14. RADIOLARIANS FROM THE SOUTHWEST PACIFIC[1]

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ABSTRACT

Radiolarians are very rare in all Leg 90 sites. They are relatively more frequent only in Neogene sediments from Sites 586 and 594, and in Eocene sediments at Site 592. In this chapter radiolarian abundances are recorded as comparative percentages for 92 Neogene morphotypes at Site 586B. Relative abundances only are estimated at Sites 592 and 594, where preservation is poor to moderate. A tentative correlation of radiolarian events at Hole 586B and Site 594 shows that only a few species can be found in both tropical and subantarctic areas.

New evolutionary lineages are proposed. 1. Middle Miocene eucyrtids like *Eucyrtidium teuscheri* group evolved into a widespread species (*E. teuscheri teuscheri*) ranging from middle Miocene to Holocene and a temperate species (*E. teuscheri orthoporus*) ranging from middle Miocene to early Pleistocene. 2. *Phormostichoartus pitomorphus* appears to be a temperate descendant of the cosmopolitan *P. fistula* and disappears in early Pleistocene time. 3. The discovery of *Lamprocyrtis daniellae* n.sp. calls into question the lineage *L. heteroporos* → *L. nigriniae*. 4. The evolution of *Lamprocyclas maritalis* from an ancestor group (*L.* aff. *maritalis*) is located in the early part of the *Pterocanium prismatium* Zone.

INTRODUCTION

Because only carbonate-rich sediments deposited in relatively shallow environments were cored during Leg 90, radiolarians are generally absent or few in the material recovered. Moderately to well-preserved radiolarian assemblages occur throughout the sequences cored at equatorial Hole 586B (00°29.84′S, 158°29.89′E; water depth from rig floor, 2217 m) and at the subantarctic Site 594 (45°31.41′S, 174°56.88′E; water depth 1204 m). At Site 592 (36°28.40′S, 165°26.53′E; water depth 1098 m), radiolarians occur in small amounts, but only in upper Eocene sediments. Of particular interest at this site is a fine, complete boundary section between the Eocene and the Oligocene in Cores 592-36 and 592-37.

Hole 586B, with relatively well preserved specimens, provides a good sequence of late Neogene assemblages deposited in tropical shallow waters. Thus, it is important to verify if the radiolarian zonation is applicable to sediments accumulated below areas of high productivity and above the carbonate compensation depth (CCD).

Site 594 lies in the subantarctic water mass immediately south of the Subtropical Convergence. Thus the relative abundance of radiolarians allows studies of late Cenozoic paleoceanographic and paleoclimatic history. Moreover, Site 594 is important for establishing a radiolarian stratigraphy for upper Neogene sediments deposited during periods of temperate climate.

PROCEDURES

Except for Hole 592, where sampling for radiolarian studies was restricted to the Eocene/Oligocene boundary, one to five samples were taken from each core, acidified to remove carbonate, sieved at 50 μm, and the coarse fraction strewn on slides according to conventional methods.

Relative abundances are recorded in two ways. At Sites 592 and 594, where radiolarian occurrences are sporadic and preservation poor to moderate, four grades of abundance are used to indicate the abundance percentage of a taxon relative to the total assemblage of a strewn slide. These abundance grades and their symbols are explained in Table 2, later. At Hole 586B, where Cenozoic sediments contain well-preserved radiolarians, percentage estimates were used. The density of radiolarians on a slide having been estimated, the percentage of unbroken shells, which can be recognized at species level, was calculated by counting well-preserved individuals among 800 radiolarian whole specimens plus fragments. Next, 92 taxons were searched for and counted, if present, over the whole surface of the slide, and their abundance percentages were calculated relative to the number of unbroken shells. Radiolarian density is of the same order as in the study of Riedel and Westberg, 1982. The procedure developed by Westberg and Riedel (1982) for evaluating the stratigraphic reliability of upper and lower limits of taxa was applied at Hole 586B.

The radiolarian zones used in this paper for the Pliocene and Miocene at Site 586B are similar to the chronozones defined by Riedel and Sanfilippo (1978). The Quaternary zones are those defined by Caulet (1979).

At Site 594, the antarctic/subantarctic zonation proposed by Chen (1975) is not used because antarctic species occur so sporadically throughout the sequence and because some morphotypes are completely absent. Because equatorial and high-latitude assemblages are mixed, parts of both preexisting equatorial and antarctic event scales have been employed. Artostrobiidae are abundant, and the sequence of events proposed by Nigrini (1977) was successfully used and compared to occurrences of tropical and antarctic morphotypes. The Quaternary zones are those defined by Caulet (1982) for mid-latitude assemblages.

As part of the investigation of Leg 90 radiolarians, the data are supported by detailed radiolarian documentation from many *Marion Dufresne* (MD) piston cores from the South Indian Ocean region. These include the cores:

MD 73028: 49°25.9′S, 61°46.5′E, 2650 m water depth.
MD 75071: 38°24.9′S, 69°34.2′E, 4305 m water depth.
MD 75072: 37°55.7′S, 67°58.6′E, 4260 m water depth.
MD 75075: 34°23.4′S, 66°26.7′E, 4725 m water depth.
MD AET 75002: 34°34.5′S, 63°31.0′E, 4147 m water depth.
MD 77157: 4°48.2′S, 90°02.3′E, 4833 m water depth.

Detailed studies of these cores have been published (Caulet, 1977, 1982) or are in preparation.

RADIOLARIANS IN HOLES 586B, 592, AND 594

In Tables 1, 2, and 3 radiolarian occurrences are summarized for those stratigraphic intervals in which there are identifiable radiolarians.

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Table 1. Relative abundance (%) of radiolarians from Hole 586B.

Age	Radiolarian zone	Core-Section (interval in cm)	Radiolaria density (thousands)	Preservation (% of entire shells)	Reworking (%)	*Buccinosphaera invaginata*	*Collosphaera* sp. A	*Pterocorys hertwigii*	*Collosphaera tuberosa*	*Pterocorys zancleus*	*Lamprocyrtis nigriniae*	*Eucecryphalus petrushevskaae*	*Androspyris anthropiscus*	*Anthocyrtidium angulare*	*Pterocorys* c. *variabilis*	? *(Axoprunum) monostylum*	*Lophophaena hispida*	*Theocalyptra davisiana*	*Acanthodesmia circumflexa*	*Lamprocyclas maritalis*
	NR1	1-1, 60–62	7.9	24	0.2	0.16		0.32	0.05	0.42	0.05						1.05	0.79		0.84
		1-2, 60–62	5.0	25	0.1		0.48	0.32	0.08	0.64	0.24						0.72	0.96		1.2
	NR2	1-4, 60–62	3.6	30	0.1		0.09	0.74	0.19	0.37	0.09						0.28	0.74		0.93
		1-5, 60–62	7.0	30	0.1			0.19	0.14	0.57	0.14						0.71	0.76		0.86
	NR3	1-6, 60–62	4.6	8	0.2			0.27		0.54								1.36		0.54
		2-4, 60–62	0.8	9	0.2				5.71									2.86		
		2-5, 60–62	23.1	9	0					0.05	0.05							0.29		0.38
	NR4	3-1, 60–62	1.2	6	0						1.36								1.36	
Pleistocene		3-2, 60–62	15.1	9	0.1										0.22			0.37	0.15	0.66
		3-3, 60–62	8.4	4	0.1													1.78	0.30	0.30
		3-4, 60–62	0.7	4	0.1															
	NR5	4-1, 60–62	30.0	22	0.1							0.02		0.05	0.14		0.02	0.23	0.05	0.35
		4-2, 60–62	22.0	32	0.1							0.03	0.01	0.28	0.13		0.03	0.20	0.04	0.37
		4-4, 60–62	8.0	20	0.2										0.13		0.06	0.63	0.06	0.94
		4-5, 60–62	18.4	35	0.1								0.03	0.03	0.06		0.02	0.26	0.03	0.36
		4-6, 60–62	15.0	17	0.1							0.04			0.20	0.12		0.31	0.08	0.98
		5-1, 60–62	35.0	17	0.2								0.02	0.02	0.10	0.02	0.02	0.20	0.02	0.76
		5-2, 60–62	7.6	13	0.1												0.20		0.20	1.42
		5-3, 60–62	15.1	7	0.1											0.09	0.38	0.66	0.28	1.41
		5-4, 60–62	17.5	24	0.1									0.02	0.10	0.02				
		5-5, 60–62	7.7	15	0.1												0.26	1.13	0.09	0.52
		5-6, 60–62	3.5	7	0.1												0.41			2.04
	Pterocanium prismatium	6-1, 60–62	9.4	29	0.1											0.04	0.11	0.55		0.36
		6-2, 60–62	4.5	12	0.1												0.37	0.37		1.11
		6-3, 60–62	7.6	10	0															
		6-4, 60–62	5.3	18	0.1													0.21		0.21
		6-5, 60–62	6.8	15	0														0.20	
		6-6, 60–62	6.6	18	0.1															0.08
		7-1, 60–62	8.0	22	0															
		7-2, 60–62	3.8	12	0															
		7-3, 60–62	7.7	13	0															
		7-4, 60–62	3.5	13	0															
		7-5, 60–62	8.4	11	0															
		7-6, 60–62	10.5	8	0.1															
		8-1, 60–62	11.0	5	0															
		8-3, 60–62	10.2	10	0															
Pliocene		8-5, 60–62	18.0	16	0															
		11-1, 60–62	12.0	2	0.1															
		11-3, 60–62	5.6	2	0															
	Spongaster pentas	11-5, 60–62	12.0	4	0															
		12-1, 60–62	6.8	4	0.1															
		12-3, 60–62	11.4	2	0.1															
		12-5, 60–62	4.1	6	0															
		13-4, 50–62	3.7	5	0															
		14-1, 60–62	15.0	41	0															
		14-3, 60–62	11.5	15	0															
		14-5, 60–62	10.5	14	0															
		15-1, 60–62	6.6	12	0															
		15-3, 60–62	10.4	19	0															
		15-5, 60–62	15.0	26	0															
		16-1, 60–62	13.2	16	0															
		16-3, 60–62	4.8	15	0															
		16-5, 60–62	11.5	27	0															
		17-2, 60–62	1.5	12	0															
		17-3, 60–62	11.0	13	0															
		18-1, 60–62	13.7	14	0															
		18-5, 60–62	5.9	11	0															
		19-1, 60–62	0.9	27	0															
		19-3, 60–62	3.0	32	0															
		19-5, 60–62	6.5	17	0															
		20-1, 60–62	3.0	10	0															
		20-3, 60–62	6.7	15	0											0.10				
	Stichocorys peregrina	20-5, 60–62	6.9	18	0															
		21-1, 60–62	2.5	15	0.1															
late Miocene		21-3, 60–62	4.0	9	0.1															
		21-5, 60–62	1.0	18	0															
		22-1, 60–62	0.2	26	0															
		22-3, 60–62	1.0	9	0															
		22-5, 60–62	1.9	16	0															
		23-3, 60–62	4.2	8	0															
		23-5, 60–62	2.7	26	0															
		24-1, 60–62	6.9	30	0															
		24-3, 60–62	10.8	32	0															
		24-5, 60–62	7.3	27	0															
		25-1, 60–62	8.8	18	0															
		25-5, 60–62	4.2	32	0															

Note: Quantitative approach outlined in procedures. In the body of the table numbers indicate abundance in percent of total unbroken radiolarians on the slide. The following samples were barren of radiolarians: 586B-2-1, 60–62 cm; 586B-2-2, 60–62 cm, 586B-2-3, 60–62 cm; 586B-2-6, 60–62 cm; 586B-3-5, 60–62 cm; 582B-3-6, 60–62 cm.

Hole 586B

Radiolarians are rare and are poorly to moderately preserved in the samples from Core 586B-1 through 586B-25. A limited number of samples are barren (see Table 1), and there is some evidence of reworking.

The late and early Pleistocene faunas are well preserved but mid-Pleistocene Radiolaria are rare to absent and frequently dissolved. Zone NR1 (= *Buccinosphaera invaginata* Zone) yielded a rich fauna with the zone fossil, identified in Sample 586B-1-2, 60–62 cm. Zone NR2 extends from Samples 586B-1-2, 60–62 cm to 586B-1-4, 60–62 cm. Zone NR3 occurs between the first occurrence of *Collosphaera tuberosa* in Sample 586B-2-4, 60–62 cm and the last occurrence of *Stylatractus universus* in Sample 586B-1-5, 60–62 cm.

Table 1. (Continued).

Anthocyrtidium michelinae	*Theocorythium vetulum*	*Eucyrtidium indiensis*	*Lamprocyclas junonis*	*Lamprocyrtis neoheteroporos*	*Amphiropalum virchowi*	*Dictyophimus crisiae*	*Lophophaena cylindrica*	*Amphiropalum ypsilon*	*Anthocyrtidium nosicaae*	*Didymocyrtis tetrathalamus*	*Spirocyrtis scalaris*	*Spongaster tetras*	*Botryostrobus b. seriatus*	*Actinomma tetrapyla*	*Stylatractus aff. universus*	*Botryostrobus b. reedi*	*Eucyrtidium t. teuscheri*	*Spongaster pentas*	*Pterocorys longicollis*	*Phormostichoartus pitomorphus*	*Lamprocyrtis daniellae*	*Eucyrtidium t. orthoporus*
			0.37			0.79	0.21	0.32		1.58	0.05	1.84	0.21				0.53					
			0.48		0.48	0.64	0.4	0.48		2.08	0.08	2	0.24				0.4					
			0.46			0.83	0.74	1.39		2.31		2.13	0.37				0.56					
			0.43			0.57	0.67	0.86		1.29	0.05	0.71	0.10				0.24					
			0.54			0.54	2.72			1.36		1.09					0.54					
												12.9										
						0.10		0.24		0.29		0.43										
			0.37			0.44	0.22	0.66		1.54		1.10					0.44					
			0.60			1.49		1.79		1.79		2.38					0.89					
								17.9		17.9		21.4					7.14					
		0.02	0.33	0.18		0.38	0.15	0.24		0.47	0.02	0.35					0.09		0.02	0.03		0.03
			0.30	0.13		0.26	0.30	0.26	0.13	0.40		0.26	0.03				0.06		0.01	0.13		0.03
		0.06	0.63	0.06		0.75	0.63	1.00	0.25	1.25		0.44	0.13				0.19			0.13		0.06
0.17		0.02	0.34	0.06	0.05	0.36	0.19	0.39	0.15	0.59	0.02	0.09	0.02	0.02			0.03		0.02	0.08		0.02
0.35			0.35	0.24	0.08	0.31	0.39	0.59	0.16	0.47		0.71	0.12				0.08		0.08	0.24		
0.18		0.02	0.30	0.05	0.07	0.22	0.27	0.52	0.15	0.25	0.03	0.27	0.07	0.03			0.03	0.02	0.03	0.05		0.02
0.20			0.30	0.10		0.20	0.51	0.40	0.10	1.42		1.42					0.10					0.10
0.09			0.47	0.66		0.75	0.66	0.66	0.66	0.94	0.09	1.51			0.09		0.19		0.09			0.19
0.02				0.07			0.38	0.43	0.09	0.5	0.02	0.55	0.05							0.07		0.02
			0.78	0.09	0.26	0.95	1.04	0.43	0.26			1.04	0.17				0.17		0.09	0.26		0.09
			1.22		0.41	0.82	2.86	2.86		0.82			0.41				0.82			0.82		1.22
		0.07	0.11		0.18	0.36	0.18	0.69	0.04	0.08		0.15	0.11		0.22		0.26		0.07	0.11		0.04
			0.19		0.37	0.93	1.30	0.19		0.37		1.85	0.18				0.18		0.18	0.37		0.18
					0.53		0.53		0.39	0.39	0.13	0.26					0.13					0.13
			0.31	0.10	0.10	0.31	0.52			0.52	0.10	0.52			0.42		0.10			0.31		0.10
0.10						0.29	0.49		0.10	0.29	0.10	0.39	0.10				0.20	0.10	0.10	0.29		0.10
		0.08		0.17	0.08	0.42	0.50	0.34	0.08	0.50	0.08	0.59	0.08				0.08	0.17		0.08		
0.06	0.17		0.06		0.17		0.40	0.57	0.17	0.91		0.40					0.11		0.06	0.11		
							0.66	1.53		1.10		0.66	0.22									0.22
				0.10	0.20		0.50	2.09	0.20	0.30		0.10		0.10			0.20			0.10		0.10
		0.22			0.66			2.19	0.87	1.53		0.66		0.22			0.22					
			0.11	0.22	0.32	0.43	0.43	0.11	0.22	0.76		0.97	0.22		0.11		0.11	0.11	0.32			
					0.12			0.71	0.12	1.19		0.71					0.12	0.12				
					0.18	0.36	0.18	0.72	0.36	0.18	0.18	0.36							0.18	0.18		
							0.10	0.40	0.10	0.10		0.78					0.10			0.20		
									0.17	0.10	0.07							0.03		0.07		
												0.42	0.42							0.42		
															0.89							
													0.21		0.21							
																				0.44		
																	0.53					
															0.02			0.10	0.03	0.03		
														0.06								
														0.07	0.07		0.07	0.27		0.07		
																0.13				0.13		0.13
																0.05	0.05	0.05		0.10	0.15	
																			0.05	0.03	0.05	
																					0.05	0.05
																				0.39		

The first occurrence of *Lamprocyrtis nigriniae* in Sample 586B-1-5, 60–62 cm places this sample in Zone NR4 and the last occurrence of *Anthocyrtidium angulare* in Sample 586B-4-1, 60–62 cm places this sample in Zone NR5. But the limit between Zones NR4 and NR5 is difficult to position, because radiolarians are rare and dissolved in Sample 586B-3-2, 60–62 cm to 586B-3-6, 60–62 cm. The presence of *Pterocanium prismatium* in Sample 586B-4-6, 60–62 cm, places Samples 586B-4-1, 60–62 cm to 586B-4-5, 60–62 cm in the early Pleistocene Zone NR5. The first occurrence of *A. angulare* in Sample 586B-5-4, 60–62 cm is just below the Pliocene/Pleistocene boundary.

Radiolarians are rare and are moderately to well preserved in the upper Pliocene. Shells are often dissolved and poorly preserved in the middle to late *Spongaster pentas* Zone. The latest occurrence of *Stichocorys peregrina* marks the bottom of the *Pterocanium prismatium*

Table 1. (Continued).

Age	Radiolarian zone	Core-Section (interval in cm)	Radiolaria density (thousands)	Preservation (% of entire shells)	Reworking (%)	*Pterocorys c. campanula*	*Didymocyrtis avita*	*Spongaster berminghami*	*Botryostrobus b. tumidulus*	*Siphonosphaera hyalina*	*Phormostichoartus platycephala*	*Pterocanium prismatium*	*Spirocyrtis subscalaris*	*Lamprocyrtis heteroporos*	*Eucyrtidium anomalum*	*Eucyrtidium teuscheri* gr.	*Stylatractus universus*	*Botryostrobus pretumidulus*	*Botryostrobus aquilonaris* gr.	*Lamprocyclas* aff. *maritalis*
	NR1	1-1, 60–62	7.9	24	0.2				0.83		0.36				0.36				0.05	
		1-2, 60–62	5.0	25	0.1				0.96		0.32				0.24				0.08	
	NR2	1-4, 60–62	3.6	30	0.1				1.11		0.37				0.19				0.09	
		1-5, 60–62	7.0	30	0.1				0.33		0.24				0.24		0.57		0.10	
	NR3	1-6, 60–62	4.6	8	0.2				1.36		0.54						0.82		0.27	
		2-4, 60–62	0.8	9	0.2						2.86						1.43		2.86	
		2-5, 60–62	23.1	9	0				0.14		0.05						1.11		0.24	
	NR4	3-1, 60–62	1.2	6	0												5.42			
Pleistocene		3-2, 60–62	15.1	9	0.1				0.59		0.22				0.07		0.73		0.44	
		3-3, 60–62	8.4	4	0.1				1.79		0.60						0.89		1.49	
		3-4, 60–62	0.7	4	0.1				17.8		3.57						3.57		17.8	
	NR5	4-1, 60–62	30.0	22	0.1	0.06			0.18		0.08				0.05		0.20	0.06	0.12	
		4-2, 60–62	22.0	32	0.1	0.09			0.16		0.04				0.01		0.40	0.10	0.04	
		4-4, 60–62	8.0	20	0.2	0.19			0.56		0.06				0.13		1.25	0.50	0.38	
		4-5, 60–62	18.4	35	0.1	0.22			0.15	0.05	0.03			0.02	0.03		0.34	0.02	0.06	
		4-6, 60–62	15.0	17	0.1	0.20			0.39	0.12		1.49	0.08	0.08	0.39		0.71	0.82	0.12	
		5-1, 60–62	35.0	17	0.2	0.30				0.08		0.24		0.03	0.15		0.29	0.37	0.05	
		5-2, 60–62	7.6	13	0.1	0.20						3.9	0.20		0.40		0.10	0.91	0.30	
		5-3, 60–62	15.1	7	0.1	0.09			0.19	0.09		0.19	0.19				1.80	0.66	0.47	
		5-4, 60–62	17.5	24	0.1	0.19			0.14			0.57					0.52	0.36		
		5-5, 60–62	7.7	15	0.1	0.17			0.52			0.69	0.52		0.69		0.69	1.04	0.43	
		5-6, 60–62	3.5	7	0.1				0.92		0.41	0.41						3.67	1.22	
	Pterocanium prismatium	6-1, 60–62	9.4	29	0.1	0.07			0.04		0.04	0.22	0.15	0.04	0.33		0.11	0.62	0.51	0.07
		6-2, 60–62	4.5	12	0.1	1.11			1.30			0.93	0.37		0.19		2.41	2.04	2.41	
		6-3, 60–62	7.6	10	0	0.79			1.45	0.13							1.05	2.37	2.11	
		6-4, 60–62	5.3	18	0.1	0.84			0.31	0.10		0.10	0.42		0.42		0.94	0.10	0.31	
		6-5, 60–62	6.8	15	0		0.20					0.10			0.10		0.59		0.20	0.49
		6-6, 60–62	6.6	18	0.1	0.50			0.25		0.08	0.17	0.08		0.25		0.17	0.34	0.42	0.25
		7-1, 60–62	8.0	22	0	0.11			0.17	0.06		0.45	0.06				0.34	0.06	0.68	
		7-2, 60–62	3.8	12	0	0.22	0.22					0.88		0.22			1.75	0.66	1.31	0.22
		7-3, 60–62	7.7	13	0	0.20	0.80		0.10	0.20	0.10	0.30	0.10	0.10			0.70	0.30	0.80	
		7-4, 60–62	3.5	13	0	0.22			0.87	0.22		0.22		0.22			0.87		0.44	0.22
		7-5, 60–62	8.4	11	0	0.11	0.11		0.54		0.11		0.32	0.11	0.11		0.97	1.41	1.84	0.43
		7-6, 60–62	10.5	8	0.1		0.12		0.36			0.12	0.12				1.19	0.48	1.19	0.24
		8-1, 60–62	11.0	5	0		0.18		0.18				0.18	0.18			0.36	0.54	2.17	1.63
		8-3, 60–62	10.2	10	0				0.10		0.20	0.20					0.20	0.29	0.49	0.59
Pliocene		8-5, 60–62	18.0	16	0	0.10			0.10		0.03	0.31	0.17				0.14	0.56	0.14	
		11-1, 60–62	12.0	2	0.1							0.42		0.42			0.84	0.42		1.25
		11-3, 60–62	5.6	2	0															4.46
	Spongaster pentas	11-5, 60–62	12.0	4	0				0.21	0.21		2.29		0.21			1.04	0.42	0.21	2.29
		12-1, 60–62	6.8	4	0.1		0.37										1.10	0.74		0.74
		12-3, 60–62	11.4	2	0.1	0.44	0.88		0.44					0.44			0.44	1.32	3.07	1.75
		12-5, 60–62	4.1	6	0															
		13-4, 60–62	3.7	5	0		0.53		0.53	0.53			0.53				0.53	0.53	2.13	1.07
		14-1, 60–62	15.0	41	0	0.10	0.03			0.03		0.11	0.13		0.52		0.05	0.05	0.03	0.08
		14-3, 60–62	11.5	15	0		0.23			0.29		0.12	0.06		0.06		0.06	0.12		0.29
		14-5, 60–62	10.5	14	0	0.07	0.07			0.07		0.07					0.14	0.14	0.54	0.34
		15-1, 60–62	6.6	12	0		0.51		0.13	0.13		0.13					0.38	0.25	0.63	0.51
		15-3, 60–62	10.4	19	0		0.10		0.05			0.30					0.15	0.05	0.40	0.30
		15-5, 60–62	15.0	26	0		0.05			0.03		0.10					0.03	0.03	0.18	
		16-1, 60–62	13.2	16	0	0.03	0.14			0.09	0.05		0.05				0.05	0.05		0.09
		16-3, 60–62	4.8	15	0	0.09	0.14	0.14		0.28							0.56		0.97	0.69
		16-5, 60–62	11.5	27	0				0.03	0.10			0.03	0.10	0.10	0.03	0.03		0.10	0.13
		17-2, 60–62	1.5	12	0					0.56								0.56	1.67	0.56
		17-3, 60–62	11.0	13	0						0.07		0.07		0.21		0.14	0.07	0.21	0.14
		18-1, 60–62	13.7	14	0											0.05	0.16	0.05		
		18-5, 60–62	5.9	11	0									0.15					0.15	0.15
		19-1, 60–62	0.9	27	0															
		19-3, 60–62	3.0	32	0										0.20				0.20	0.81
		19-5, 60–62	6.5	17	0										0.27	0.18			0.36	0.36
		20-1, 60–62	3.0	10	0														0.67	
	Stichocorys peregrina	20-3, 60–62	6.7	15	0										0.30					0.30
		20-5, 60–62	6.9	18	0										0.32		0.08	0.16	0.89	0.08
		21-1, 60–62	2.5	15	0.1												0.27	0.27		
late Miocene		21-3, 60–62	4.0	9	0.1													0.28	1.40	
		21-5, 60–62	1.0	18	0														0.56	
		22-1, 60–62	0.2	26	0													3.85	5.77	
		22-3, 60–62	1.0	9	0														1.11	3.33
		22-5, 60–62	1.9	16	0														0.33	0.33
		23-3, 60–62	4.2	8	0															
		23-5, 60–62	2.7	26	0															
		24-1, 60–62	6.9	30	0															
		24-3, 60–62	10.8	32	0															
		24-5, 60–62	7.3	27	0															
		25-1, 60–62	8.8	18	0															
		25-5, 60–62	4.2	32	0															

Zone between Samples 586B-7-3, 60–62 cm and 586B-7-2, 60–62 cm. The event indicating the bottom of the *Spongaster pentas* Zone is the evolutionary transition between *Spongaster berminghami* and *S. pentas*. Because *S. berminghami* is rare, this event cannot be used in Hole 586B. Thus, the bottom of the *S. pentas* Zone occurs in the interval between Samples 586B-16-3, 60–62 cm (occurrence of *S. berminghami*) and 586B-15-3, 60–62 cm (first occurrence of *S. pentas*). This conclusion is supported by the first occurrence of *Didymocyrtis avita* in Sample 586B-16-3, 60–62 cm and the morphotypic bottom of *Pterocanium prismatium* in Sample 586B-15-5, 60–62 cm.

Although few individuals of *Stichocorys peregrina* and numerous ones of *S. delmontensis* occur in Samples 586B-24-3, 60–62 cm to 586B-25-5, 60–62 cm, the evolutionary transition between the two species cannot be reported, and the bottom of the *Stichocorys peregrina* Zone remains below the last sample cored. Thus, the interval

Table 1. (Continued).

Lamprocyclas margatensis	*Solenosphaera omnitubus* gr.	*Botryostrobus aust/aur.* gr.	*Dendrospyris bursa*	*Didymocyrtis penultima*	*Hexacontium hootsi*	*Hexacontium medusa*	*Lyriospyris ovalis*	*Platybursa clathrobursa*	*Spirocyrtis gyroscalaris*	*Stauroxiphos communis*	*Acrobotrys tritubus*	*Anthocyrtidium ehrenbergi*	*Botryostrobus b. bramlettei*	*Calocycletta caepa*	*Centrobotrys thermopila*	*Cyclampterium neatum*	*Desmospyris stabilis*	*Dictyophimus splendens*	*Didymocyrtis antepenultima*	*Spongodiscus klingi*	*Eucyrtidium anniae*	*Lamprocyclas hannai*
		1.30					0.10								0.05							
		1.84					0.08															
		2.13																				
		1.67																				
		1.36																				
		0.24																				
							0.07															
		1.79					0.60															
		7.14																				
		0.12					0.03															
		0.50					0.04															
		1.25																				
		0.54					0.02															
		1.49													0.08							
		0.76			0.02		0.02															
		0.81													0.10	0.10						
		0.94																				
		0.76													0.02							
		2.16			0.09																	0.09
		6.12													0.41							
		1.20			0.04																	0.04
		1.85			0.37																	0.56
		3.68																				
		1.15																				0.10
		0.69			0.10							0.10										0.39
		1.68			0.17										0.17							0.34
		1.70			0.06										0.11							
		1.54																				
		2.48										0.10										
		4.81													0.44							
		4.44			0.11		0.11								0.54	0.11						0.11
		1.43			0.12																	
		1.63														0.72						0.54
		1.47													0.29							
		1.11													0.17							
		1.67					0.42								2.51	0.84						0.42
		0.89													1.79	0.89						2.68
		1.46													308	38.5						135
		0.74													1.10					2.21		
		1.75													3.51	1.75				3.51		0.44
		1.07													1.07	1.07				1.07		1.07
0.02		0.15			0.07		0.05								0.59	0.02				0.11		0.03
0.06		0.23			0.06		0.12						0.06		0.17	0.17				0.46		
	0.07	0.20			0.27								0.07		0.20	0.14		0.07		0.14		0.07
	0.25												0.13		0.38	1.26						
	1.81	0.10		0.10	0.05										0.05	0.10		0.15		0.10		
	0.54	0.08		0.03											0.26	0.05				0.10		
0.05	2.08			0.09							0.05		0.05		0.38	0.24		0.09				
0.14	6.25			0.83											2.08	0.42		0.14		1.39		
	1.13	0.06		0.13									0.06		0.32	0.03		0.10		0.48		0.19
1.11	12.78			0.56									0.56		1.11	0.56				1.67		
	2.10	0.28		0.28	0.07		0.07						0.14		0.35	0.14		0.14		0.21		0.07
0.05	0.58	0.47		0.52									0.16		0.16			0.16		0.16		0.05
	5.89			0.46											0.31	0.15				0.15		
		0.39		0.39														0.39		0.39		0.39
	3.55	0.61		0.41							0.20		0.10		0.30	0.20	0.10			0.81		0.30
	3.63	0.45		0.18							0.45	0.09	0.27		0.63	0.09		0.36		0.36		0.09
	4.67			0.67			0.33											0.33		0.67		0.33
	2.28	0.10										0.10				0.10		0.20		0.30		0.40
0.08	2.42	0.08		0.56							0.16	0.16	0.56		0.08	0.16	0.08	0.40		0.48	0.32	0.08
0.53	0.27			0.53									0.53			0.8		0.53		0.8		
0.56	1.40	0.28														0.28		0.56		0.84		
	0.56															0.56				0.56		0.56
	15.38												1.92					3.85				1.92
1.11	1.11	1.11									1.11					1.11				2.22		
	32.57												0.33			0.33						
0.89	6.55		0.30	1.19			0.30				0.30	0.89	0.30		0.60	0.89		1.19		1.19	0.60	0.30
0.28	5.07	0.14		0.28			0.14				0.28		0.14		0.70	0.42		0.28		1.13		0.28
	2.32		0.05	0.19						0.05	0.10	0.14	0.05		0.10	0.05				0.14		
	1.74	0.03		0.20			0.03	0.03	0.06	0.09	0.12	0.12		0.14	0.12	0.06	0.20	0.03	0.03	0.20	0.12	0.06
	1.31					0.05	0.10			0.05	0.05	0.10	0.05		0.05	0.10		0.10	0.10	0.05	0.10	
		0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.13	0.06	0.13	0.19	0.13	0.19	0.19	0.13	0.25	0.13	0.06	0.38	0.19
											0.07	0.15	0.15	0.15	0.07	0.07	0.07	0.07	0.22	0.07	0.37	0.07

between Samples 586B-15-3, 60–62 cm and 586B-25-5, 60–62 cm is placed in the late Miocene *S. peregrina* Zone.

Site 592

At Site 592, radiolarians are present in only part of the upper Eocene. Samples available for radiolarian studies range from Sections 592-37-1 to 592-40-5. Well-preserved radiolarian faunas are present in Sample 592-40-4, 40–42 cm, 592-40-3, 40–42 cm, 592-40-2, 40–42 cm, 592-40-1, 40–42 cm, 592-39-4, 40–42 cm, and 592-39-3, 40–42 cm. Very rare specimens are present in Samples 592-37-4, 15–16 cm and 592-37-3, 15–16 cm. Samples 592-37-1, 15–16 cm and 592-37-2, 15–16 cm contain only some fragments.

As radiolarian assemblages are different in tropical and polar areas, dating of temperate latitude sediments by the use of either the low-latitude or the high-latitude radiolarian biostratigraphy is often unsuccessful. Fortu-

Table 1. (Continued).

Age	Radiolarian zone	Core-Section (interval in cm)	Radiolaria density (thousands)	Preservation (% of entire shells)	Reworking (%)	*Lithomelissa ultima*	*Tessarastrum* sp.	*Phormostichoartus corbula*	*Phormostichoartus doliolum*	*Phormostichoartus fistula*	*Pterocanium trilobum* gr.	*Polysolenia s. hamospina*	*Polysolenia s. fasciculopora*	*Rhopalastrum oracuitibrachium*	*Siphostichartus corona*	*Stichocorys delmontense*	*Stichocorys peregrina*	*Stichocorys johnsoni*	*Stylosphaera angelina*	*Tricolospyris b. variabilis*	*Tricolospyris newtoniana*
	NR1	1-1, 60-62	7.9	24	0.2			0.89									0.05				
		1-2, 60-62	5.0	25	0.1			0.64													
	NR2	1-4, 60-62	3.6	30	0.1			0.37													
	NR3	1-5, 60-62	7.0	30	0.1			0.24													
		1-6, 60-62	4.6	8	0.2			0.82													
		2-4, 60-62	0.8	9	0.2																
	NR4	2-5, 60-62	23.1	9	0			0.29													
		3-1, 60-62	1.2	6	0																
Pleistocene		3-2, 60-62	15.1	9	0.1			0.51													
	NR5	3-3, 60-62	8.4	4	0.1																
		3-4, 60-62	0.7	4	0.1																
		4-1, 60-62	30.0	22	0.1	0.03		0.27													
		4-2, 60-62	22.0	32	0.1	0.01		0.21													
		4-4, 60-62	8.0	20	0.2	0.13		0.25													
		4-5, 60-62	18.4	35	0.1	0.05		0.09													
	Pterocanium prismatium	4-6, 60-62	15.0	17	0.1	0.04		0.24	0.04												
		5-1, 60-62	35.0	17	0.2	0.02		0.13	0.02												
		5-2, 60-62	7.6	13	0.1			0.20													
		5-3, 60-62	15.1	7	0.1			0.28											0.09		
		5-4, 60-62	17.5	24	0.1	0.14		0.17	0.02												
		5-5, 60-62	7.7	15	0.1	0.78		0.35													
		5-6, 60-62	3.5	7	0.1	0.41		0.41													
		6-1, 60-62	9.4	29	0.1	0.22		0.29													
		6-2, 60-62	4.5	12	0.1	0.19		0.74											0.37		
		6-3, 60-62	7.6	10	0	0.26		0.26													
		6-4, 60-62	5.3	18	0.1	0.21		0.31													
		6-5, 60-62	6.8	15	0	0.10		0.59													
		6-6, 60-62	6.6	18	0.1	0.34		0.17													
		7-1, 60-62	8.0	22	0	0.23		0.23													
		7-2, 60-62	3.8	12	0			0.44											0.44		
	Spongaster pentas	7-3, 60-62	7.7	13	0	0.40		0.70									4.47				
		7-4, 60-62	3.5	13	0	0.66		0.44									9.40				
		7-5, 60-62	8.4	11	0	0.22		0.54									5.41		0.11		
		7-6, 60-62	10.5	8	0.1	0.12								0.24			6.55		0.36		
		8-1, 60-62	11.0	5	0	0.36											10.9				
		8-3, 60-62	10.2	10	0	0.10		0.20									5.30		0.10		
Pliocene		8-5, 60-62	18.0	16	0	0.17		0.10	0.03							0.03	2.29				
		11-1, 60-62	12.0	2	0.1			0.42	0.42					1.25			8.78				
		11-3, 60-62	5.6	2	0												44.6		1.79		
		11-5, 60-62	12.0	4	0				57.7	19.2						19.2	865		76.9		
		12-1, 60-62	6.8	4	0.1				0.37	0.37							12.9				
		12-3, 60-62	11.4	2	0.1			0.44	0.44	0.44							17.9		2.19		
		12-5, 60-62	4.1	6	0																
		13-4, 60-62	3.7	5	0														1.07		
		14-1, 60-62	15.0	41	0	0.18		0.03	0.15	0.02		0.02					0.54		0.03	0.02	
		14-3, 60-62	11.5	15	0							0.29					2.96		0.23		
		14-5, 60-62	10.5	14	0	0.20			0.27			0.27					2.31		0.07		
		15-1, 60-62	6.6	12	0			0.51	0.13			1.14				0.38	5.68		0.13		
		15-3, 60-62	10.4	19	0			0.05	0.15	0.10		3.02					2.01		0.05		
	Stichocorys peregrina	15-5, 60-62	15.0	26	0			0.08	0.10			0.41					0.95				
		16-1, 60-62	13.2	16	0	0.09			0.09	0.05		2.60		0.05		0.05	1.99		0.09		
		16-3, 60-62	4.8	15	0	0.28			0.14	0.28		6.39	0.42	0.14					0.56		
		16-5, 60-62	11.5	27	0	0.03		0.03	0.19	0.03		0.19	2.51						0.29		
		17-2, 60-62	1.5	12	0					0.56		0.56	36.1				0.56		0.56		
		17-3, 60-62	11.0	13	0	0.14			0.14		0.07	0.07	0.07			0.07	2.30			0.07	
		18-1, 60-62	13.7	14	0	0.10		0.10	0.05	0.05	0.05	0.26	0.16			0.10	2.23		0.21	0.05	
		18-5, 60-62	5.9	11	0							0.15					6.96				
		19-1, 60-62	0.9	27	0			0.39		0.39			0.39								
		19-3, 60-62	3.0	32	0			0.10			0.10		0.41				4.57				
		19-5, 60-62	6.5	17	0	0.09		0.18		0.18	0.45	1.09	0.36	0.09			3.45		0.09		
		20-1, 60-62	3.0	10	0					1.0		0.33	1.33			0.33	7.67				
		20-3, 60-62	6.7	15	0			0.10	0.10	0.20		0.20	0.60			0.30	2.08				
		20-5, 60-62	6.9	18	0			0.16	0.24		0.32	0.16	0.16			0.16	3.62	2.25	0.24	0.08	
		21-1, 60-62	2.5	15	0.1							0.27				0.27	6.4	1.07			
late Miocene		21-3, 60-62	4.0	9	0.1						0.28	0.28	0.56	0.28			3.09	1.96	0.84		
		21-5, 60-62	1.0	18	0							0.56		0.56		0.56	0.56	0.56			
		22-1, 60-62	0.2	26	0					1.92	1.92			46.2		5.77	7.69				
		22-3, 60-62	1.0	9	0					1.11				68.9			5.56				
		22-5, 60-62	1.9	16	0							1.32		4.61			0.66	0.99	0.33		
		23-3, 60-62	4.2	8	0			0.30	0.89		1.19	10.4	0.60	1.19		9.23	3.27	3.27			
		23-5, 60-62	2.7	26	0	0.14		0.14			1.13	0.70	0.28	3.10		3.10	0.85	0.28	0.14	0.14	0.14
		24-1, 60-62	6.9	30	0						0.48	0.53	0.14	0.97	0.05	0.97	0.48	0.10	0.10		
		24-3, 60-62	10.8	32	0				0.41		0.49	0.38	0.06	0.43	0.26	1.01	0.46	0.55	0.23		0.03
		24-5, 60-62	7.3	27	0	0.05			0.15		0.20	0.71	0.10	1.01	0.10	2.02	0.30	0.30	0.40		
		25-1, 60-62	8.8	18	0		0.06	0.06	2.02	0.06	0.69	0.19	0.32	2.71	0.95	2.84	0.44	0.32	0.13		0.13
		25-5, 60-62	4.2	32	0		0.07	0.07	0.37		0.37	0.07	0.07	2.60	0.52	3.20	0.45	0.15	0.22	0.07	0.07

nately, late Eocene radiolarian assemblages from Site 592 are not very different from tropical faunas and thus the classic biostratigraphy of Riedel and Sanfilippo (1978) can be used.

Radiolarian abundances were roughly estimated from the density of radiolarians on strewn slides, from counts of 2000 to 5000 well-preserved tests for each sample. A large number of morphotypes were encountered, but only 39 well-known forms are tabulated in Table 2. A considerable amount of taxonomic work remains to be completed to describe the other morphotypes but because very little material is available, the descriptions and the ranges will be prepared for separate publication with other material cored on the Kerguelen Plateau.

Only one radiolarian zone was identified in Site 592: the *Cryptoprora ornata* Zone from Sections 592-39-3 to 592-40-4. The *C. ornata* Zone (= top of the former *Thyrsocyrtis bromia* Zone of Riedel and Sanfilippo,

Table 2. Abundance of some radiolarians from Hole 592.

Age	Radiolarian zone	Core-Section (interval in cm)	Abundance	Preservation	Number of morphotypes	*Astostrobus elegans* gr.	*Astophacus inca*	*Astrophacus linckiaformis*	*Axoprunum euterpe* gr.	*Axoprunum polycentrum*	*Botryocella cribrosa* gr.	*Botryopera* gr.	*Calocycletta parva*	*Clathrocyclas spatiosa*	*Clathrocyclas universa*	*Cryptoprora ornata*	*Cyclampterium milowi*	*Desmospyris b. stabiloides*	*Dictyoprora urceolus*	*Tristylospyris triceros*	*Lithapium mitra*	*Lithomelissa haeckeli*	*Lithomitra* sp.	*Lithomitrella acephala*	*Lithomitrella elizabethae*
?	?	37-3, 15–16	+	M	7				+								+		+	+				+	
		37-4, 15–16	+	P	4												+							+	
		39-3, 40–42	R	M	24			+			C	+	+	+	+	F	F	R	F	F	R			F	F
late Eocene	*C. ornata*	39-4, 40–42	R	M	28	R	+			R	R		C		+	+	R	+	F	C	R	+		C	R
		40-1, 40–42	R	M	20	C		R		C	+		R		R	R			R	C	R			C	
		40-2, 40–42	R	G	28	F	+		C	R	R		R		R	R	C		C	R	C			R	R
		40-3, 40–42	R	G	31	F		R	R	R	R		C		R	F	F	R	F	R	F	R		+	R
		40-4, 40–42	R	G	33	F	+	R	+	C	R		F		C	F	F	+	F	R	F	+	+	C	R

Core-Section (interval in cm)	*Lithomitrella minuta*	*Lophocyrtis biaurita* gr.	*Lophocyrtis jacchua*	*Lychnocanium tripodium*	*Lychnocanoma bellum*	*Lychnocanoma amphitrite*	*Lychnocanoma babylonis*	*Periphaena decora*	*Periphaena heliasteriscus*	*Pseudodictyophimus callosus*	*Pseudodictyophimus gracilipes* gr.	*Pterocyrtidium barbadense* gr.	*Stylosphaera minor*	*Theocorys spongoconum*	*Theocorys cretica* gr.	*Thyrsocyrtis bromia*	*Tricolocapsa bergontiana* gr.	*Tripodiscinus clavipes*	*Velicucullus magnificum*
37-3, 15–16	+														+				
37-4, 15–16	+												+						
39-3, 40–42	R		R		F	F	C					F	R		R	R	C		
39-4, 40–42	+		R		R	F	C	+	R			R		R	+	C	C		+
40-1, 40–42	C		+			F	C		+			C		R		C	C		
40-2, 40–42	C		R		R	F	C			+		C	R	R	R	R	C	+	+
40-3, 40–42	R		+		R	F	C		+	+	+	F	R	R	+		F	R	R
40-4, 40–42	F	+		R	C	F	F			R	+	R	+	R	R		C	C	C

Note: Morphotype abundances: + = one specimen; R = rare (less than 5 specimens); C = common (between 5 and 20 specimens); F = frequent (more than 20 specimens). Abundance of radiolarians in samples: + = very rare; R = rare. Preservation: P = poor; M = moderate; G = good.

emended by Maurrasse and Glass (1976) and Saunders et al. (in press), is the uppermost radiolarian zone of the Eocene. Since no radiolarian forms were found in sediments of early Oligocene age, the Eocene/Oligocene radiolarian boundary cannot be located at Site 592.

Late Eocene radiolarian assemblages from Site 592 are similar to tropical faunas but lack some typical morphotypes, like the *Lithocyclia* group. Other tropical species like *Thyrsocyrtis bromia* appear to be rare and are restricted to the upper part of the radiolarian zone. However, their skeletons are somewhat different from the tropical forms. The tests of *Cyclampterium(?) milowi* are frequent, but the test outline is narrower in the mid-latitude assemblages. Some forms like *Lychnocanoma amphitrite* and *Lithapium mitra* are more frequent than in the tropical assemblages. As shown by Chen (1975), high-latitude radiolarian assemblages "are similar to but less diverse than the late middle Eocene to late Eocene low-latitude assemblages previously described by Riedel and Sanfilippo (1971) and Foreman (1973)." Petrushevskaya (1975) reported that Eocene radiolarian faunas from the South Pacific sector of the Southern Ocean (DSDP Leg 29) are more similar to the Californian Eocene assemblages than those from the Caribbean. This is also the case for Eocene radiolarians from Site 592.

The preservation of the tests is good only in Samples 592-40-2, 40–42 cm, 592-40-3, 40–42 cm and 592-40-4, 40–42 cm. In these samples, the diversity of morphotypes is higher and diatoms are more abundant. In Sample 592-39-3, 40–42 cm the siliceous fraction is represented only by broken radiolarian tests. In Samples 592-37-3, 15–16 cm and 592-37-4, 15–16 cm, the number of the forms found is low and their state of preservation poor. It may be concluded that the deposition of radiolarians and other siliceous microfossils ceased at Site 592 before the very end of the late Eocene and that reworking processes are responsible for the rare latest Eocene siliceous accumulations near the Eocene/Oligocene boundary.

Site 594

Radiolarians are rare throughout the core recovered at Site 594; moderately to well-preserved faunas are encountered in all cores.

Stratigraphic correlation of Neogene Radiolaria from Site 594 is difficult because siliceous material is scarce and greatly diluted by terrigenous material, and paleoenvironments have changed. Because warm-water and polar assemblages are mixed, zonations proposed for both regions have been employed. Samples 594-1-1, 84–86 cm to 594-6-4, 84–86 cm contain a typical late Quaternary (less than 400,000 yr.) antarctic radiolarian assemblage that can be assigned to the *Antarctissa denticulata* Zone or NR1 Zone. Common species include *A. denticulata, A. strelkovi, Theocalyptra davisiana*, and *Rhizosphaera antarctica*.

Samples 594-7-2, 84–86 cm to 594-8-1, 84–86 cm, below the last appearance of *Stylatractus universus* in 594-7-2, 84–86 cm, are placed in Zone NR2 (Quaternary). The next marker observed was *Phormostichoartus pitomorphus* n. sp. (described in this chapter) whose last occurrence is in Sample 594-9-4, 84–86 cm. Therefore, Samples 594-9-4, 84–86 cm to 594-11-5, 84–86 cm are in the NR3/NR4 Zone (early to middle Pleistocene). It is not possible to distinguish between NR3 and NR4 because of the lack of warmer-water species.

Clathrocyclas bicornis occurs sporadically between Samples 594-11-6, 84–86 cm and 594-14-2, 84–86 cm. This occurrence is interpreted as reworking, because the first consistent occurrences of *A. denticulata* and *Theocalyptra bicornis* were found in Sample 594-12-3, 84–86 cm. Thus, Samples 594-11-6, 84–86 cm to 594-14-4, 84–86 cm are placed in the NR4 Zone.

The last consistent occurrence of *C. bicornis* in Sample 594-15-2, 84–86 cm is used to mark the top of the Pliocene. Rare radiolarians occur in Samples 594-15-2, 84–86 cm to 594-20-3, 84–86 cm. Typical Pliocene species like *Pseudocubus vema* occur sporadically. Because preservation was poor and markers were scarce the interval between Samples 594-15-2, 84–86 cm and 594-20-3, 84–86 cm remains unzoned.

Samples 594-20-4, 84–86 cm to 594-27-1, 84–86 cm, below the first occurrence of *Antarctissa ewingi* and above the first appearance of *Stichocorys peregrina*, are placed in the *Stichocorys peregrina* Zone (late Miocene). In the best preserved samples, forms like *Anthocyrtidium ehrenbergi* and *Hexacontium hootsi* indicate warmer condi-

Table 3. Abundance of some radiolarians from Hole 594.

Age	Radiolarian zone	Core-Section (interval in cm)	Abundance	Preservation	Reworking	*Theocalyptra bicornis*	*Antarcissa denticulata*	*Botryostrobus b. tumidulus*	*Antarcissa strelkovi*	*Phormostichoartus furcaspiculata*	*Triceraspyris antarctica*	*Theocalyptra davisiana*	*Actinomma popofskii*	*Pseudocubus vema*	*Antarcissa ewingi*	*Saccospyris antarctica*	*Stichopodium calvertense*	*Phormostichoartus multiseriatus*	*Rhizosphaera antarctica*	*Spongotrochus glacialis*	*Botryostrobus aquilonaris* gr.	*Botryostrobus b. seriatus*	*Druppatractus irregularis*	*Dictyophimus crisiae*	*Lonchosphaera spicata* gr.	*Clathrocyclas bicornis*	*Botryostrobus b. pretumidulus*	*Eucyrtidium t. orthoporus*	*Stichopodium biconica*	*Stylatractus universus*	*Actinomma tetrapyla*	*Lamprocyrtis heteroporos*	*Stylatractus* aff. *universus*	*Botryostrobus aur./australis* gr.	*Saccospyris preantarctica*	*Spircyrtis subscalaris*
Quaternary	NR1	5-4, 84-86	R	G	O		F	R	R	R	F	F	F			F	R	R	F	C	F	R		+										C		
		6-4, 84-86	R	G	O		F	C	R	R	F	F	F			F	R	C	F	F	F	R		+										R		
	NR2	7-2, 84-86	R	M	)		F	C	R	C	C	F	F			F	R	C	F	C	C	R	+	+						+				C		
		8-1, 84-86	R	M	R		F	R	R	R	C	F	F			F	C	C	F	F	R	R		+						+				R		
	NR3 + 4	9-4, 84-86	R	M	R		F	R	R	R	C	F	F			F	C	R	F	F	C	R								+				C		
		10-2, 84-86	R	G	R		F	R	R	R	F	F	F			F	R	R	F	F	C	R	+				+			+				R		
		11-4, 84-86	R	G	O		F	R	R	+	C	F	F			C	R	R	F	F	F	C					+			+			+	R	+	
		11-5, 84-86	+	G	O		F	R	R	+	+	C	F			C	R	R	F	C	F	+					+			R				R		
	NR4	11-6, 84-86	R	G	O		F	R	R	+	C	C	F			R	+	R	C	C	F	+					+			+				R	+	
		12-2, 84-86	+	P	O	+	C	+	+		+	+	+			+	+		C		+					+	R			+				R		
		12-3, 84-86	+	M	O	+	C	R				R	R			+	R		+		F		+			+	+			+				C		
		12-4, 84-86	+	P	O														R		+									+						
		12-5, 84-86	+	P	O	+		+			+	+	+			+	+									+	+			+				+		
		13-3, 84-86	+	P	O	+				+	+		+			+	+				+		+	+		+			+	+		+		+	+	
		14-2, 84-86	+	P	O	+					+		+			+	C		+				+			+	+		+	+				+	+	
	Unzoned	15-2, 84-86	R	G	O	C	+	+	+	R	+	R	F	R		+	F		R	+		+	R	+	+	C	R	+	C	R			R	C	R	R
		16-2, 84-86	C	G	O			+					F	+		+	F		F	+			R		+	C	R	+	F	R		C		F	+	R
		16-4, 84-86	+	P	O			+				+	R	+		R	C		+	+			+	+		C			C	R		C		R	+	
		19-1, 84-86	+	P	O										+	+	+										+									
		19-4, 84-86	+	P	O										+	+	+	+				+		+			+	+	+							+
		20-1, 84-86	+	P	O										+	+	+									+	+							+		
late Miocene	*S. peregrina*	20-4, 84-86	R	M	O												+		+	R		R		R			R			+		+	+	R	C	
		21-2, 84-86	R	M	O																					C	+		R	+				R		
		23-1, 84-86	C	M	R													R	+	R	+					F	C		C		R			C	R	
		23-4, 84-86	C	M	R													R	+	+	+					F	C	+	C		R			C	R	
		24-1, 84-86	C	M	R																	R				C			C					C	+	
		24-4, 84-86	C	P	R																					F			R	+	R				+	
		25-1, 84-86	R	M	R																+		+			F	C		F	C	+			C		F
		25-4, 84-86	C	G	R																	+	+	+		F	C	+	C	C			R	C	+	C
		26-2, 84-86	C	G	R																			+	+	F	C	+	C	R	+		R	C	R	C
		26-4, 84-86	R	M	R					R																C	R	+	C	R	+	R	R	R	+	R
		27-1, 84-86	+	M	O																					C	R		C					R	+	R
	D. penultima + *D. ante-penultima*	27-4, 84-86	+	G	O																					C	C		C		+		R	R	+	
		28-1, 84-86	R	G	O					+																C	C		C		R		R	R	R	+
		28-3, 84-86	R	G	R					+																F	C		C				R	R	R	+
		29-2, 84-86	R	G	O					+																F	R		C		R		R	R	C	
		29-4, 84-86	R	G	O					+									+							C	R		C	+	+		C	R	C	
		30-1, 84-86	+	M	O																					R	+		C	+	+		R			
		31-1, 84-86	R	M	O																					+	+		C		+		C	R	+	
		31-2, 84-86	+	M	O																					+	+		R				+	R	R	
		31-3, 84-86	R	G	O					+																	+	R	C			+	C	R	R	+
		31-4, 84-86	R	G	R																						+	+	C				R	R	R	
		31-5, 84-86	R	G	O																							+	C	+			R	R	R	
?	Unzoned	34-2, 84-86	+	P	O					+																					R					
		34-3, 84-86	+	P	R																															
		34-4, 84-86	+	P	O																															
		35-1, 84-86	+	P	O					+																						+			+	
		35-3, 84-85	+	P	R																															
		35-4, 84-86	R	M	O																															
		36-1, 84-86	+	M	O																												R	R		
		36-3, 84-86	+	M	O																													R		
		37-1, 84-86	R	M	O																															+
middle Miocene	*D. petterssoni*	38-1, 84-86	+	P	O																												+		+	
		39-2, 84-85	+	P	O																															
		40-1, 84-86	R	M	O																															
		40-2, 84-85	+	P	O																						C									
		40-4, 84-86	+	P	O																															
		41-2, 84-86	R	G	O																						+	+						+		
		42-1, 84-86	+	P	O																										+			+		
		42-4, 84-86	+	P	+																								+							
		44-1, 84-86	+	P	O																								+							
		45-1, 84-86	R	G	R																														R	R
		46-1, 84-86	+	M	O																														+	+
		46-2, 84-86	+	P	O																														+	+
		47-1, 84-86	R	G	O																														R	R
		48-1, 84-86	R	M	O																														R	
		48-2, 84-86	R	M	O																															
		48-3, 84-86	R	M	O																														R	+
		49-1, 84-86	R	M	O																														R	+
		49-2, 84-86	+	M	O																														+	+
		49-3, 84-86	+	P	O																															+
		50-1, 84-86	+	P	O																															
		51-1, 84-86	+	P	O																														+	+
		52-1, 84-86	R	G	O																															+
		52-2, 84-86	R	G	O																															+

Note: Symbols as for Table 2. The following samples were barren of radiolarians: 594-18-1, 84-86 cm; 594-18-2, 84-86 cm; 594-18-4, 84-86 cm; 594-21-4, 84-86 cm; 594-34-1, 84-86 cm; 594-34-5, 84-86 cm; 594-38-2, 84-86 cm; 594-41-3, 84-86 cm; 594-41-4, 84-86 cm; 594-43-1, 84-86 cm.

Table 3. (Continued).

Anthocyrtidium ehrenbergi	*Lamprocyclas* aff. *maritalis*	*Stichocorys peregrina*	*Stichopodium inflatum*	*Prunopyle titan*	*Spongodiscus* sp.	*Didymocyrtis antepenultima*	*Diartus hughesi*	*Eucyrtidium punctatum*	*Phormostichoartus doliolum*	*Haliometta miocenica*	*Lamprocyclas margatensis*	*Eucyrtidium teuscheri* gr.	*Lamprocyclas hannai*	*Stylosphaera angelina*	*Phormostichoartus platycephala*	*Dictyophimus splendens*	*Lithopera neotera*	*Cyrtocapsella japonica*	*Botryostrobus b. bramlettei*	*Spirocyrtis subtilis*	*Polysolenia* aff. *murrayana*	*Cyrtocapsella elongata*	*Botryostrobus miralentensis*	*Lithomelissa ehrenbergi*	*Siphostichartus corona*	*Prunopyle hayesi*	*Siphocampe modeloensis*	*Botryostrobus* sp.	*Botryocella cribrosa* gr.	*Botryopyle dionisi*	*Circodiscus ellipticus*	*Clathrocyclas cabrilloensis*	*Clathrocyclas humerus*	*Cyrtocapsella cornuta*	*Cyrtocapsella tetrapera*	*Didymocyrtis laticonus*	*Eucyrtidium cienkowskii*	*Lynchocanium grande*	*Phormostichoartus corbula*	*Phormostichoartus fistula*	*Phormostichoartus marylandicus*	*Collosphaera polygona* gr.	*Stauroxiphos communis*	*Stichocorys delmontensis*
															+																													
										F																															R				
								+		R																															+				
			+																																										
		+																																											
		+	+																																								+	
		R	C							C				R																								+						
		C	R	+																																		+		+					
R	F		R	+						C				+	F												R									+	F		+			C	C	+
R	F	F	R	+						C				+	C			+								R									+	F		+			C	C	R
	F	F	+	+																							+									+	C						R	R	
	F	F								C		+														+	+									R	F			+				
C	C	F	C		+					C					+			+									R					+				+	F		R	+		C		+
F	C	F	C	R						C	C				R	+		+	C								R		+			+	R		+		F		R	R		C	R	R
C	C	C	R	R	R	+	+			R	C			+		C								+						R		R		+		R		+		C		R	R		C	+	R
		+	R	R	+	+	R			C	C			+	+	R		+	R			+							R							C				C	+	R			C	R	+
		+				+	+			C	R								+								+	R		+										C	+	+					R	+
				R	R	+	R			R	R	+	+		R	+			+								R	R						C				C	R	+	+				C	+
				R	R	+	R			C	R	+	+		R	+			R								+	R						R				C	R	R	+		+	F	+
				R		R	R			C	C		+		+				R								R	R	+					R				C	R						F	
				R	R	R	C			R	C	+	R	+		+		+	R			+						R	R							C		+		C	R	R	R		+	F	
				R	R	R	R			R	C	+	R		+	R			R			+						C	C							R				C		R	R			F	R
				+	+	+				R	R				R							+						C	C												C						R
							R		+	+	R				R	+			C									R	+							R				C	+				+	+	R
										+	R				R			+	R								R	+							C				C		R				+		R
						+	R	+	+	+	C	+	+		R			R	C									R						C				R	+	R	+				R
							+	+		+	C		+		F	R		R	C			+						R	R	+					C		+		C	+	R						F
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tions. Reworked specimens of Eocene to middle Miocene age occur in Samples 594-23-1, 84–86 cm to 594-26-4, 84–86 cm.

The next markers observed were *Didymocyrtis antepenultima* and *Diartus hughesi*, whose first appearances are tabulated in Sample 594-31-5, 84–86 cm. Thus, Samples 594-27-4, 84–86 cm to 594-31-5, 84–86 cm are placed in the *Didymocyrtis antepenultima* Zone and the *D. penultima* Zone. The *D. penultima* and *D. antepenultima* zones are amalgamated because the species *D. penultima* was not found in the radiolarian assemblages. Moreover, the base of the *D. penultima* Zone, which is also recognized in tropical areas at the top of the range of *Diartus hughesi*, cannot be located in Site 594 because the last occurrence of *D. hughesi* is tabulated in the *S. peregrina* Zone. It is possible that *D. hughesi* as well as *Didymocyrtis laticonus* and *D. antepenultima* have different ranges in the mid-latitude sediments. Close examinations of numerous specimens show distinct morphological differences with tropical forms. Further studies, including size measurements, are needed to estimate the importance of these morphologic differences (Caulet, in preparation).

Samples 594-31-6, 84–86 cm to 594-37-1, 84–86 cm contain poorly preserved and rare radiolarian assemblages. Barren levels occur sporadically throughout this interval, which cannot be related to a well-defined zone.

Most radiolarian species recognized in the samples below 594-37-1, 84–86 cm are well known in the tropical assemblages of the *Diartus petterssoni* Zone (middle Miocene). The most significant transition in the radiolarian fauna is observed between Cores 594-23 and 594-21. In Core 21 and above, most temperate or warm-water radiolarians have disappeared. Radiolarian abundances are greatly reduced and antarctic or subantarctic species become more dominant. Their occurrence suggests a northward migration of the Antarctic Convergence.

DISCUSSION

Radiolarian Events and Potential Datum Levels

Figure 1 summarizes the sequence of events at Hole 586B and Site 594 for which adequate stratigraphic coverage is available. The list includes only those events which appear to be of potential stratigraphic significance.

Comparison between the sites shows that not all the available stratigraphically important species are reliable over the equatorial to subantarctic area. Only 14 events from a total of 38 (in the same stratigraphic interval) can be reported from both sites. Most of the correlation lines present no problem, but there are a few conflicts.

1. The discrepancy between the position of the upper limit of *Stichocorys delmontensis* in Holes 586B and 594 is resolved in favor of Hole 586B by the reliability indices (14 in Hole 586B and 7 in Hole 594). However, the last occurrence of this morphotype is very difficult to place because in temperate latitudes the shells of *S. peregrina* present many variations that are probably due to different local environments (W. R. Riedel, personal communication).

2. There is also a great discrepancy between the relative positions of the upper limit of *Phormostichoartus fistula*. The stratigraphic range assigned to this species by Nigrini (1977) is large: from the *Thyrsocyrtis bromia* Zone to the *Spongaster pentas* Zone. In Hole 586B, the upper limit of this species is located in the *S. pentas* Zone, but in Site 594, its last occurrence is tabulated in the *Stichocorys peregrina* Zone. However, the indices of reliability (20 at Hole 586B and 1 at Hole 594) show that the discrepancy is not due to different paleoenvironmental conditions.

3. The upper limit of *Lamprocyclas* aff. *maritalis* is also located in different radiolarian zones: the *Pterocanium prismatium* Zone at Hole 586B and the *S. peregrina* at Site 594. But the indices of reliability present the same value (25) and the discrepancy seems to be due to paleoecological fluctuations. However, the subantarctic morphotypes could be different from equatorial ones.

In addition to previously reported datum levels, several last occurrences that may be of stratigraphic significance (possibly only local) are worth noting here:

1. Top of *Phormostichoartus pitomorphus*. The last occurrence of this species is located in the early to middle Pleistocene in Hole 594 and near the Pliocene/Pleistocene boundary in Hole 586B. However, this species is consistently present in the sediments of the subantarctic area but is only scarce and sporadic in equatorial samples of the same age. The indices of reliability are difficult to calculate in the equatorial case and do not allow interpretation of the results. Data from current studies on Indian Ocean cores show this species gradually disappearing in cores located at different latitudes (Caulet, in preparation).

2. Top of *Lamprocyrtis heteroporos*. This species reaches an upper limit at the Pliocene/Pleistocene boundary in Hole 586B. However, it persists into the Pleistocene at Site 594.

3. As previously noted by Weaver (1983), the last occurrence of *Diartus hughesi* is higher in subantarctic material (in the *Didymocyrtis antepenultima/D. penultima* Zone in Hole 594, just below the first evolutionary transition to *S. peregrina*).

Evolutionary Lineages

Of importance for biostratigraphic application of the information included in this report are several suggested evolutionary transitions. Some of these are new, whereas others are modifications of trends previously reported in other areas.

1. *Eucyrtidium teuscheri* gr.–*E. teuscheri teuscheri* (Fig. 2) The *E. teuscheri* gr. evolves from large eucyrtids, which are rare in the middle Miocene, to slender forms in the late Miocene. These big specimens evolve into *E. teuscheri orthoporus* and *E. teuscheri teuscheri*. In the temperate area (Site 594), the transition to *E. teuscheri orthoporus* occurs in the late Miocene. In the tropical area (Hole 586B), *E. teuscheri orthoporus* evolves from the *E. teuscheri* gr. in the beginning of the *Spongaster pentas* Zone. This species reaches extinction without apparent descendants in the early Pleistocene. Intermediate forms between the *E. teuscheri* gr. and its two descendants are reported in the late Miocene to early Pliocene. The modern *E. teuscheri teuscheri* morphotypes evolve in the early *S. pentas* Zone. As *E. teuscheri*

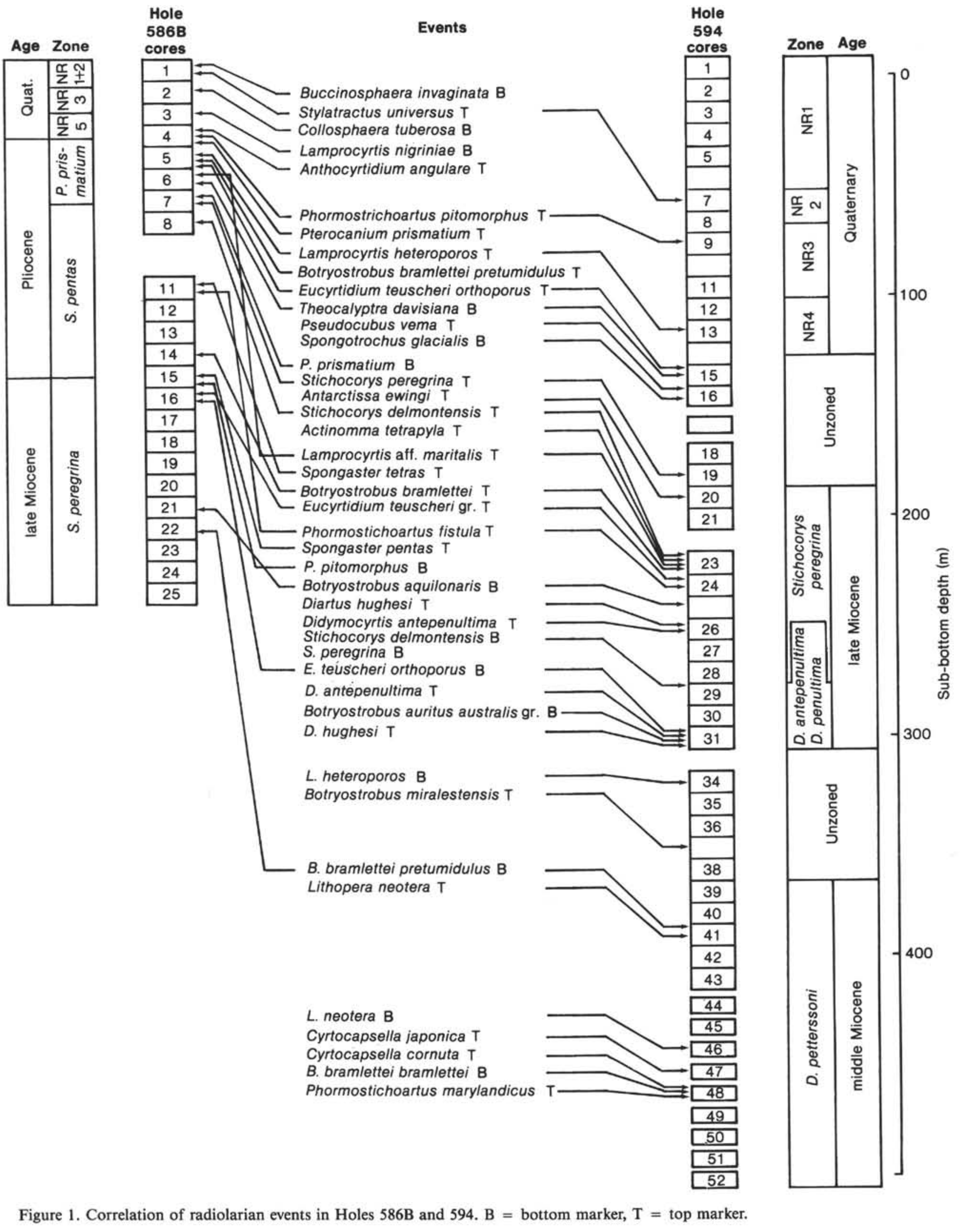

Figure 1. Correlation of radiolarian events in Holes 586B and 594. B = bottom marker, T = top marker.

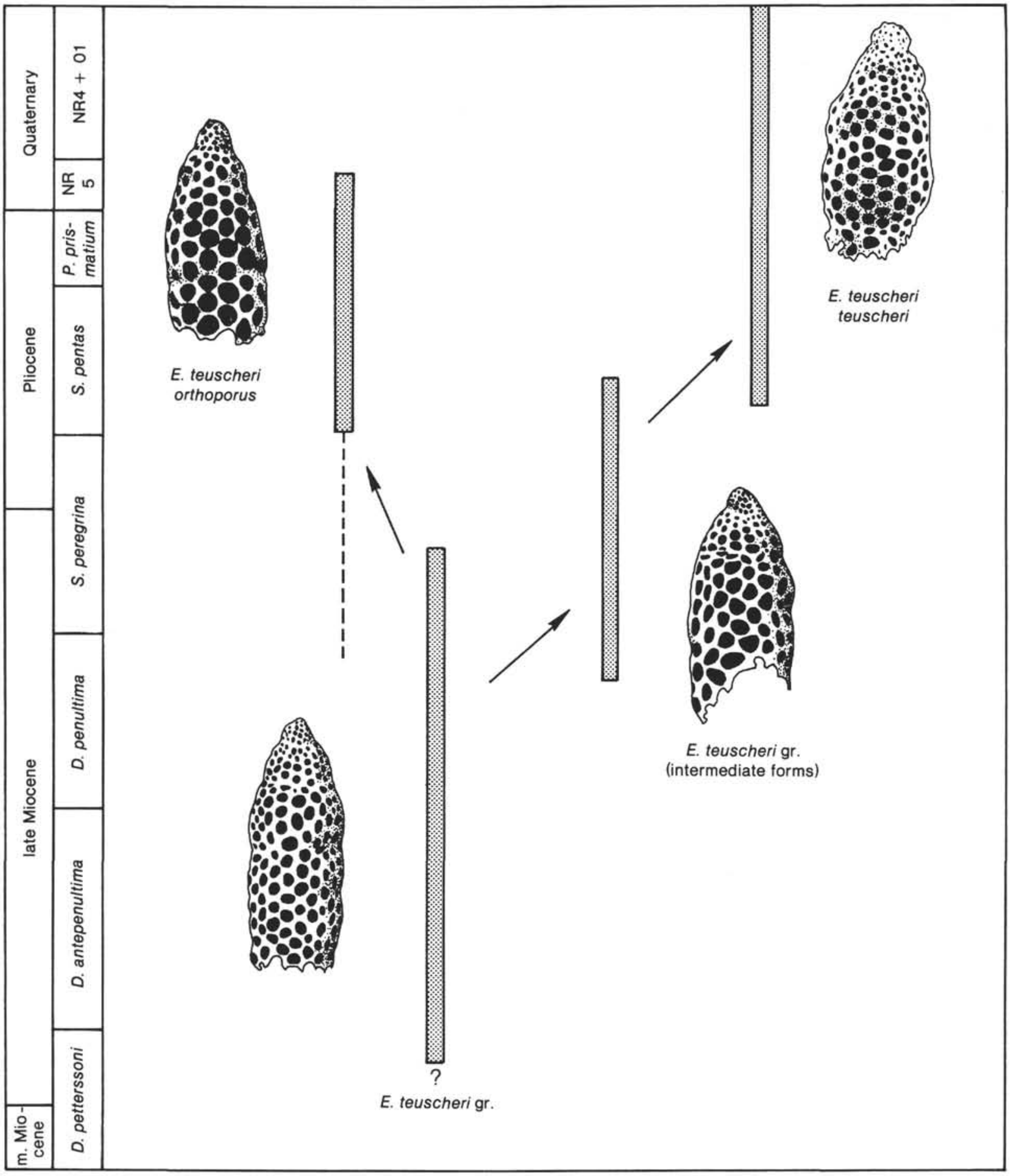

Figure 2. Range chart of relationships among the *Eucyrtidium teuscheri* group. The broken line indicates the subantarctic range of *E. teuscheri orthoporus* at Site 594.

orthoporus appears to be more frequent in the temperate sediments with a longer range, its evolution is probably controlled by paleoenvironmental conditions.

2. *Phormostichoartus fistula–P. pitomorphus* (Fig. 3) *Phormostichoartus fistula* is reported to appear in the late Eocene (Nigrini, 1977). It is rare in late Miocene sediments of both tropical and temperate areas. The transition to *P. pitomorphus* occurs in the early Pliocene. Transitional forms present gradually shorter tests and the width of the third segment increases. *P. pitomorphus* is more frequent in temperate to subtropical areas (Caulet, unpublished data), and becomes extinct in the early Pleistocene.

Intermediate forms with the *P. platycephala* gr. occur in the late Pliocene period: fourth segment smaller and enlarged cephalis. As *P. platycephala* gr. specimens are

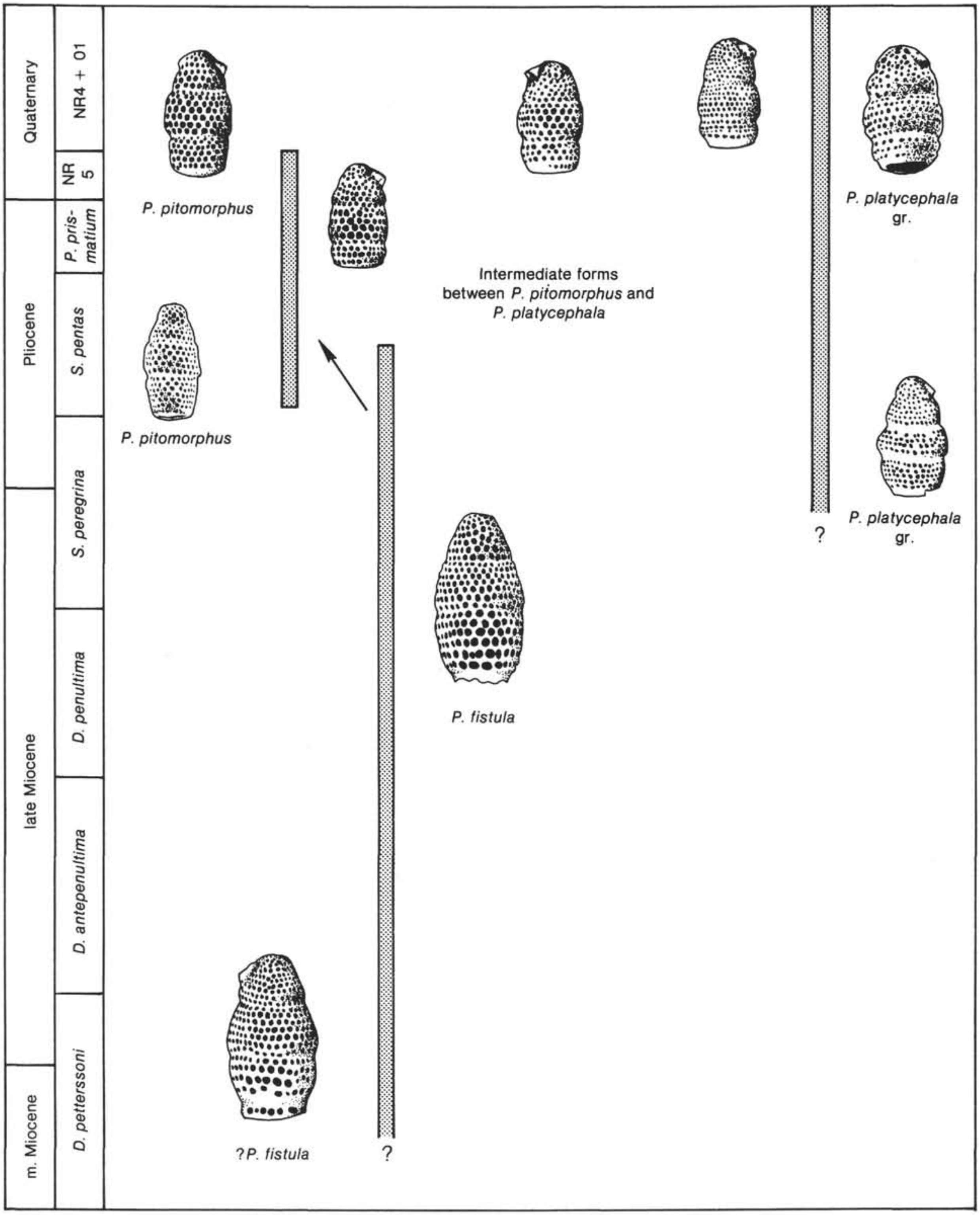

Figure 3. Range chart of relationships among the *Phormostichoartus fistula–P. pitomorphus* group. *P. fistula* has a widespread distribution in tropical and temperate areas. Its evolution into *P. pitomorphus* took place only in temperate areas. Intermediate forms between *P. pitomorphus* and *P. platycephala* group are commonly found in temperate sediments of Pliocene to early Pleistocene age. Relations between *P. platycephala* and *P. fistula* are not clear.

present in Messinian sediments (Caulet, unpublished data), it is possible that a hybridization takes place between the two groups of morphotypes. However, older ancestors of *P. platycephala* are unknown, and the phylogeny of the whole groups is not yet precise.

3. *Lamprocyclas* aff. *maritalis–L. maritalis. L. maritalis* appears approximately in the early *Pterocanium prismatium* Zone, where it probably evolves from the *L.* aff. *maritalis* gr. The relationships with the temperate forms of the same age are not clear.

4. *Lamprocyrtis heteroporos–L. nigriniae.* The discovery of *L. daniellae* calls into question the lineage proposed by Kling (1973) for the open-cephalis pterocoryds. But the distinction between *Lamprocyclas junonis* and *Lamprocyrtis neoheteroporos* and the range of *Lamprocyclas hannai* remain problematical. Before changing the phylogeny of this group, it is necessary to answer these questions, and to define precisely the stratigraphic range of *Lamprocyrtis daniellae*, which seems, unfortunately, to be very rare.

Preservation

Estimates of radiolarian preservation are generally imprecise. Preservation is considered "good" where a large number of species is present, and some skeletons of each species are reasonably complete. Samples in which incomplete specimens are frequent are considered to have "poor" preservation. Samples in which species diversity and specimen integrity are intermediate between the two are included in the "moderate" preservation category. The location of most Leg 90 sites under the mid-latitude water masses and in shallow depths is responsible for the absence or poor preservation of the radiolarian assemblages.

Some aspects of radiolarian preservation in Hole 586B are noteworthy (Fig. 4). Preservation appears to have been very poor during the middle Pleistocene and the middle Pliocene. Very good preservation occurred during the early Pleistocene and the early Pliocene. It is beyond the scope of this report to examine all the possible explanations for these events. However, some radiolarian and diatom contents measured in a few mid-latitude piston cores from the Indian Ocean have been shown to increase in the early Pleistocene and in the early Pliocene (Caulet, 1977). These greater amounts were interpreted as an increase of equatorial productivity. Thus, as biogenous silica dissolution is nearly constant in shallow-water sediments above the CCD (Johnson, 1975), the peaks of the preservation curve at Hole 586B can be interpreted as periods of increasing productivity.

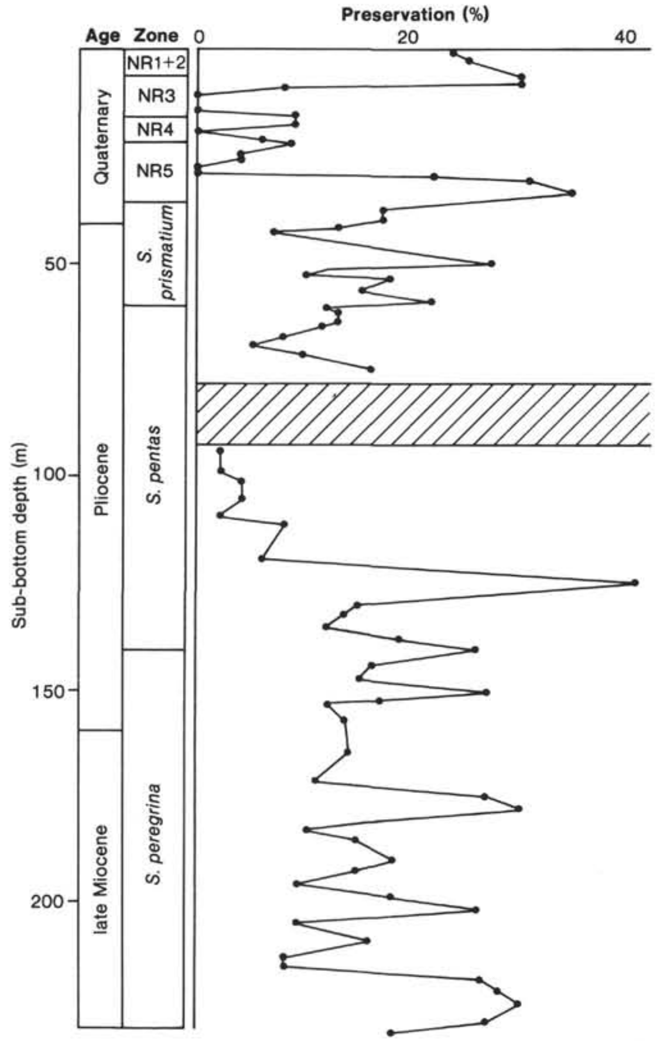

Figure 4. Fluctuations of radiolarian preservation in Hole 586B (in percentages of well-preserved individuals among 800 radiolarian shells). Hatched area shows barren samples.

SYSTEMATICS

The systematic study of radiolarians from Leg 90 is presented in two parts:

1. Taxonomic notes: descriptions of new species with or without revised concepts of the genus
2. Species list: bibliographic references for well-known taxa which are not discussed in the taxonomic notes.

The only literature references given are to the original description, and to my present concept of the species, if different from the original one. Type specimens are deposited in the Muséum National d'Histoire Naturelle, Paris. Measurements have been made on 20 specimens.

Taxonomic Notes

Family COLLOSPHAERIDAE Müller, 1858
Genus *ACROSPHAERA* Haeckel, 1881

Type species. *Collosphaera spinosa* Haeckel, 1862, p. 536, pl. 34, figs. 12–13. Bjørklund and Goll (1979) gave a good discussion of the genus. However, their choice of *A. echinoides* Haeckel, 1887 as the type species seems questionable (although technically correct), because they assign to *A. echinoides* the rank of a subspecies of *A. spinosa*, which was originally described by Haeckel in 1862.

***Acrosphaera spinosa hamospina* n.ssp.**
(Plate 1, Figs. 2, 3)

Description. A subspecies of *Polysolenia spinosa* characterized by more than 10 strong spines ending in hooks.

Name. *Hamus* (Latin: hook) and *spina* (Latin: spine).

Holotype. Pl. 1, Fig. 2, Sample 586B-23-3, 60–62 cm, slide 2.

Dimensions. Shell diameter, 70–90 μm; spine length, 60–80 μm.

Distribution. The first occurrence is not recognized. But the first consistent occurrence seems to be in the *Stichocorys peregrina* Zone at Sample 586B-24-5, 60–62 cm.

Remarks. This morphotype is closely related to the *Acrosphaera echinoides* gr. Haeckel and it could be included in that species. But its stratigraphic range is very short and its last appearance is an event with a good index of reliability. Very common in equatorial Indian Ocean material of the same age.

***Acrosphaera spinosa fasciculopora* n.ssp.**
(Pl. 1, Fig. 1)

?*Acrosphaera spinosa echinoides* (Haeckel) Bjørklund and Goll, 1979, pl. 1, figs. 10, 11.

Description. *Acrosphaera spinosa* with 10–15 spines, strong, long, arising from a cluster of pores that are larger than the irregular small pores of the shell and that form small protuberances on the shell surface.

Name. *fasciculum* (Latin: cluster)

Holotype. Pl. 1, Fig. 1, Sample 586B-20-3, 60–62 cm, slide 1.

Dimensions. Shell diameter, 80–100 μm; Spine length, 30–100 μm.

Distribution. First occurrence not recognized. Very abundant in samples near the very end of the *Stichocorys peregrina* Zone (Sample 586B-16-5, 60–62 cm), a few meters below its last occurrence.

Remarks. This subspecies is closely related to the *A. echinoides* group but its external spines are less numerous, longer, and arise from a very typical cluster of larger pores. Its stratigraphic range is narrower, and the last occurrence seems to be a very good event.

Genus *SIPHONOSPHAERA* Müller, 1858

Type species. *Collosphaera tubulosa* Müller, 1855.

***Siphonosphaera hyalina* n.sp.**
(Plate 2, Fig. 1)

Description. Subspherical shell with two distal tubes and numerous very small circular pores. Extremity of tubes not latticed, perforated by small pores.

Name. *hyalin* (Greek: glassy).

Holotype. Pl. 2, Fig. 1, Sample 586B-17-2, 60–62 cm, slide 1.

Dimensions: Total length, 100–130 μm.

Distribution. First occurrence in the early Pliocene (Sample 586B-17-2, 60–62 cm). Last occurrence in the early Pleistocene (Sample 586B-4-5, 60–62 cm).

Remarks. Bjørklund and Goll (1979) point out the problems that arise from collosphaerid taxonomy. They think that all morphotypes can be assigned to one or two genuses. Until a detailed study of tube-bearing collosphaerids is completed, it seems more reasonable to use the old genera.

Family ACTINOMMIDAE Haeckel, 1862, emend. Riedel 1967
Genus *AXOPRUNUM* Haeckel, 1887, emend. Koslova, 1972

Type species. *A. stauraxonium* Haeckel, 1887, pl. 48, fig. 4.

?(*Axoprunum*) *monostylum* n.sp.
(Plate 1, Figs. 9–11)

Description. *Axoprunum* with one single strong polar spine. Three shells subspherical to cuboid; 20–25 pores on the equatorial plane. The medullary and cortical shells are joined by rods (about 6) disposed in the equatorial plane, and by 2 rods going to the opposite poles of the shell. One rod penetrates the cortical shell and forms a strong spine, three-edged and thorny at its end. The other rod projects as a small thorn. Secondary spines, three-edged, often broken, arise from the bars of the third shell.

Name. *monostylus* (Latin: with one stylus).

Holotype. Pl. 1, Fig. 9, Sample 586B-5-4, 60–61 cm, slide 1.

Dimensions. Polar spine length: 100–120 μm. Shell diameter: 80–90 μm.

Distribution. Very rare in the sediments of the upper *Pterocanium prismatium* Zone. First common occurrence in Sample 586B-6-1, 60–61 cm. Last occurrence in Sample 586B-4-6, 60–61 cm.

Remarks. Very similar morphotypes can be found in some Langhian marls from Spain (Pl. 1, Fig. 11) (Caulet, unpublished results). But these older forms possess shells with 35–40 small pores. A nearly dissolved specimen was found in Sample 586B-20-3, 60–61 cm, but it is difficult to describe with precision.

Assignment of a generic name to this morphotype poses a difficult taxonomic problem. Vinassa (1900) describes two Prunoidea and two Sphaeroidea with a single polar spine (*Dorydruppa, Doryprunum* and *Dorysphaera, Dorylonchidium*). But the descriptions are very sketchy and the figures of his species cannot be compared to this species. As the inner structure of *A. monostylum* seems to be similar to the inner structure of *A. stauraxonium*, this new morphotype is provisionally ascribed to the genus *Axoprunum*.

Family SPONGODISCIDAE Haeckel, 1862, emend. Riedel, 1967
Genus *RHOPALASTRUM* Ehrenberg, 1847

Type species. *Haliomma lagena* Ehrenberg, 1840, p. 200. See discussion in Nigrini and Moore, 1979, p. 580.

***Rhopalastrum oracutibrachium* n.sp.**
(Plate 2, Fig. 4)

Description. Spongodiscid with three simple, undivided, spongy arms. Triangular shells, equilateral. Patagium present. Central structure partly obscured by spongy network, consisting of 5 to 6 concentric chambered rings. Spongy arms with sharp edges and ragged ends.

Name. *ora* (Latin: edge), *acutus* (Latin: sharp), *brachium* (Latin: arm).

Holotype. Pl. 2, Fig. 4, Sample 586B-23-5, 60–62 cm, slide 2.

Dimensions. Arm length: 120–130 μm. Inner disk diameter: 70–80 μm.

Distribution. First occurrence not recognized. Abundant from Sample 586B-25-5, 60–62 cm to 586B-22-1, 60–62 cm. Last consistent occurrence in the *Stichocorys peregrina* Zone (Sample 586B-21-3, 60–62 cm). Sporadic occurrences in the *Spongaster pentas* Zone.

Remarks. Some Pleistocene forms present well-marked arm edges, but these forms are smaller and their arm edges less sharp and thick.

Genus *SPONGODISCUS* Ehrenberg, 1854

Type species. *S. resurgens* Ehrenberg, 1854c, p. 66.

***Spongodiscus klingi* n.sp.**
(Plate 2, Figs. 2, 3)

Circular spongodiscid. Kling, 1971, p. 1086, pl. 1, fig. 8.

?Spongodiscid. Johnson, 1974, pl. 9, fig. 18.

?*Spongodiscus communis fragilis* Riedel, 1953, p. 809, pl. 84, fig. 6.

Description. Disc circular, spongy, subdivided into three concentric parts, with a regular margin. Inner disc with 4–5 chambered rows partly obscured by a spongy network. Median part of the disc a net of small irregular pores with 5–7 large meshes. External part of the disc strong and spongy with a delicate margin and fragile short spines, often broken.

Name. In honor of S. Kling, who first reported the species.

Holotype. Pl 2, Fig. 3, Sample 586B-18-1, 60–62 cm, slide 1.

Dimensions. Total diameter: 210–220 μm. Median thin area width: 40 μm. Maximum dimension of larger elliptical pores: 20 μm.

Distribution. First occurrence not recognized. Last occurrence at Sample 586B-12-1, 60–62 cm in the *S. pentas* Zone.

Remarks. This species differs from all other spongodiscid species in the broader pores located in the median part of the shell. Frequently, the fragile margin is not observed. The number of inner broad pores is variable. Riedel (1953) described a form with a thin region between a plain margin and a central chambered region, without larger pores. Relationships with other spongodiscids unknown.

Family PTEROCORYTHIDAE Haeckel, 1881, emend. Moore, 1972
Genus *LAMPROCYCLAS* Haeckel, 1881, emend. Nigrini, 1967

Type species. *Lamprocyclas nuptialis* Haeckel, 1887, p. 1390, pl. 74, fig. 15.

***Lamprocyclas* aff. *maritalis* gr.**
(Plate 4, Figs. 1, 2)

Calocyclas margatensis Campbell and Clark *in* Riedel, 1953, p. 811, pl. 85, fig. 8.

?*Lamprocyclas aegles* gr. Petrushevskaya, 1975, pl. 16, figs. 2–4, *non* fig. 1. Weaver, 1983, pl. 4, figs. 4–5.

Description. Shell not entirely campanulate, thick-walled, and with a rough surface. Cephalis subspherical, with small subcircular pores, very thick-walled. Stout three-bladed apical horn, 2 or 3 times cephalis length. Lateral lobes not bulging. Primary and dorsal spines do not continue as ribs in the thoracic wall. Thorax cupola-shaped with subcircular pores, arranged in latitudinal rows and increasing slightly in size toward the third segment. Abdomen ovoid, 12–15 pores on a half equator. Peristome well differentiated, poreless, with two rows of teeth. Terminal teeth better developed than subterminal teeth.

Dimensions. Total length: 200–220 μm. Maximum width: 100 to 110 μm.

Distribution. In Hole 586B, the first occurrence is at Sample 586B-22-5, 60–62 cm in the *Stichocorys peregrina* Zone; the first common occurrence is in the same zone. In Hole 594, the first occurrence is in the same zone (Sample 594-26-2, 84–86 cm). But in the equatorial area the last occurrence of this species group is in the *Pterocanium prismatium* Zone (Sample 586B-6-5, 60–62 cm) and in the subantarctic area it is in the *S. peregrina* Zone (Sample 594-23-1, 84–86 cm).

Remarks. The individuals included in this species group are quite variable. They differ from *L. maritalis* by the shape of the cephalis and abdomen. Some specimens with intermediate morphology can be found in Hole 586B, where the first occurrence of *L. maritalis maritalis* Nigrini is reported 7 m below the last occurrence of *L.* aff. *maritalis*. Thus it can be assumed that *L.* aff. *maritalis* is the ancestor of *L. maritalis maritalis*. *L.* aff. *maritalis* gr. differs from *L. margatensis* Campbell and Clark by a longer shell, a more ovoid abdomen, and a strong terminal peristome (Pl. 4, Fig. 3). Moreover, the first occurrence of *L. margatensis* in Hole 586B is 10 m below the first occurrence of *L.* aff. *maritalis* gr., and the last occurrence of *L. margatensis*, in the early *Spongaster pentas* Zone, is reported 69 m below the last occurrence of *L.* aff. *maritalis* gr. A possible evolutionary lineage would be *L. margatensis* → *L.* aff. *maritalis* → *L. maritalis*. However, the mid- and high-latitude specimens of *L. maritalis* gr. have more ovoid shells than equatorial ones, with a spherical cephalis, and have a very different range. Relationships between these morphotypes are not well understood and more precise work, including size measurements, is necessary before a detailed description of this group can be presented (Caulet, in preparation).

Genus *LAMPROCYRTIS* Kling, 1973

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

Lamprocyrtis daniellae n.sp.
(Plate 3, Figs. 13–16)

Description. Two-segmented form with very small cephalis, open, with irregularly circular pores and a small apical spine arising gradually from the periphery of the cephalis like a short beak. No accessory spines on the periphery of cephalic top. Collar stricture distinct. Thorax spindle-shaped, thick-walled, smooth with subcircular to irregular pores aligned in longitudinal rows. Thorax constricted distally, terminating in a peristome with an irregular row of strong irregular teeth.

Name. In memory of my wife Daniele.

Holotype. Pl. 3, Fig. 14, Sample 586B-16-1, 60–61 cm, slide 1.

Dimensions. Total length: 120–130 μm. Maximum width: 70 μm.

Distribution. Very rare in the sediments of the early *Spongaster pentas* Zone (Samples 586B-16-1, 60–62 cm to 586B-15-3, 60–62 cm).

Remarks. This morphotype is very similar to *L. nigriniae* (Caulet), with nearly the same shell. But the general shape and structure of the shell, the presence of a well-developed peristome, and the slightly developed apical spine are different. *L. daniellae* could be the ancestor of *L. nigriniae* and the *L. heteroporos*–*L. nigriniae* lineage may need to be revised. However, it is necessary to find evolutionary morphotypes between *L. daniellae* and *L. nigriniae*. As *L. heteroporos* is generally abundant in high-latitude sediments and *L. nigriniae* is restricted to the equatorial area, evolutionary morphotypes like *L. daniellae* must be found in mid-latitude sediments.

Genus *PTEROCORYS* Haeckel, 1881

Type species. *P. campanula* Haeckel, 1887, p. 1316, pl. 71, fig. 3.

Pterocorys longicollis n.sp.
(Plate 4, Figs. 4, 5)

Description. Shell rather thin-walled. Three-lobed cephalis subdivided into two parts: (1) upper portion, open, cylindrical, with circular pores, bearing a stout three-bladed apical horn, strong, with a great pore at its base; (2) lower "neck," formed by a very prominent dorsal lobe. Primary lateral and dorsal spines continue as ribs in the thoracic wall for about half its length. Sometimes, they are external, forming very small wings. Thorax is large, cupola-shaped with hexagonally framed, circular pores, quincuncially arranged and aligned longitudinally, 12–15 on a half-equator, 8–10 in a vertical series. Pronounced lumbar stricture. Abdomen campanulate. Distal end ragged; aperture never observed.

Name. *longus* (Latin: long), *collum* (Latin: neck).

Holotype. Pl. 4, fig. 4, Sample 586B-6-2, 60–61 cm, slide 2. (All specimens in Leg 90 samples are broken.)

Dimensions. Apical horn length: 50–60 μm. Total length of thorax: 40–50 μm. Maximum width: 80 μm.

Distribution. Very rare, with sporadic occurrences in Pliocene samples of Hole 586B. First occurrence in Sample 586B-15-5, 60–62 cm. Last occurrence in early Pleistocene, Sample 586B-4-1, 60–62 cm. More abundant in high-latitude sediments of Pliocene to early Pleistocene age from the Indian Ocean.

Remarks. Distinguished from the *P. campanula* group by pronounced bulging of the "D-lobe." Also more elongated, with abdomen walls not curved.

Family ARTOSTROBIIDAE Riedel, 1967, emend Foreman, 1973
Genus *PHORMOSTICHOARTUS* Campbell, 1951, emend. Nigrini, 1977

Type species. *Cyrtophormis cylindrica* Haeckel, 1887, p. 1461, pl. 77, fig. 17.

Phormostichoartus pitomorphus n.sp.
(Plate 3, Figs. 3, 4, 9, 10, 12)

Description. Shell smooth, spindle-shaped, consisting of four segments. Cephalis conical with well-developed, poreless, vertical tube lying along the thorax for about a third of its total length. Numerous circular pores, hexagonally framed, in regular horizontal rows. No apical horn.

Name. *pito* (Greek: barrel), *morphos* (Greek: shape).

Holotype. (Pl. 3, Fig. 12) Sample MD 75072-VI-100 cm.

Dimensions. Total length: 75–80 μm. Maximum width: 25–30 μm.

Distribution. Range is detailed in Figure 3. First common occurrence in early Pliocene at Sample 586B-16-1, 60–62 cm. Last occurrence in early Pleistocene (Sample 586B-4-1, 60–62 cm). The disappearance of this morphotype was previously documented in piston-core sediments from the southern Indian Ocean (Caulet, 1982).

Remarks. Relationships of this species with *P. fistula* and *P. platycephala* are described earlier in this chapter. In specimens of *P. pitomorphus*, the thorax is always longer then the abdomen.

Family THEOPERIDAE Heckel, 1881, emend. Riedel, 1967
Genus *EUCYRTIDIUM* Ehrenberg, 1847, emend. Nigrini, 1967

Type species. *Lithocampe acuminata* Ehrenberg, 1844b, p. 84.

Eucyrtidium anniae n.sp.
(Plate 5, Fig. 10)

Description. Five- to six-segmented shell, subcylindrical. Very small apical horn, often broken. Thorax longer than other segments. Longitudinal rows of circular pores on second and third segments. Horizontal rows on subsequent segments. Apertural margin rarely observed.

Name. After Annie Maurs who greatly helped in typing the tables.

Holotype. (Pl. 5, fig. 10) Sample 594-31-4, 84–86 cm.

Dimensions. Total length: 90–100 μm. Thoracic length: 40 μm. Thoracic width: 50 μm.

Distribution. First occurrence not recognized. Last common occurrence at Sample 586B-24-3, 60–62 cm (*Stichocorys peregrina* Zone). Last sporadic occurrence at Sample 586B-20-5, 60–62 cm, (*S. peregrina* Zone, late Miocene).

Remarks. This morphotype displays numerous resemblances to *E. punctatum* (broad second segment, shape of the shell). It differs by the longitudinal rows on the third segment and a less cylindrical shell. *E. anniae* could be the ancestor of *E. anomalum*, as the first occurrence of this species is recognized at Sample 586B-20-5, 60–62 cm. Close relationship seem to exist between *E. punctatum, E. anniae*, and *E. anomalum*, but the oldest species are very rare, occurring sporadically, and further examination is needed.

Eucyrtidium teuscheri gr. (Haeckel) sensu emend.
(Plate 5, Figs. 1–8)

Eucyrtidium teuscheri Haeckel, 1887, p. 1491, pl. 77, fig. 5.
Stichopilium variabilis Popofsky, 1908, p. 290, pl. 35, figs. 4–7.

Description. Four- to six-segmented shell; sinuous sutures between the segments. Cephalis hemispherical with a small, conical horn of the same length. Third segment longer and broader than the others. Fourth joint cylindrical. Apertural margin rarely observed. Cephalis and thorax with small subspherical pores and spiny walls. Vertical and dorsal spines prolonged as slight ribs along the thorax and the upper part of the abdomen. Pores large, subcircular, of variable sizes, and set in irregular, vertical rows.

Distribution. First occurrence not recognized. Rare in the *Diartus petterssoni* Zone in Hole 594 and in late Miocene to early Pliocene material. Common in late Pliocene to Pleistocene sediments from the subantarctic area, sparse in equatorial sediments of the same age.

Remarks. The individuals included in this group are quite variable. A provisional attempt is made to divide them into different subspecies when first and last occurrences of morphotypes are known. A subspecific name is not assigned to the oldest morphotypes because their first occurrence is unknown and individuals are too rare in the present material for an adequate description. An evolutionary lineage is proposed for late Miocene to living forms of this group (Fig. 2).

Eucyrtidium teuscheri **s.sp.indet.**
(Plate 5, Figs. 1-3)

Description. More than 10 vertical rows of pores on the third segment. Fifth segment very short but always recognized. Lateral and dorsal ribs not present on thorax.

Distribution. Rare and sporadic occurrences in the sediments of the *Diartus petterssoni* to *Stichocorys peregrina* Zone from Holes 586B and 594. Rare in Messinian samples from Spain and upper Miocene red clays from the South Indian Basin. Last occurrence in the *S. peregrina* Zone at Sample 586B-24-1, 60–62 cm and 594-24-4, 84–86 cm.

Remarks. The individuals included in this species group are quite variable. Further work is necessary to subdivide the group and understand its relationships with other eucyrtids of the same age.

Eucyrtidium teuscheri teuscheri **n.ssp.**
(Plate 5, Figs. 5-8)

Eucyrtidium teuscheri Haeckel, 1887, p. 1491, pl. 77, fig. 5.
Eucyrtidium (?) *teuscheri* Haeckel *in* Petrushevskaya, 1967, p. 121, pl. 68, fig. 1, 2.

Description. Four-segmented form with 8–10 vertical rows of pores on the third segment. External ribs very pronounced. Shell cylindrical after the third segment.

Holotype. Pl. 5, Fig. 6, Sample MD 75071-V-100 cm, slide 1.

Dimensions. Total length: 100–120 μm. Thoracic length: 20 μm. Maximum width: 40 μm.

Distribution. Very rare in the *Spongaster pentas* Zone. First common occurrence at Sample 586B-6-1, 60–61 cm in the *Pterocanium prismatium* Zone. Common in Pleistocene samples.

Remarks. Pleistocene forms are characterized by less cylindrical shells with more irregular pores.

Eucyrtidium teuscheri orthoporus **n.ssp.**
(Plate 5, Fig. 4)

Description. No internal ring between third and fourth segment, but slight stricture externally. Five to six vertical rows of subcircular pores. Shell cylindrical after the second segment.

Name. *orthos* (Greek: straight), *poros* (Greek: pore).

Holotype. Pl. 5, Fig. 4, Sample MD 73028-II-30 cm, slide 1 (Crozet Basin, Indian Ocean).

Dimensions. Nearly the same as for *E. teuscheri teuscheri*.

Distribution. Very rare in tropical sediments. Common in mid-latitude material from the subantarctic area. First occurrence at Sample 586B-16-1, 60–62 cm in the early *Spongaster pentas* Zone and at Sample 594-31-5, 84–86 cm (*Didymocyrtis antepenultima/penultima* Zone). Nonsporadic occurrences only in the *Pterocanium prismatium* Zone. Last occurrence at Sample 586B-4-1, 60–62 cm (early Pleistocene) and at Sample 594-15-1, 84–86 cm (late Pliocene to early Pleistocene). In both Hole 586B and Site 594, the last occurrence of this subspecies has no real significance because radiolarians are absent or very rare in all samples. Previous studies of Indian Ocean piston cores show that the last occurrence of *E. teuscheri orthoporus* occurs in the mid-Pleistocene period between 0.9 and 0.7 m.y. (Caulet, 1982).

Genus *STICHOCORYS* Haeckel, 1881

Type species. *S. wolffii* Haeckel, 1887, p. 1479, pl. 80, fig. 10.

Stichocorys johnsoni **n.sp.**
(Plate 6, Figs. 5, 6)

?Theoperid, gen. et sp. indet., Johnson, 1974, pl. 8, fig. 18.

Description. shell with four (or more ?) segments, distinctly separated by constrictions, the first three segments together forming a conical section. Cephalis subspherical, rough, poreless, and bearing a slightly curved apical horn generally longer than the first segment. Thorax subspherical, well developed, having 20–30 irregularly arranged subcircular pores. Third segment conical, longer and broader than any other, bearing two kinds of pores: ordinary small pores on the whole surface and a single row of pores twice as large as the others just below the lumbar stricture. Fourth segment generally ragged with smaller pores irregularly arranged. Entire apertural margin never observed.

Name. After D. A. Johnson, who first reported the morphotype.

Holotype. Pl. 6, Fig. 5, Sample 586B-20-5, 60–62 cm, slide 1.

Dimensions. Length of first, second, and third segments: 120–130 μm. Thoracic length: 40 μm. Abdominal length: 50–60 μm.

Distribution. First occurrence not recognized. Last occurrence in the *Stichocorys peregrina* Zone (Sample 586B-20-5, 60–62 cm) with a good reliability index.

Remarks. This morphotype seems to be related to the genus *Stichocorys* by the shape of the shell and the structure of the cephalis. It differs from other stichocorids in having a larger thorax and a big third segment (see figures of *S. peregrina* and *S. johnsoni* with same enlargement, Pl. 6, Figs. 4–6). Johnson and/or Nigrini (personal communication) show that Pacific Ocean forms (Pl. 6, Fig. 5) have no indentation on third segment like Indian Ocean forms (Pl. 6, Fig. 6). The species *Eucyrtidium diaphanes* (= *Calocyclas coronata* Carneval) is characterized by a single row of large pores just below the lumbar stricture but the shell has a different shape and the stratigraphic range is quite different. *E. diaphanes* could be a probable ancestor of *S. johnsoni* but the relationships between the two morphotypes must be studied more precisely.

Species List

Acanthodesmia circumflexa (Goll). *Giraffospyris circumflexa* Goll, 1969, p. 332, pl. 60, figs. 1–4, text-fig. 2. *Acanthodesmia circumflexa* (Goll) *in* Petrushevskaya, 1971, p. 274, pl. 142, figs. 4, 5.
Actinomma popofskii n. comb. *Echinomma popofskii* Petrushevskaya, 1967, p. 23, fig. 12 I–III.
Actinomma tetrapyla (Hays). *Prunopyle tetrapyla* Hays, 1965, p. 172, pl. 2, fig. 5. *Actinomma tetrapyla* (Hays) *in* Petrushevskaya, 1975, p. 569.
Acrobotrys tritubus Riedel, 1957, p. 80, pl. 1, fig. 5.
Amphirhopalum virchowii (Haeckel). *Euchitonia virchowii* Haeckel, 1862, p. 503, pl. 30, figs. 1–4. *Amphirhopalum virchowii* (Haeckel) *in* Dumitrică, 1973, p. 835, pl. 9, figs. 2–4; pl. 11, fig. 6; pl. 21, figs. 2–13.
Amphirhopalum ypsilon Haeckel, 1887, p. 522; Nigrini, 1971, p. 447, pl. 34.1, figs. 7a–c.
Androspyris anthropiscus Haeckel, 1887, p. 1093, pl. 83, fig. 8.
Antarctissa denticulata (Ehrenberg). *Lithobotrys ? denticulata* Ehrenberg, 1884a, p. 203. *Antarctissa denticulata* (Ehrenberg) *in* Petrushevskaya, 1967, p. 87, fig. 49, I–IV.
Antarctissa ewingi Chen, 1975, p. 457, pl. 16, figs. 5–9.
Antarctissa strelkovi Petrushevskaya, 1967, p. 89, fig. 51, III–VI.
Anthocyrtidium angulare Nigrini, 1971, p. 445, pl. 34.1, figs. 3a–b.
Anthocyrtidium ehrenbergi (Stöhr) gr. *Anthocyrtis ehrenbergi* Stöhr, 1880, p. 100, pl. 3, figs. 21a, b. *Anthocyrtidium ehrenbergi* (Stöhr) *in* Riedel et al., 1974, p. 712, pl. 60, fig. 10; pl. 61, fig. 1.
Anthocyrtidium michelinae Caulet, 1979, p. 132, pl. 2, figs. 8, 9.
Anthocyrtidium nosicaae Caulet, 1979, p. 132, pl. 2, fig. 6.
Artostrobus elegans (Ehrenberg) gr. n. comb. *Eucyrtidium elegans* Ehrenberg, 1854c, pl. 36, fig. 17; 1875, pl. 11, fig. 12.
Astrophacus inca (Clark and Campbell) n. comb. *Heliodiscus inca* Clark and Campbell, 1942, p. 38, pl. 3, fig. 17.
Astrophacus linckiaphormis (Clark and Campbell) n. comb. *Heliodiscus linckiaphormis* Clark and Campbell, 1942, p. 40, pl. 5, figs. 1, 2.

Axoprunum euterpe (Haeckel) gr. n. comb. *Stylosphaera euterpe* Haeckel, 1887, p. 135.
Axoprunum polycentrum (Campbell and Clark). *Druppatractus (Druppatractus) polycentrus* Campbell and Clark, 1942, p. 35, pl. 5, fig. 19. *Axoprunum polycentrum* (Campbell and Clark) *in* Petrushevskaya and Koslova, 1972, p. 521, pl. 10, figs. 11-12.
Botryocella cribrosa (Ehrenberg) gr. ? *Lithobotrys cribrosa* Ehrenberg, 1873, p. 237; 1875, pl. 3, fig. 20. *Botryocella* aff. *B. cribrosa* (Ehrenberg) gr. *in* Petrushevskaya and Koslova, 1972, p. 554, pl. 39, figs. 4-6.
Botryopyle (?) dionisi Petrushevskaya, 1975, p. 589, pl. 13, fig. 18, pl. 26, fig. 10.
Botryostrobus aquilonaris (Bailey) gr. *Eucyrtidium aquilonaris* Bailey, 1856, p. 4, pl. 1, fig. 9. *Botryostrobus aquilonaris* (Bailey) *in* Nigrini, 1977, p. 246, pl. 1, fig. 1.
Botryostrobus auritus/australis (Ehrenberg) gr. *Lithocampe australe* Ehrenberg, 1844a, p. 187; 1854b, pl. 35A, 21, fig. 18. *Botryostrobus auritus/australis* (Ehrenberg) gr. *in* Nigrini, 1977, p. 246, pl. 1, figs. 2-5.
Botryostrobus bramlettei bramlettei (Campbell and Clark) *Lithomitra bramlettei* Campbell and Clark, 1944, p. 53, pl. 7, figs. 10-14. *Botryostrobus b. bramlettei* (Campbell and Clark) *in* Caulet, 1979, p. 129, pl. 1, fig. 8.
Botryostrobus bramlettei pretumidulus Caulet, 1979, p. 129, pl. 1, fig. 5.
Botryostrobus bramlettei reedi (Campbell and Clark) n. comb. *Siphocampe (Siphocampula) reedi* Campbell and Clark, 1944, p. 58, pl. 7, fig. 24.
Botryostrobus bramlettei seriatus (Jørgensen) *Eucyrtidium seriatum* Jørgensen, 1905, p. 150. *Botryostrobus bramlettei seriatus* (Jørgensen) *in* Caulet, 1979, p. 130, pl. 1, fig. 6, text-fig. 4.
Botryostrobus bramlettei tumidulus (Bailey) *Eucyrtidium tumidulus* Bailey, 1856, p. 5, pl. 1, fig. 11. *Botryostrobus bramlettei tumidulus* (Bailey) *in* Caulet, 1979, p. 131, pl. 1, fig. 9.
Botryostrobus miralestensis (Campbell and Clark) *Dictyocephalus miralestensis* Campbell and Clark, 1944, p. 45, pl. 6, figs. 12-14. *Botryostrobus miralestensis* (Campbell and Clark) *in* Petrushevskaya and Koslova, 1972, p. 539, pl. 24, fig. 31.
Buccinosphaera invaginata Haeckel. 1887, p. 99, pl. 5, fig. 11.
Calocycletta caepa Moore, 1972, p. 149, pl. 2, figs. 4-7.
Calocycletta parva Moore, 1972, p. 148, pl. 1, figs. 1-5.
Centrobotrys thermophila Petrushevskaya, 1965, p. 115.
Circodiscus ellipticus (Stöhr) *Trematodiscus ellipticus* Stöhr, 1880, p. 108, pl. 4, fig. 16. *Circodiscus ellipticus* (Stöhr) gr. *in* Petrushevskaya, 1975, p. 575, pl. 6, figs. 1-6.
Clathrocyclas bicornis Hays, 1965, p. 179, pl. 3, fig. 3.
Clathrocyclas (Clathrocycloma) cabrilloensis Campbell and Clark, 1944, p. 48, figs. 1-3.
Clathrocyclas humerus Petrushevskaya, 1975, p. 586, pl. 15, figs. 7, 12, 22, 23, pl. 43, figs. 1, 2.
Clathrocyclas spatiosa (Ehrenberg) n. comb. *Cycladophora spatiosa* Ehrenberg, 1875, pl. 18, figs. 5, 6.
Clathrocyclas (Clathrocyclia) universa Clark and Campbell gr., 1942, p. 87-88, pl. 7, figs. 11-20.
Collosphaera polygona Haeckel gr., 1887, p. 96, pl. 13, fig. 15.
Collosphaera tuberosa Haeckel, 1887, p. 97; Nigrini, 1971, p. 445, pl. 34.1, fig. 1.
Collosphaera sp. A Knoll and Johnson, 1975, p. 63, pl. 1, figs. 1, 2, 7, pl. 2, figs. 4-6.
Cryptoprora ornata Ehrenberg, 1873, p. 222; 1875, pl. 5, fig. 8.
Cyclampterium (?) milowi Riedel and Sanfilippo, 1971, p. 1593, pl. 38, fig. 3; pl. 7, figs. 8, 9.
Cyclampterium ? neatum Sanfilippo and Riedel, 1970, p. 457, pl. 2, figs. 17, 18.
Cyrtocapsella cornuta Haeckel. *Cyrtocapsa (Cyrtocapsella) cornuta* Haeckel, 1887, p. 1513, pl. 78, fig. 9. *Cyrtocapsella cornuta* Haeckel *in* Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 19-20.
Cyrtocapsella elongata (Nakaseko). *Theocapsa elongata* Nakaseko, 1963, p. 185, pl. 3, figs. 4-5. *Cyrtocapsella elongata* (Nakaseko) *in* Sanfilippo and Riedel, 1970, p. 452, pl. 1, figs. 11-12.
Cyrtocapsella japonica (Nakaseko). *Eusyringium japonicum* Nakaseko, 1963, p. 193, text-figs. 20-21, pl. 4, figs. 1-3. *Cyrtocapsella japonica* (Nakaseko) *in* Sanfilippo and Riedel, 1970, p. 452, pl. 1, figs. 13-15.
Cyrtocapsella tetrapera (Haeckel). *Cyrtocapsa (Cyrtocapsella) tetrapera* Haeckel, 1887, p. 1512, pl. 75, fig. 12. *Cyrtocapsella tetrapera* (Haeckel) *in* Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 16-18.
Dendrospyris bursa Sanfilippo and Riedel, *in* Sanfilippo et al., 1973, p. 217, pl. 2, figs. 9-13.
Desmospyris biceps stabiloides (Petrushevskaya). *Desmospyris stabiloides* Petrushevskaya, 1972, fig. 1, no. 14. *Desmospyris biceps stabiloides* (Petrushevskaya) *in* Caulet, 1979, p. 136, pl. 4, fig. 8.
Desmospyris stabilis (Goll) n. comb. *Dendrospyris stabilis* Goll, 1968, p. 1422, pl. 173, figs. 16-18, 20, text-fig. 8.
Diartus hughesi (Campbell and Clark). *Ommatocampe hughesi* Campbell and Clark, 1944, p. 23, pl. 3, fig. 12. *Diartus hughesi* (Campbell and Clark) *in* Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, i.
Diartus petterssoni (Riedel and Sanfilippo). *Cannartus (?) petterssoni* Riedel and Sanfilippo, 1970, p. 520, pl. 14, fig. 3. *Diartus petterssoni* (Riedel and Sanfilippo) *in* Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, h.
Dictyophimus crisiae Ehrenberg, 1854a, p. 241.
Dictyophimus splendens (Campbell and Clark) n. comb. *Pterocorys (Pterocyrtidium) splendens* Campbell and Clark, 1944, p. 46, pl. 6, figs. 19, 20.
Dictyoprora mongolfieri (Ehrenberg). *Eucyrtidium mongolfieri* Ehrenberg, 1854c, pl. 36, fig. 18, B lower. *Dictyoprora mongolfieri* (Ehrenberg) *in* Nigrini, 1977, p. 250, pl. 4, figs. 1, 2.
Dictyoprora urceolus (Haeckel). *Dictyocephalus urceolus* Haeckel, 1887, p. 1305. *Dictyoprora urceolus* (Haeckel) *in* Nigrini, 1977, p. 251, pl. 4, figs. 9-10.
Didymocyrtis antepenultima (Riedel and Sanfilippo). *Ommatartus antepenultimus* Riedel and Sanfilippo, 1970, p. 521, pl. 14, fig. 4. *Didymocyrtis antepenultima* (Riedel and Sanfilippo) *in* Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1.
Didymocyrtis avita (Riedel). *Panartus avitus* Riedel, 1953, p. 808, pl. 84, fig. 7. *Didymocyrtis avita* (Riedel) *in* Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1.
Didymocyrtis laticonus (Riedel). *Cannartus laticonus* Riedel, 1959, p. 291, pl. 1, fig. 5. *Didymocyrtis laticonus* (Riedel) *in* Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, e.
Didymocyrtis penultima (Riedel). *Panarium penultimum* Riedel, 1957, p. 76, pl. 1, fig. 1. *Didymocyrtis penultima* (Riedel) *in* Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, f.
Didymocyrtis tetrathalamus (Haeckel). *Panartus tetrathalamus* Haeckel, 1887, p. 378, pl. 40, fig. 3. *Didymocyrtis tetrathalamus* (Haeckel) *in* Sanfilippo and Riedel, 1980, p. 1010, text-fig. 1, g.
Druppatractus irregularis Popofsky, 1912, p. 114, text-figs. 24-26.
Eucecryphalus petrushevskaae Caulet, 1979, p. 131, pl. 2, fig. 3.
Eucyrtidium anomalum (Haeckel). *Lithocampe anomala* Haeckel, 1860, p. 839. *Eucyrtidium anomalum* (Haeckel) *in* Haeckel, 1862, p. 323, pl. 7, figs. 11-13.
Eucyrtidium cienkowskii Haeckel gr. *Eucyrtidium cienkowskii* Haeckel, 1887, p. 1493, pl. 80, fig. 9.
Eucyrtidium indiensis Caulet, 1979, p. 134, pl. 4, fig. 5.
Eucyrtidium punctatum (Ehrenberg). *Lithocampe punctata* Ehrenberg, 1844b, p. 84. *Eucyrtidium punctatum* (Ehrenberg) Ehrenberg, 1847, p. 43; 1854c, pl. 22, fig. 24.
Haliometta miocenica (Campbell and Clark). *Heliosphaera miocenica* Campbell and Clark, 1944, p. 16, pl. 2, figs. 10-14. *Haliometta miocenica* (Campbell and Clark) *in* Petrushevskaya and Koslova, 1972, p. 517, pl. 9, figs. 8, 9.
Hexacontium hootsi Campbell and Clark, 1944, p. 14, pl. 2, fig. 5.
Hexacontium medusa (Ehrenberg) n. comb. *Haliomma medusa* Ehrenberg, 1854b, pl. 20, figs. 21, 22, 23, pl. 21, fig. 53, pl. 22, fig. 33.
Lamprocyclas hannai (Campbell and Clark) n. comb. *Calocyclas hannai* Campbell and Clark, 1944, p. 48, pl. 69, figs. 21, 22.
Lamprocyclas junonis (Haeckel) n. comb. *Theoconus junonis* Haeckel, 1887, p. 1401, pl. 69, fig. 7.
Lamprocyclas margatensis n. comb. *Calocyclas margatensis* Campbell and Clark, 1944, p. 47, pl. 6, figs. 17-18.
Lamprocyclas maritalis Haeckel, 1887, p. 1390, pl. 74, figs. 13, 14.
Lamprocyrtis heteroporos (Hays). *Lamprocyclas heteroporos* Hays, 1965, p. 179, pl. 3, fig. 1. *Lamprocyrtis heteroporos* (Hays) *in* Kling, 1973, p. 639, pl. 5, figs. 19-21, pl. 15, figs. 4, 5.
Lamprocyrtis neoheteroporos Kling. *Lamprocyrtis neoheteroporos* Kling, 1973, p. 639, pl. 5, figs. 17, 18, pl. 15, figs. 4, 5.

Lamprocyrtis nigriniae (Caulet). *Conarachnium nigriniae* Caulet, 1971, p. 3, pl. 3, figs. 1–4, pl. 4, figs. 1–4. *Lamprocyrtis nigriniae* (Caulet) *in* Kling, 1977, p. 217, pl. 1, fig. 17.

Liriospyris ovalis Goll, 1968, p. 1429, pl. 176, figs. 4, 6, 7; text-fig. 9.

Lithapium mitra (Ehrenberg) *Cornutella mitra* Ehrenberg, 1873, p. 221; 1875, pl. 2, fig. 8. *Lithapium (?) mitra* (Ehrenberg) *in* Riedel and Sanfilippo, 1970, p. 520, pl. 4, figs. 6, 7.

Lithomelissa ehrenbergi Bütschli, 1882, p. 519, pl. 33, fig. 21.

?*Lithomelissa haeckeli* Bütschli, 1882, p. 519, pl. 33, fig. 23.

Lithomelissa ultima Caulet, 1979, p. 129, pl. 1, figs. 2, 3.

Lithomitrella acephala (Ehrenberg). *Eucyrtidium acephalum* Ehrenberg, 1875, p. 70, pl. 11, fig. 5. *Lithomitrella acephala* (Ehrenberg) *in* Petrushevskaya, 1979, p. 150, figs. 380, 409.

Lithomitrella elizabethae (Clark and Campbell) n. comb. *Lithomitra elizabethae* Clark and Campbell, 1942, p. 92, pl. 9, fig. 18.

Lithomitrella minuta (Clark and Campbell). *Lithocampe minuta* Clark and Campbell, 1942, p. 93, pl. 9, fig. 17. *Lithomitrella minuta* (Clark and Campbell) *in* Petrushevskaya, 1979, p. 154, figs. 412, 413, 478.

Lithopera neotera Sanfilippo and Riedel, 1970, p. 454, pl. 1, figs. 24–26, 28.

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Pterocanium trilobum (Haeckel). *Dictyopodium trilobum* Haeckel, 1860, p. 839; 1862, p. 340, pl. 8, figs. 6–10. *Pterocanium trilobum* (Haeckel) *in* Haeckel, 1887, p. 1333.

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Saccospyris preantarctica Petrushevskaya, 1975, p. 589, pl. 13, figs. 19, 20.

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Solenosphaera omnitubus omnitubus Riedel and Sanfilippo, 1971, p. 1586, pl. 1A, fig. 24, pl. 4, figs. 1, 2.

Spirocyrtys gyroscalaris Nigrini, 1977, p. 258, pl. 2, figs. 10, 11.

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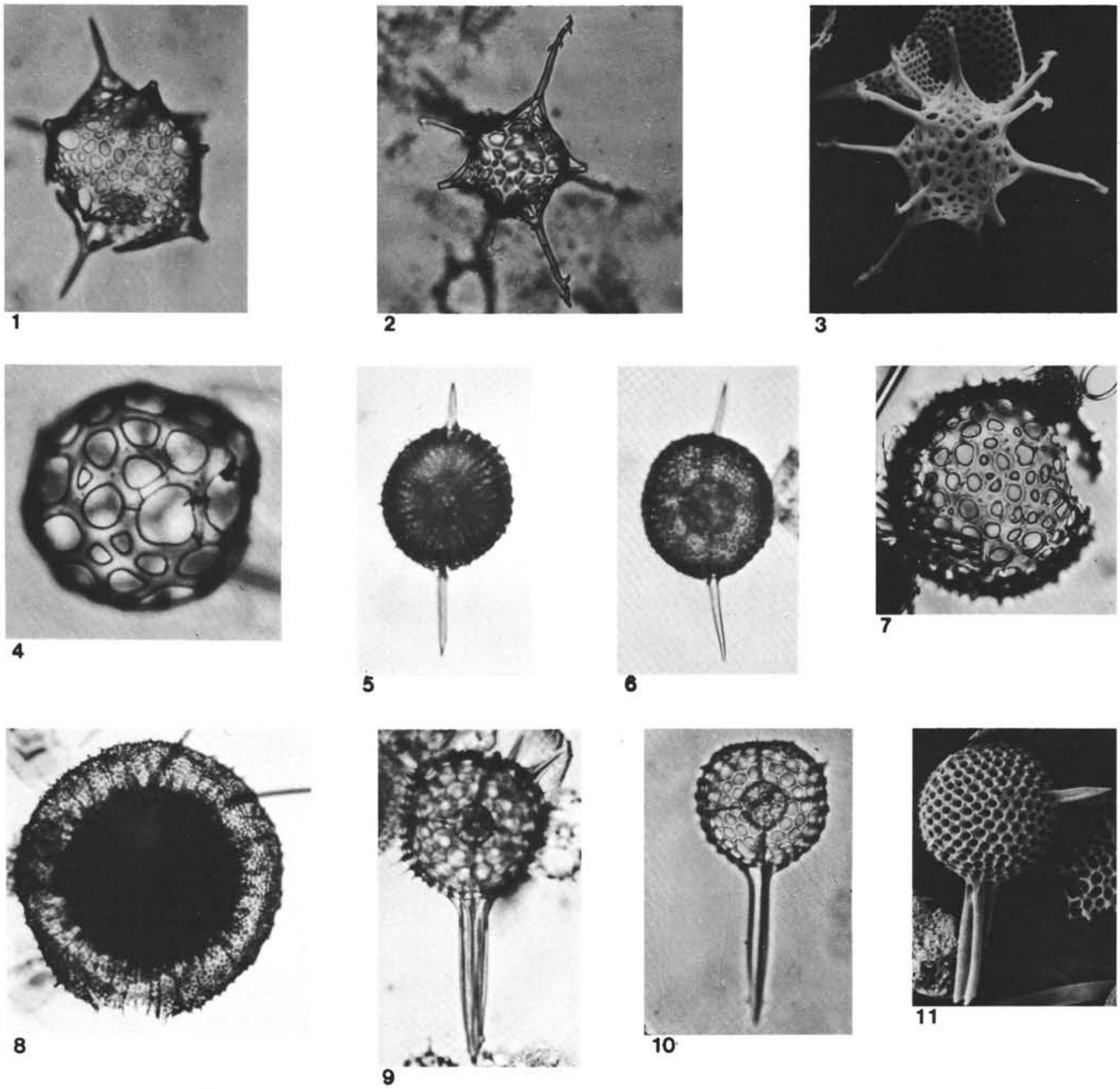

Plate 1. **1.** *Acrosphaera spinosa fasciculopora*, holotype, Sample 586B-20-3, 60–62 cm; ×250. **2–3.** *Acrosphaera spinosa hamospina*, (2) holotype, Sample 586B-23-3, 60–62 cm; ×200; (3) Sample MD 77157-VII-0, 70 cm; ×200. **4.** *Collosphaera polygona* group, Sample 594-51-1, 84–86 cm; ×400. **5–6.** *Stylatractus* aff. *universus*, (5) Sample 594-29-4, 84–86 cm; ×270; (6) Sample 594-31-4, 84–86 cm; ×270. **7.** *Polysolenia murrayana* group, Sample 594-37-1, 84–86 cm; ×230. **8.** *Spongodiscus* sp., Sample 594-28-1, 84–86 cm; ×200. **9–11.** *Axoprunum(?) monostylum*, (9) holotype, Sample 586B-5-4, 60–62 cm; ×250; (10) Sample 586B-4-6, 60–62 cm; ×250; (11) Langhian, Spain, Sample 69-34; ×250.

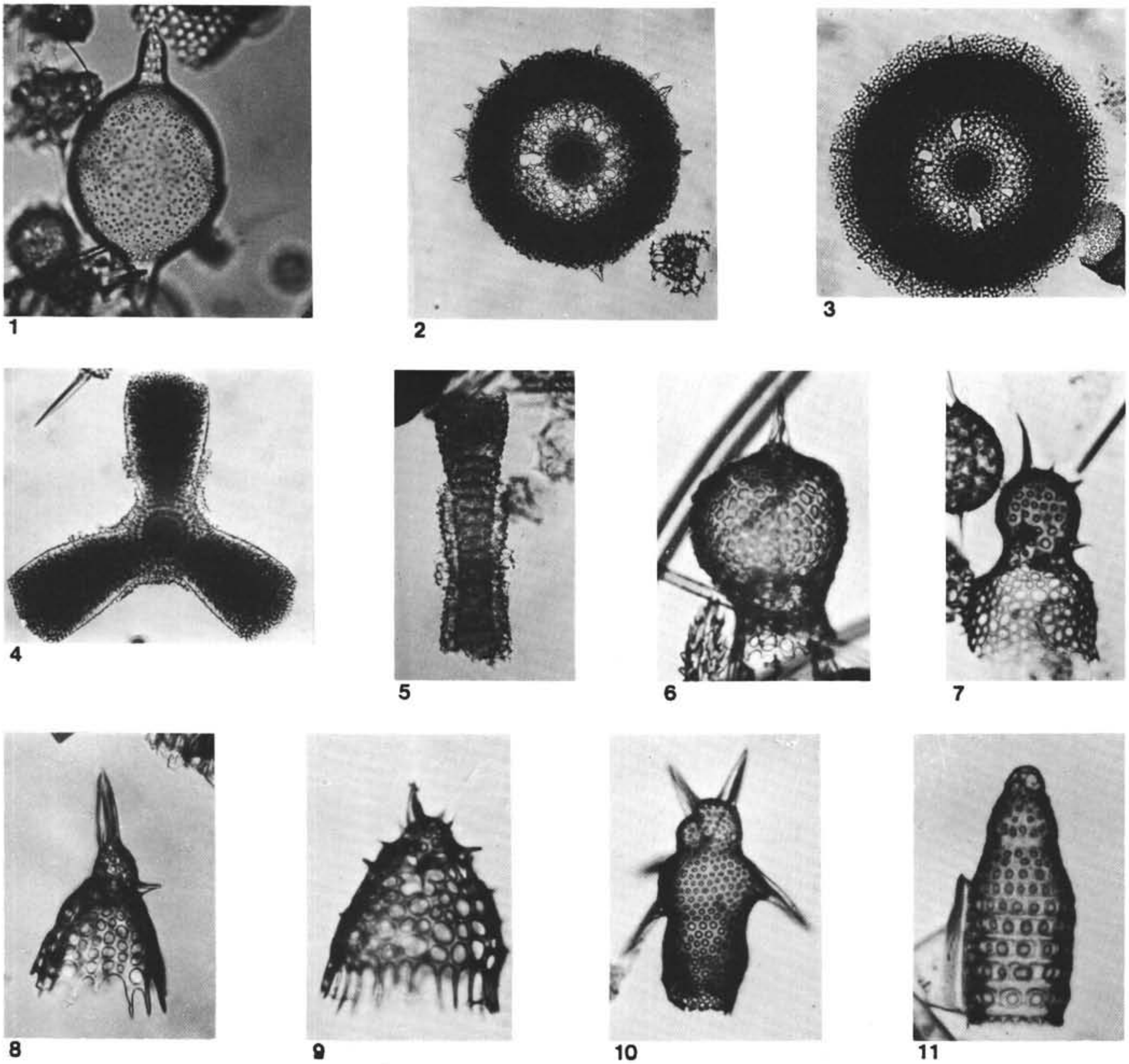

Plate 2. **1.** *Siphonosphaera hyalina*, holotype, Sample 586B-6-3, 60–62 cm; ×300. **2–3.** *Spongodiscus klingi*, (2) Sample 586B-18-1, 60–62 cm; ×200, (3) holotype, Sample 586B-19-3, 60–62 cm; ×200. **4.** *Rhopalastrum oracutibrachium*, holotype, Sample 586B-23-5, 60–62 cm; ×190. **5.** *Tessarastrum* sp., Sample MD 81481-III-24 cm; ×200. **6.** *Lithomelissa* sp., Sample 592-40-4, 40–42 cm; ×300. **7.** *Lithomelissa ehrenbergi*, Sample 594-52-2, 84–86 cm; ×280. **8.** *Pseudodictyophimus* sp., Sample 594-41-2, 84–86 cm; ×250. **9.** *Ceratocyrtis* sp., Sample 594-52-2, 84–86 cm; ×320. **10.** *Nasselaria* gen. et sp. indet., Sample 594-49-1, 84–86 cm; ×300. **11.** *Siphocampe*(?), Sample 594-48-2, 84–86 cm; ×500.

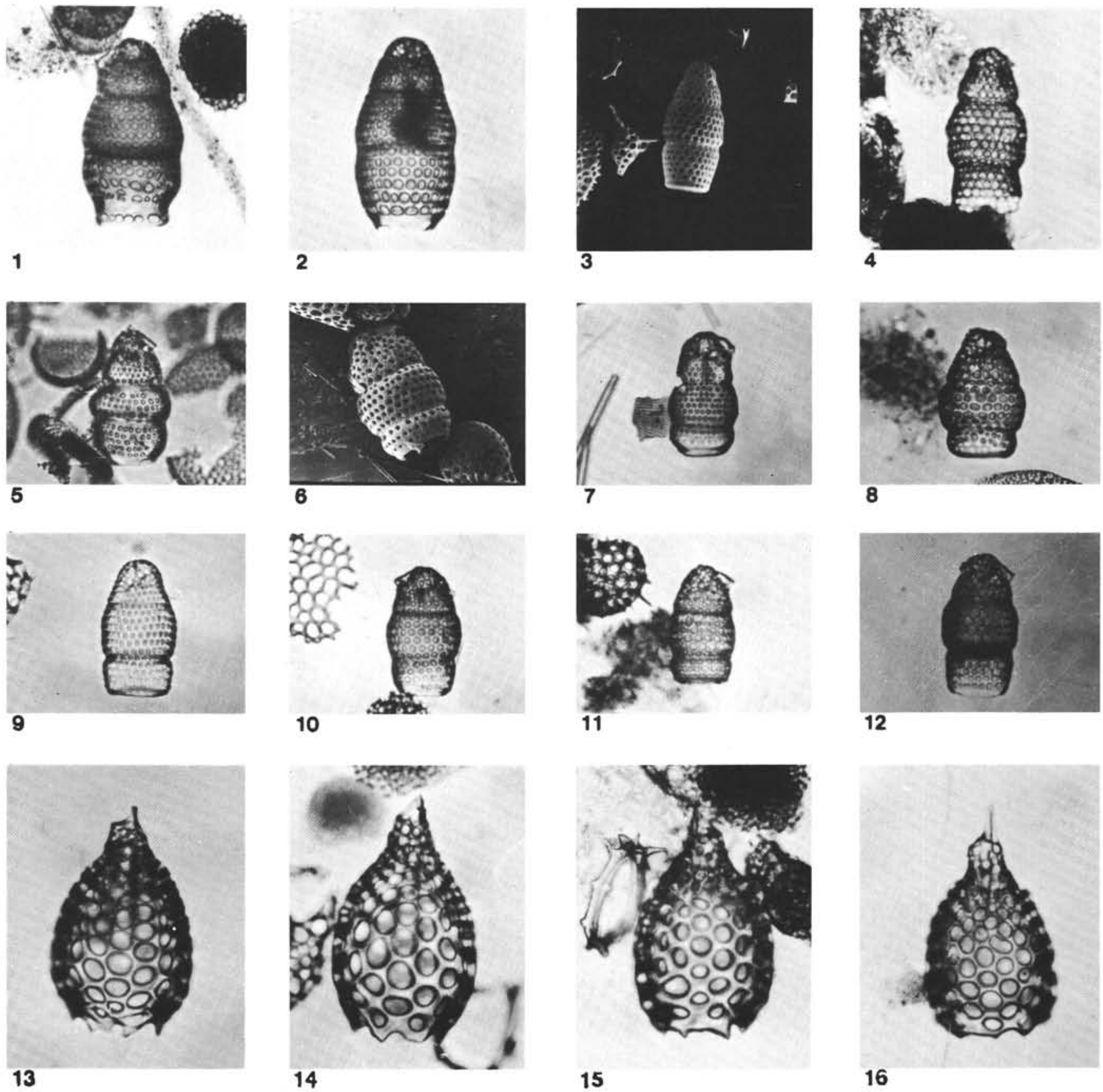

Plate 3. (Figs. 1–12 ×270; Figs. 13–16 ×310.) **1, 2.** *Phormostichoartus(?) fistula*, (1) Sample 594-52-2, 84–86 cm; (2) Sample 594-30-4, 84–86 cm. **3, 4, 9, 10, 12.** *Phormostichoartus pitomorphus*, (3) Sample "Valdivia" 62; (4) Sample 594-9-4, 84–86 cm; (9) Sample 586B-8-3, 60–62 cm, (10) Sample MD 75072-VIII-60 cm; (12) holotype, Sample MD 75072-VI-100 cm. **5, 6.** *Phormostichoartus platycephala*, (5) Messinian, Spain, Sample 76285; (6) Sample MD 75072-IX-100 cm. **7, 8, 11.** *Phormostichoartus pitomorphus–P. platycephala*, (7) Sample MD 83502-V-45 cm; (8) Sample MD 75075-X-48 cm; (11) Sample MD 75075-IX-140 cm. **13–16.** *Lamprocyrtis daniellae*, (13) Sample 586B-15-3, 60–62 cm; (14) holotype, Sample 586B-16-1, 60–62 cm, (15) Sample 586B-16-1, 60–62 cm; (16) Sample 586B-16-1, 60–62 cm.

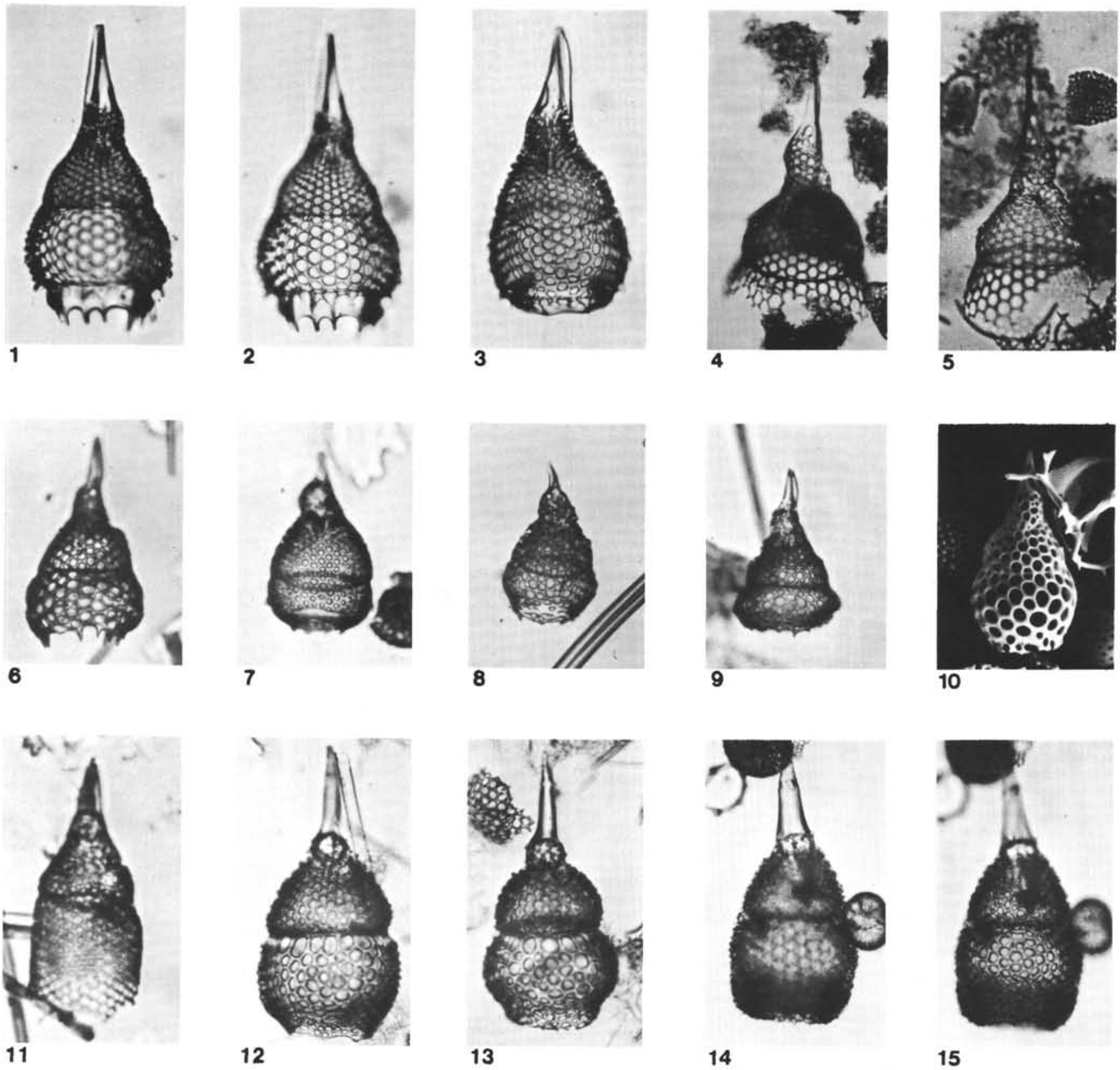

Plate 4. (Figs. 1–10 ×230.) **1, 2.** *Lamprocyclas* aff. *maritalis*, (1) Sample 594-29-4, 84–86 cm; (2) Sample 594-29-4, 84–86 cm. **3.** *Lamprocyclas margatensis*, Sample 586B-16-3, 60–62 cm. **4, 5.** *Pterocorys longicollis*, (4) holotype, Sample 586B-6-2, 60–62 cm; (5) Sample 586B-6-2, 60–62 cm. **6.** *Lamprocyclas* sp., Sample 594-41-2, 84–86 cm. **7.** *Lamprocyclas* sp., Sample 594-52-2, 84–86 cm. **8.** *Lamprocyclas* sp., Sample 594-29-4, 84–86 cm. **9.** *Lamprocyclas* sp., Sample 594-30-4, 84–86 cm. **10.** *Lamprocyclas junonis*, Sample "Valdivia" 62. **11.** *Pterocorys* sp., Sample 592-40-2, 40–42 cm; ×300. **12, 13.** ?*Lophocyrtis* sp., Sample 592-40-1, 40–42 cm; ×200. **14, 15.** ?*Thyrsocyrtis* sp., Sample 592-39-3, 40–42 cm; ×100.

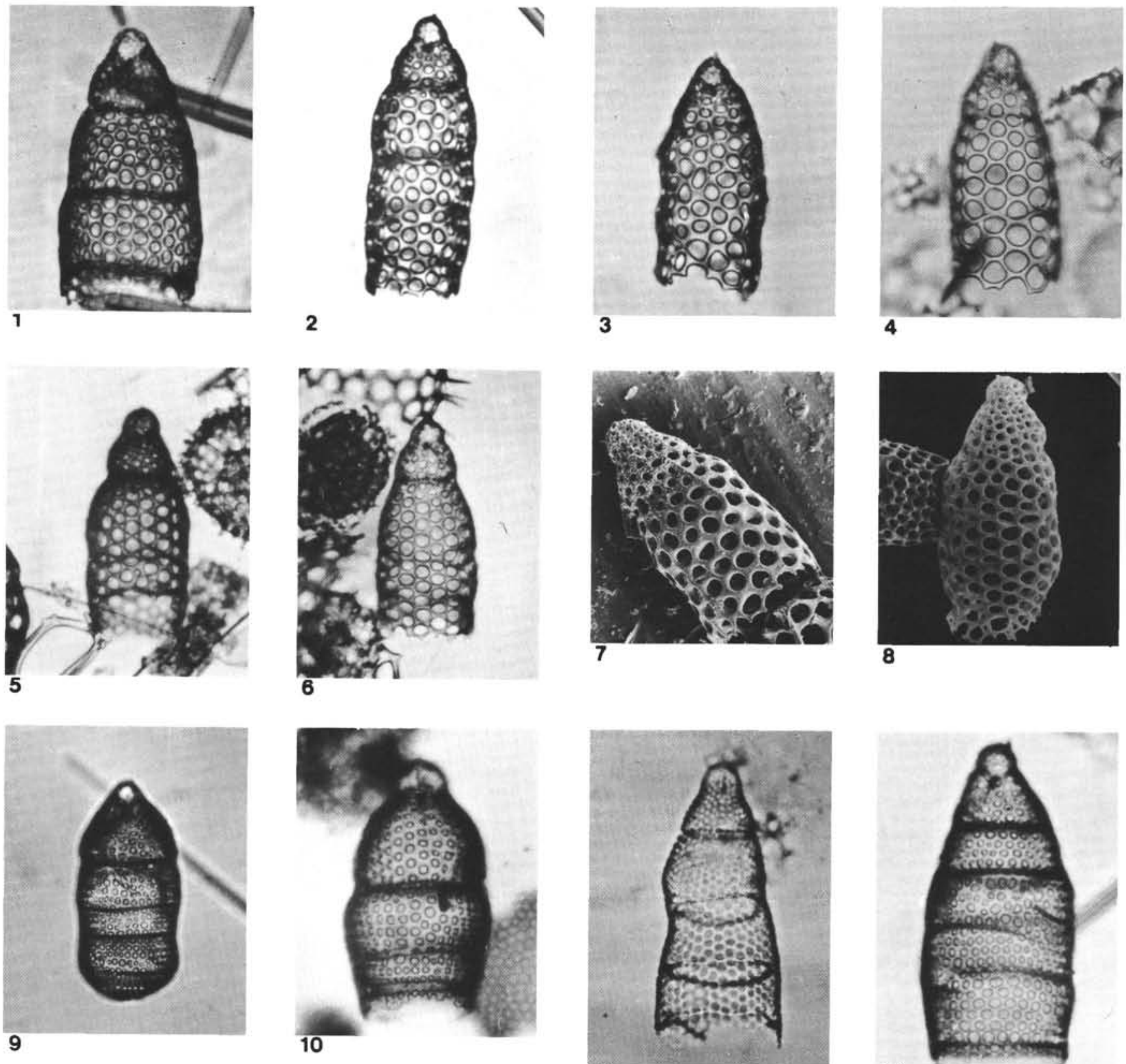

Plate 5. (All Figures ×380.) **1–3.** *Eucyrtidium* ? *teuscheri* gr., (1) Sample 594-52-1, 84–86 cm; (2) Sample 594-41-2, 84–86 cm; (3) Sample 252-6-3, 20–21 cm. **4.** *Eucyrtidium teuscheri orthoporus*, holotype, Sample MD 73028-II-30 cm. **5–8.** *Eucyrtidium teuscheri teuscheri*, (5) Sample MD 75072-VIII-111 cm; (6) holotype, Sample MD 75071-V-100 cm; (7) Sample MD 75072-IX-100 cm; (8) Sample MD 75072-II-60 cm. **9.** *Eucyrtidium punctatum*, Sample MD AET 75002-70 cm. **10.** *Eucyrtidium anniae*, holotype, Sample 594-31-4, 84–86 cm. **11.** *Eucyrtidium indiensis*, Sample 586B-15-1, 60–62 cm. **12.** *Eucyrtidium* sp., Sample 594-38-1, 84–86 cm.

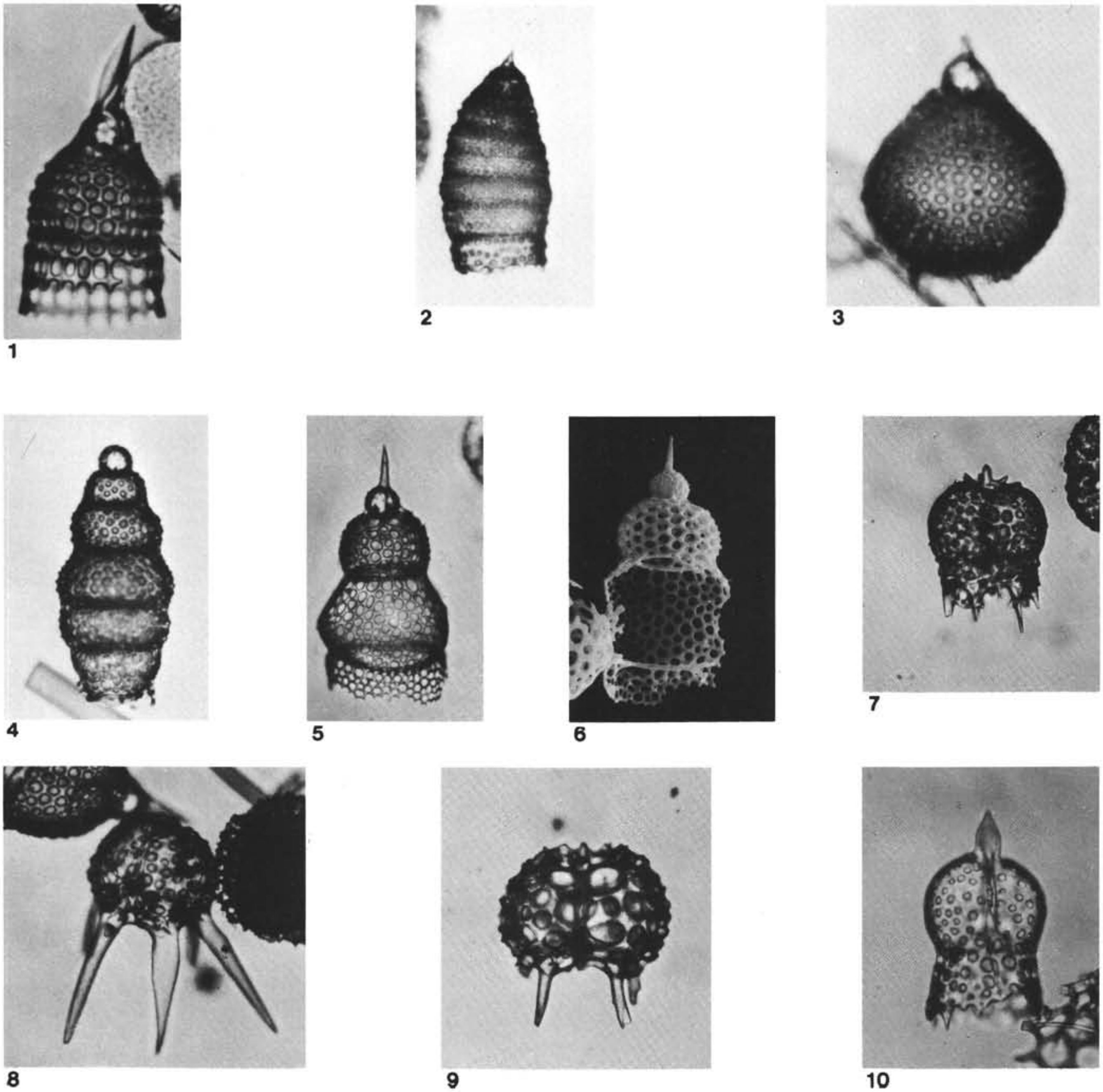

Plate 6. **1.** *Clathrocyclas* sp., Sample 592-39-3, 40–42 cm; ×450. 2. *Botryostrobus* sp., Sample 594-48-2, 84–86 cm; ×530. **3.** ?*Theocorys* sp., Sample 592-39-3, 40–42 cm; ×270. **4.** *Stichocorys peregrina*, Sample 594-24-4, 84–86 cm; ×400. **5, 6.** *Stichocorys johnsoni*, (5) holotype, Sample 586B-20-5, 60–62 cm; ×400; (6) Sample MD 77157-VI-20 cm; ×400. **7–10.** Acanthodesmiidae gen. et sp. indet., Sample 592-39-3, 40–42 cm; ×350.