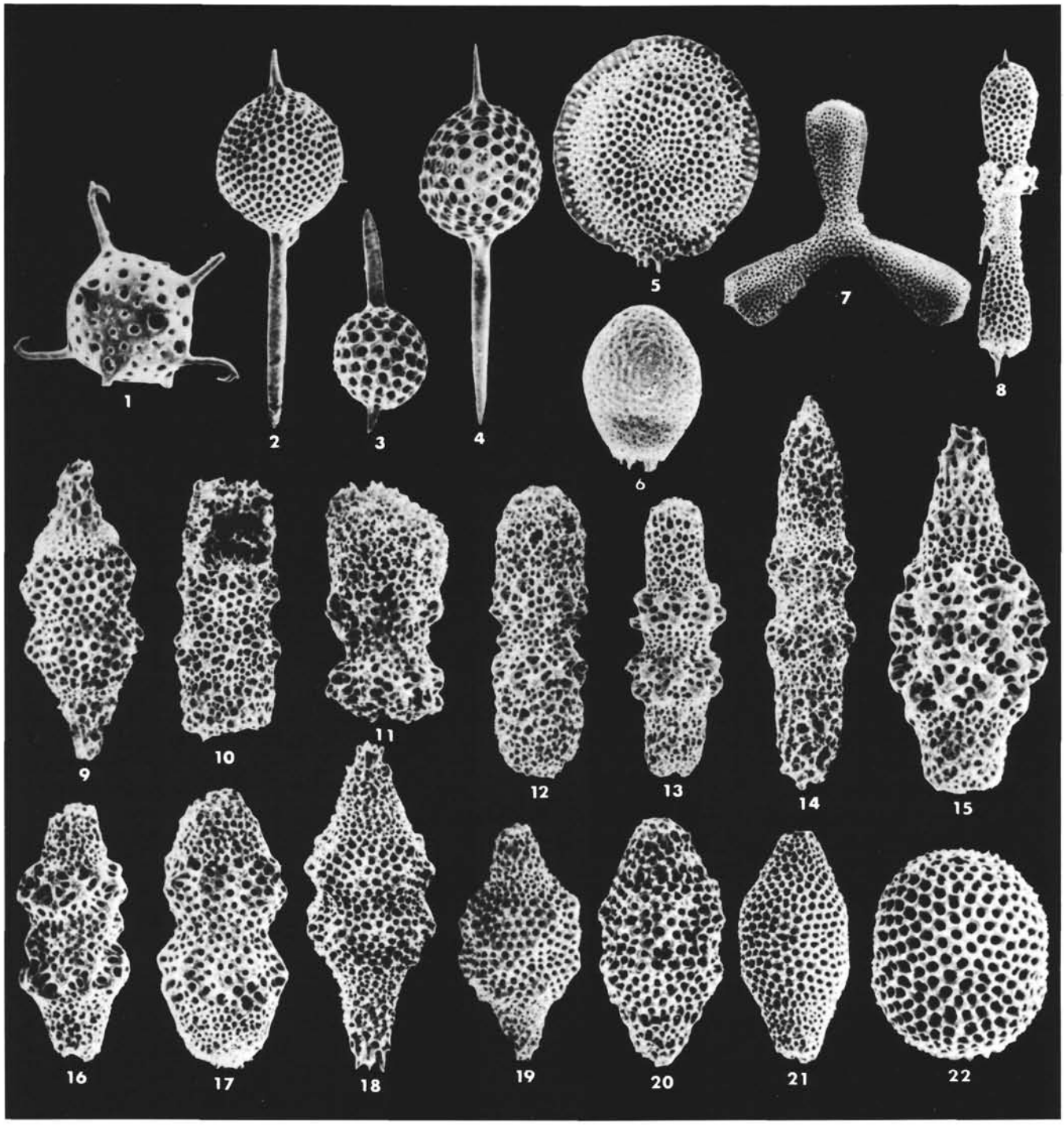

Plate 4. Scanning electron micrographs of Neogene radiolarians at Site 603. (Magnification ×200, except for Figs. 2, 9, 11, 16, 17, 20–22, ×270; Fig. 6, ×135; Fig. 7, ×100.) **1.** *Acrosphaera spinosa* (Haeckel) group, Sample 603A-50-3, 120–122 cm. **2.** *Stylosphaera angelina* Clark and Campbell, Sample 603A-50-3, 120–122 cm. **3.** *Stylosphaera* cf. *santaeannae* Campbell and Clark, Sample 603A-46-4, 120–122 cm. **4.** *Druppatractus acquilonium* Hays, Sample 603A-52-1, 120–122 cm. **5.** *Spongodiscus* cf. *osculosus* (Dreyer), Sample 603A-50-3, 120–122 cm. **6.** *Prunopyle titan* Campbell and Clark, Sample 603A-46-4, 120–122 cm. **7.** *Rhopalostrum angulatum* (Ehrenberg), Sample 603A-52-1, 120–122 cm. **8.** *Amphymenium* sp. cf. *A. splendiarmatum* Clark and Campbell, Sample 603A-46-4, 120–122 cm. **9.** *Didymocyrtis antepenultima* (Riedel), Sample 603A-46-4, 120–122 cm. **10–13.** *Diartus petterssoni* Campbell and Clark, (10) Sample 603A-46-4, 120–122 cm; (11) Sample 603A-50-3, 120–122 cm; (12) Sample 603A-52-1, 120–122 cm; (13) Sample 603A-42-1, 120–122 cm. **14–17.** *Didymocyrtis laticonus* (Riedel), (14) Sample 603A-50-3, 120–122 cm; (15) Sample 603A-52-1, 120–122 cm; (16) Sample 603A-46-4, 120–122 cm; (17) Sample 603A-50-3, 120–122 cm. **18, 19.** *Cannartus* sp. D *in* Sakai, (18) Sample 603A-50-3, 120–122 cm; (19) Sample 603A-46-4, 120–122 cm. **20.** *Didymocyrtis* sp., Sample 603A-46-4, 120–122 cm. **21.** *Didymocyrtis mammifera* (Haeckel), Sample 603A-52-1, 120–122 cm. **22.** *Didymocyrtis* (?) sp., Sample 603A-46-4, 120–122 cm.

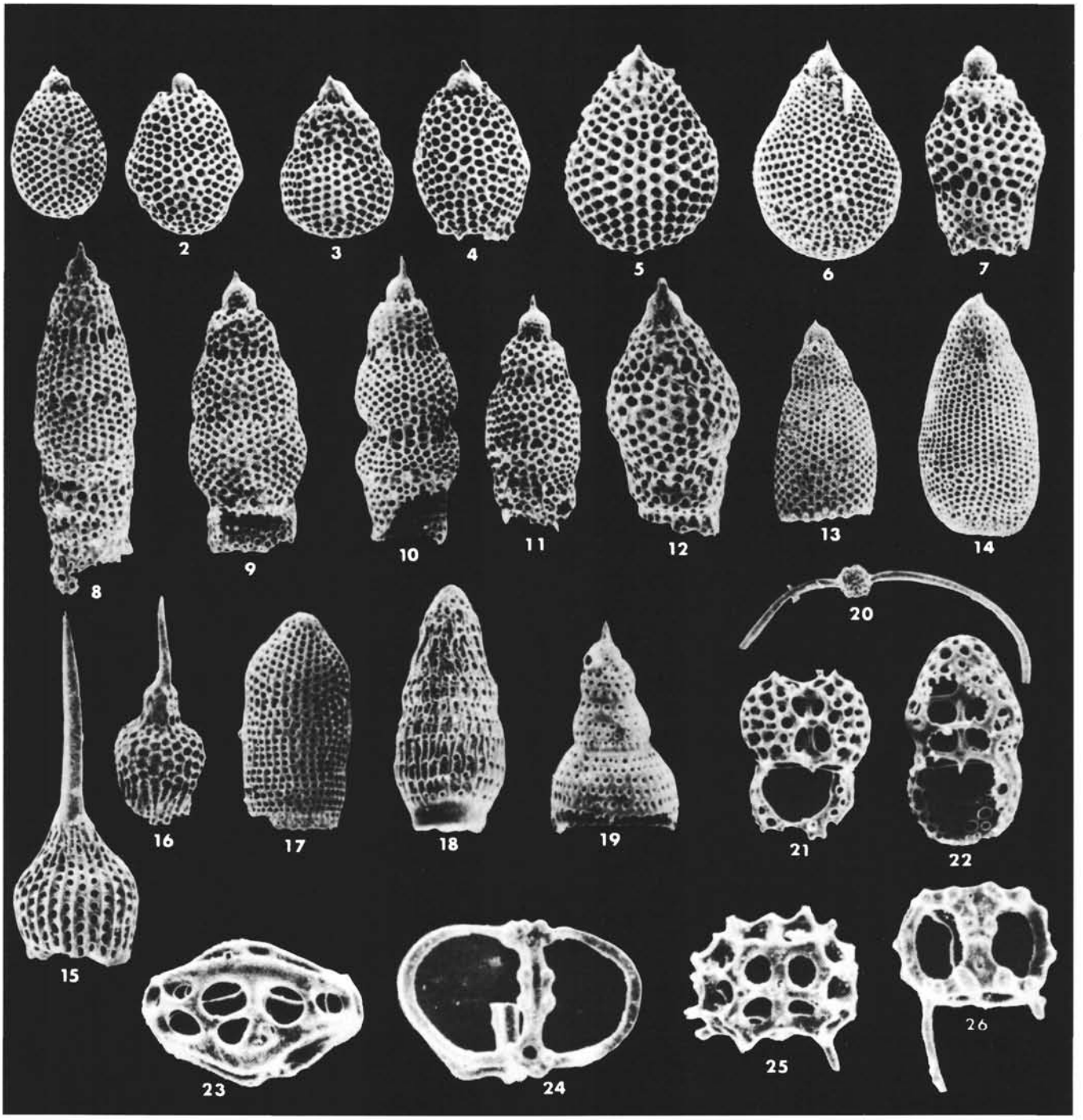

Plate 5. Scanning electron micrographs of Neogene radiolarians at Site 603. (Magnification ×270, except for Figs. 23, 25, ×405; Figs. 6, 15, 16, ×200; Fig. 20, ×100.) **1.** *Cyrtocapsella elongata* (Nakaseko), Sample 603A-50-3, 120–122 cm. **2.** *Cyrtocapsella tetrapera* Haeckel, Sample 603A-46-4, 120–122 cm. **3–5.** *Cyrtocapsella japonica* (Nakaseko), (3, 4) Sample 603A-50-3, 120–122 cm; (5) Sample 603A-46-4, 120–122 cm. **6.** *Cyrtocapsella cornuta* Haeckel, Sample 603A-52-1, 120–122 cm. **7, 12.** *Stichocorys wolffii* Haeckel, (7) Sample 603A-46-4, 120–122 cm, (12) Sample 603B-13,C. **8, 9.** *Stichocorys peregrina* Riedel, (8) Sample 603A-46-4, 120–122 cm; (9) Sample 603A-50-3, 120–122 cm. **10, 11.** *Stichocorys delmontensis* (Campbell and Clark), Sample 603A-46-4, 120–122 cm. **13.** *Eucyrtidium cienkowskii* Haeckel, Sample 603A-46-4, 120–122 cm. **14.** *Eucyrtidium hexagonatum* Haeckel, Sample 603A-52-1, 120–122 cm. **15.** *Calocycletta costata* (Riedel), Sample 603B-13,CC. **16.** *Calocycletta virginis* (Haeckel), Sample 603B-13,CC. **17.** *Eucyrtidium punctatum* (Ehrenberg), Sample 603A-46-4, 120–122 cm. **18.** *Botryostrobus miralestensis* (Campbell and Clark), Sample 603A-52-1, 120–122 cm. **19.** *Siphostichartus corona* (Haeckel), Sample 603A-52-1, 120–122 cm. **20.** *Dorcadospyris alata* (Riedel), Sample 603A-52-1, 120–122 cm. **21.** *Tholospyris* sp. aff. *T. infericosta* Goll, Sample 603A-52-1, 120–122 cm. **22.** *Tricolospyris leibnitziana* Haeckel, Sample 603A-46-4, 120–122 cm. **23.** *Liriospyris elevata* Goll, Sample 603A-50-3, 120–122 cm. **24.** *Acrocubus octopylus* Haeckel, Sample 603B-12,CC. **25.** *Tholospyris kantiana* (Haeckel), Sample 603A-52-1, 120–122 cm. **26.** *Giraffospyris toxaria* (Haeckel), Sample 603B-10,CC.

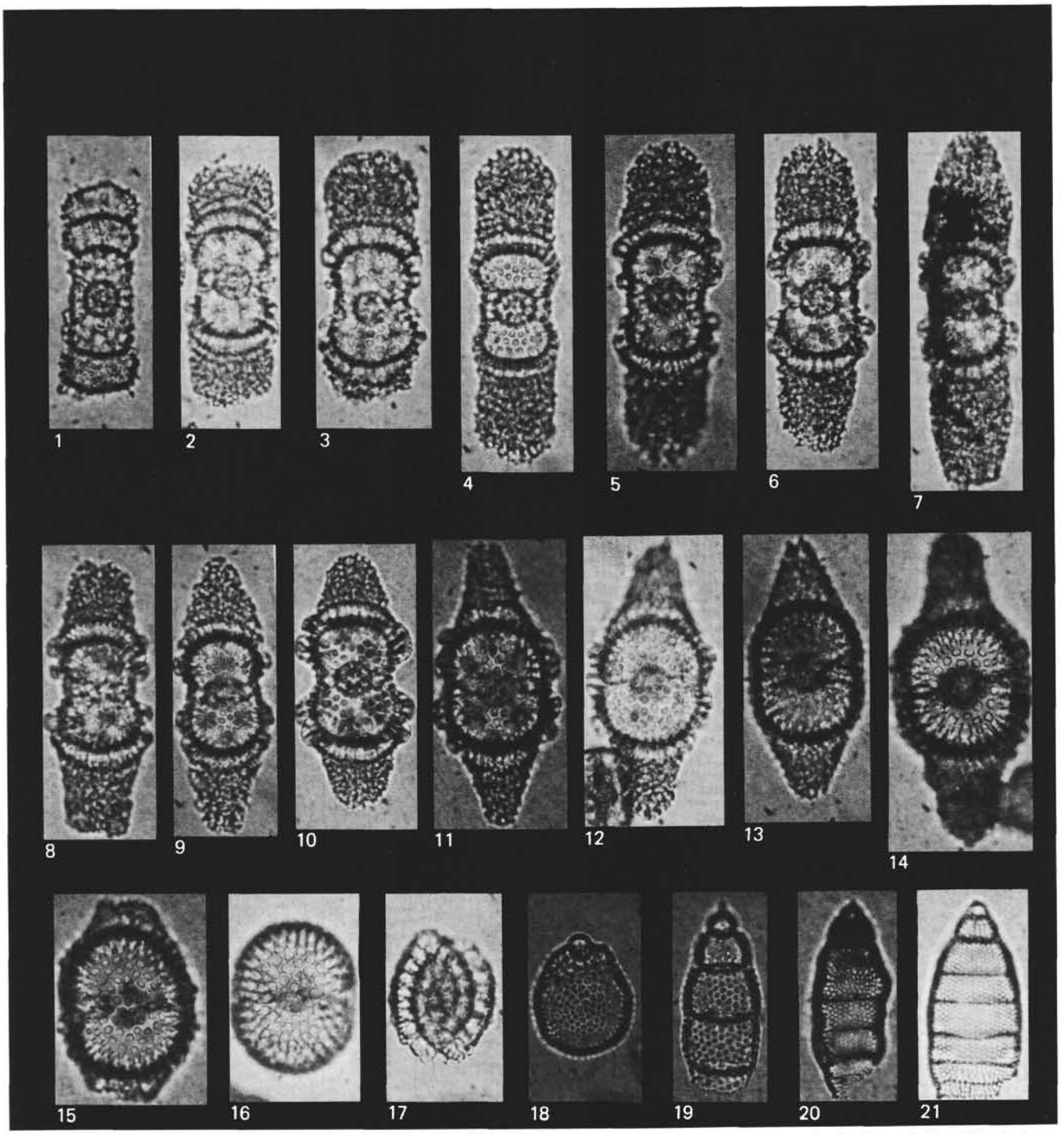

Plate 6. Transmitted-light micrographs of Neogene radiolarians at Site 603. (Magnification ×129.) **1.** *Diartus hughesi* Campbell and Clark, Sample 603B-4,CC. **2–6.** *Diartus petterssoni* (Riedel and Sanfilippo), (2) Sample 603A-46-2, 110–112 cm; (3, 5, 6) Sample 603A-52-1, 120–122 cm; (4) Sample 603A-50-3, 120–122 cm. **7–10.** *Didymocyrtis laticonus* (Riedel), (7, 9) Sample 603A-50-3, 120–122 cm; (8, 10) Sample 603A-52-1, 120–122 cm. **11–13.** *Didymocyrtis mammifera* (Haeckel), Sample 603A-52-1, 120–122 cm. **14.** *Cannartus* sp. D *in* Sakai, Sample 603B-4,CC. **15.** *Didymocyrtis* sp., Sample 603A-52-1, 120–122 cm. **16.** *Didymocyrtis* (?) sp., Sample 603B-4,CC. **17.** *Larcospira moschkovskii* Kruglikova, Sample 603A-46-4, 120–122 cm. **18.** *Lithopera neotera* Sanfilippo and Riedel, Sample 603A-52-1, 120–122 cm. **19.** *Stichocorys delmontensis* (Campbell and Clark), Sample 603A-52-1, 120–122 cm. **20.** *Eucyrtidium cienkowskii* Haeckel, Sample 603A-52-1, 120–122 cm. **21.** *Eucyrtidium hexagonatum* Haeckel, Sample 603A-46-4, 120–122 cm.