18. COCCOLITH AND SILICOFLAGELLATE STRATIGRAPHY, NORTHERN MID-ATLANTIC RIDGE AND REYKJANES RIDGE, DEEP SEA DRILLING PROJECT LEG 49

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INTRODUCTION

Leg 49 of the Deep Sea Drilling Project recovered 192 cores at eight drilling sites, 407 through 414 (Figure 1). Light-microscope techniques were used to study the coccoliths, silicoflagellates, and sponge spicules of 120 samples from these cores. The coccolith zonation of the samples follows Bukry (1975a), and is summarized in Figure 2. Silicoflagellate zonation, summarized in Figure 3, is explained in text. Siliceous sponge spicules are common in many samples and are briefly discussed and illustrated. One new silicoflagellate, *Distephanus sulcatus,* from the Pliocene of Site 407, is described.

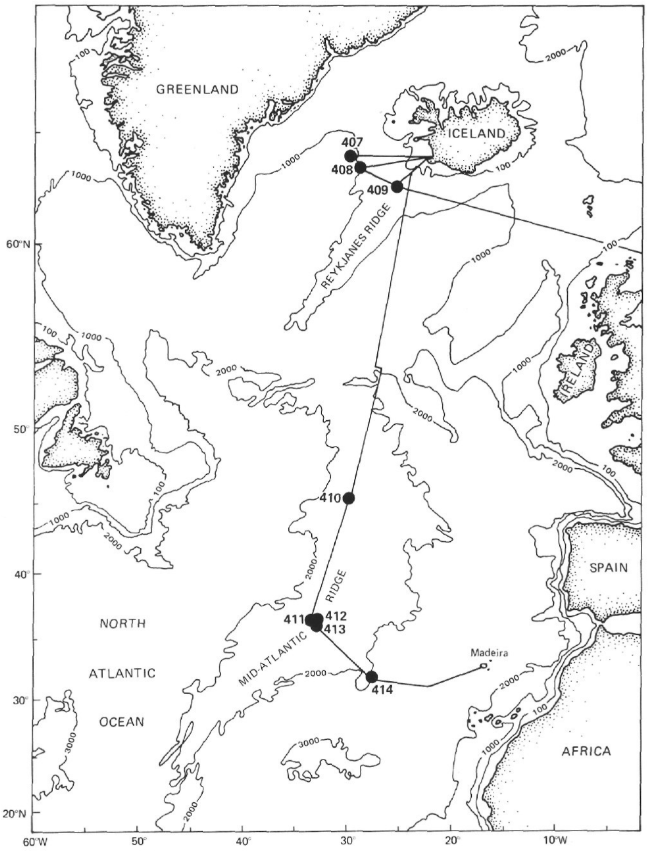


Figure 1. *Location of Deep Sea Drilling Project sites for Leg 49. Depth contours in fathoms.*

SITE SUMMARIES

Site 407
(lat 63°56.32′ N, long 30°34.56′ W, depth 2472 m)

Site 407, on the western flank of the Reykjanes Ridge between Iceland and Greenland at the position of magnetic anomaly 13 (approximately 36 to 38 m.y.), contains coccolith assemblages ranging from lower Oligocene to Holocene. Silicoflagellates are common in the Pliocene and lower Miocene.

The oldest coccolith assemblage occurs in Sample 407-43, CC (405 to 424 m), which is a sandy calcareous claystone recovered between cores of vesicular aphyric basalt. The presence of *Isthmolithus recurvus, Chiasmolithus oamaruensis,* and *Reticulofenestra hillae* in the absence of *Coccolithus formosus, Discoaster barbadiensis,* and *Reticulofenestra umbilica* suggests the lower Oligocene *Helicosphaera reticulata* Zone. A possibly higher zonal assignment is indicated by the presence of two specimens of *Helicosphaera* sp. cf. *H. perch-nielsenasae,* which is generally accorded a middle Oligocene appearance. Because *Isthmolithus recurvus* is considered a reliable stratigraphic indicator at high latitude (Martini, 1971; Bukry, 1975a; Müller, 1976), a lower Oligocene *H. reticulata* Zone or *Sphenolithus predistentus* Zone assignment is made. A cool-water character of the assemblage is shown by the common occurrence of *Chiasmolithus altus* and the paucity of *Discoaster* sp. cf. *D. nodifer* and *Sphenolithus* sp.

The oldest sample that was available, from 17 meters above the top of the basalt interval, 407-31-4, 91-93 cm (287 m), contains a coccolith assemblage which is probably correlative with the *Sphenolithus ciperoensis* Zone on the basis of common *Chiasmolithus altus, Dictyococcites bisectus,* and *Zygrhablithus bijugatus*. The assemblage is dominated by *Coccolithus pelagicus* s. ampl.; *Discolithina* spp., *Cyclicargolithus abisectus, C. floridanus, Discoaster deflandrei, Sphenolithus moriformis,* and *Triquetrorhabdulus carinatus* also occur. Because *C. altus, D. bisectus,* and *Z. bijugatus* occur as scarce reworked specimens through the lower Miocene of Site 407, their abundance in Core 31 below the first *Helicosphaera carteri* is used to make the upper Oligocene. The Oligocene/Miocene boundary is not distinct, because of reworking and a paucity of *Sphenolithus*. On the basis of the appearance of *Helicosphaera carteri,* the boundary is tentatively placed between samples from Cores 29 and 30 (263 to 282 m). These cores also contain the only specimens from Site 407 of the diatoms *Rocella gelida* and *R. schraderi* (Bukry, this chapter). These species have a brief acme near the Oligocene/Miocene boundary (Ling, 1972; Bukry, 1976a; in press c).

Lower Miocene coccolith assemblages from Cores 20 to 24 (177 to 225 m) lack zonal marker species, but silicoflagellates show a three-zone sequence from the *Naviculopsis lata* Zone to the *Corbisema triacantha* Zone. The lack of coccolith resolution caused by a lack of short-ranged marker

System or Series	Zone	Subzone	Hole 407	408	409	410	411A	412
Quaternary	*Emiliania huxleyi*		1-2	1-2		1-4		1-2 3-5/4-4
	Gephyrocapsa	*Ceratolithus cristatus*						5-4
	oceanica	*Emiliania ovata*	3-2/5-2			3-4/5-4	2-2	6-2/7-2
	Crenalithus	*Gephyrocapsa caribbeanica*		3-2	2-2/4-2	8-2	3-1	8-4/14-6
	doronicoides	*Emiliania annula*		4-4?	5-2/7-2?	10-7		
Pliocene		*Cyclococcolithina macintyrei*				11-3/14-2		
	Discoaster	*Discoaster pentaradiatus*	6-2/7-2			14-4/14-6		
	brouweri	*Discoaster surculus*						
		Discoaster tamalis		5-2/11-4		15-4/16-3		
	Reticulofenestra	*Discoaster asymmetricus*						
	pseudoumbilica	*Sphenolithus neoabies*	9-2/14-4					
	Amaurolithus	*Ceratolithus rugosus*						
	tricorniculatus	*Ceratolithus acutus*						
		Triquetrorhabdulus rugosus						
Miocene	*Discoaster*	*Amaurolithus primus*	16-2/17-2	13-2		18-2/22-2		
	quinqueramus	*Discoaster berggrenii*				24-2/26-2		
	Discoaster	*Discoaster neorectus*		16-2/21-4		28-2		
	neohamatus	*Discoaster bellus*				30-2/32-2		
	Discoaster	*Catinaster calyculus*				34-2		
	hamatus	*Helicosphaera carteri*						
	Catinaster coalitus			24-2/27-2				
	Discoaster	*Discoaster kugleri*						
	exilis	*Coccolithus miopelagicus*		28-2/30-2				
	Sphenolithus heteromorphus			31-2				
	Helicosphaera ampliaperta		18-4/19-2	32-6/33-4				
	Sphenolithus belemnos		19, CC	34-4				
	Triquetrorhabdulus	*Discoaster druggii*	20-2/29-4					
	carinatus	*Discoaster deflandrei*						
Oligocene		*Cyclicargolithus abisectus*	30-4					
	Sphenolithus	*Dictyococcites bisectus*	31-4					
	ciperoensis	*Cyclicargolithus floridanus*						
	Sphenolithus distentus							
	Sphenolithus predistentus		43, CC					
	Helicosphaera	*Reticulofenestra hillae*						
	reticulata	*Coccolithus formosus*						
		Coccolithus subdistichus						

Figure 2. *Coccolith zonation of core samples from Deep Sea Drilling Project Leg 49. (The numbers assigned to zonal intervals are core and section numbers of samples examined. Where a zone or subzone is represented in samples from two or more sections, the highest and lowest are given, separated by a slash.)*

System, Series, or Subseries	Zone/Subzone	Site 407	408	410	412
Quaternary	*Dictyocha aculeata*			3-4/8-4	1-1/5-3
	Mesocena quadrangula				6-2/14-4
	Dictyocha stapedia stapedia			10-7/14-6	
Pliocene	*Distephanus speculum*	7-2/14-4	5-1/12-2		
Upper Miocene	*Distephanus speculum/Mesocena circulus*		13-2/23-3		
	Distephanus longispinus		24-2		
Middle Miocene	*Corbisema triacantha*	18-4/?20-2	25-6/?30-2		
Lower Miocene	*Naviculopsis quadrata*	22-2/24-1			
	Naviculopsis lata	24-2/24-6			
Upper Oligocene	*Naviculopsis biapiculata*	30-4			

Figure 3. *Summary of silicoflagellate zonal assignments for Deep Sea Drilling Project Leg 49. (The numbers assigned to zonal intervals are core and section numbers of samples examined. Where a zone or subzone is represented in samples from two or more sections, the highest and lowest are given, separated by a slash.)*

species below the *Helicosphaera ampliaperta* Zone in Cores 18 and 19 (158 to 177 m) is similar to the relationship reported by Müller (1976) for cores from the more northerly Norwegian-Greenland Sea. The occurrence of *Helicosphaera ampliaperta* in Cores 18 and 19 and *Sphenolithus belemnos* in Core 19 (reworked?) above the range of silicoflagellate *Naviculopsis quadrata* s. str. (Cores 22 to 24) supports a correlation with the middle or lower Miocene *H. ampliaperta* Zone, (Ryan et al., 1974).

Small but well-formed specimens of *Discoaster quinqueramus* with distinct knobs are sparse in Cores 16 and 17 (139 to 158 m), and signify the upper Miocene *Discoaster quinqueramus* Zone. A middle or late Miocene sedimentary break of approximately 10 m.y., or a greatly compressed section, is indicated between the samples examined from Cores 17 and 18. Placoliths, especially *Coccolithus pelagicus* s. ampl., predominate in upper Miocene and higher samples, suggesting generally cool conditions for most younger intervals. Discoasters are sparse and belong to long-ranging species such as *Discoaster braarudii, D. intercalaris,* and *D. variabilis*. The low diversity of the coccolith assemblages involves the absence of many subtropical and tropical genera such as *Amaurolithus, Ceratolithus, Discolithina, Rhabdosphaera, Scyphosphaera, Sphenolithus,* and *Triquetrorhabdulus*. The upper Pliocene lacks discoasters and is identified by the disappearance of *Reticulofenestra pseudoumbilica* in Core 7 (54 to 63 m) and by the presence of *Helicosphaera sellii* and *Cyclococcolithina macintyrei* in Core 6 (44 to 54 m). Cores 1, 3, and 5 (1 to 44 m) contain *Gephyrocapsa caribbeanica,* indicating Quaternary.

Most upper Miocene to Quaternary samples prepared for silicoflagellate study proved barren; these include samples from Cores 1, 2, 3, 5, 13, 16, and 17. Silicoflagellates are common in two of the samples examined from Cores 7 and 14 (Figure 4). The predominance of just a few taxa of *Distephanus* indicates cold-water conditions (Ciesielski, 1975; Poelchau, 1976).

Site 408
(lat 63°22.63′N, long 28°54.71′W, depth 1624 m)

Site 408, on the western flank of the Reykjanes Ridge west of Iceland at the position of magnetic anomaly 6 (approximately 20 m.y.), contains coccolith assemblages ranging from lower Miocene to Holocene. Silicoflagellates are missing in the lower Miocene, common in the middle Miocene, and abundant in the upper Miocene and Pliocene.

The oldest coccolith assemblage, which occurs in Sample 408-34-4, 34-36 cm (318 m), is assigned to the lower Miocene *Sphenolithus belemnos* Zone because of the occurrence of *Sphenolithus* sp. cf. *S. belemnos, Helicosphaera ampliaperta, H. carteri,* and *Discoaster deflandrei*. The estimated age of 17 to 19 m.y. for the overlap of *S. belemnos* and *H. ampliaperta* (Nakagawa et al., 1974; Ryan et al., 1974; LaBrecque et al., 1977) is only slightly younger than the suggested age for the sea floor magnetic anomaly.

The lower or middle Miocene *Helicosphaera ampliaperta* Zone in Samples 408-32-6, 84-86 cm (301 m) and 408-33-4, 76-78 cm (309 m), contains a coccolith species array similar to the correlative assemblage at Site 407. Both samples contain *Sphenolithus heteromorphus, Helicosphaera ampliaperta, H. carteri, Discoaster deflandrei,* and *Cyclicargolithus floridanus*. The *H. ampliaperta* Zone is assigned, here, to the lower or middle Miocene because *H. ampliaperta* ranges up into the lower part of the type Langhian Stage (Bramlette and Wilcoxon, 1967; Martini, 1971) which has been used as the stratotype for the lower middle Miocene in recent years (Ewing et al., 1969; Berggren, 1971; Ryan et al., 1974). The foraminiferal *Orbulina* datum, which has also been used for the lower to middle Miocene boundary by Berggren (1972), Berggren and Van Couvering (1973), and, seemingly, by Martini (1971, 1976), would place the boundary higher than the *H. ampliaperta* Zone, within the *Sphenolithus heteromorphus* Zone. Although conflicts with stratotype definitions could arise, the pragmatic use of generic events of planktonic foraminifers for series and subseries boundaries (Berggren, 1972) is an appealing and effective means for transoceanic chronostratigraphy. But, other more abundant and less solution-susceptible fossil groups, such as coccoliths, might also be effectively employed in this manner, leading to slightly different subseries assignments. Differences between stratotype concepts and generic events of planktonic and benthic fossil groups must still be resolved.

Placoliths predominate in the middle Miocene of Cores 24 to 31 (219 to 295 m). Sparse discoasters include *Discoaster* sp. cf. *D. exilis, D. subsurculus,* and *D. variabilis*. *Helicosphaera carteri* and variants are common, and together with the presence of *Sphenolithus neoabies* and *Coccolithus miopelagicus* suggest cool-temperate conditions.

Except for common *Discoaster variabilis* in Sample 408-16-2, 45-47 cm (143 m), discoasters are scarce through the upper cores. Small *Discoaster quinqueramus* in Core 13 and *D.* sp. cf. *D. loeblichii* and *D.* sp. cf. *D. pseudovariabilis* in Core 16 are the only short-ranged species observed.

Scyphosphaera, which is believed to suggest shallow-oceanic deposits and relatively warm water in the Pacific (Roth and Berger, 1975), occurs in Sample 408-7-2, 40-42 cm (59 m), where cool-water *Coccolithus pelagicus* also predominates. Cool water is also suggested by the low 0 to 2 per cent level of *Dictyocha* in nearby silicoflagellate assemblages from Cores 5 and 8. Therefore, the temperature tolerance of *Scyphosphaera* is extended by this occurrence west of Iceland. Elsewhere in the North Atlantic it was recorded between 50°N and 57°N lat at Sites 111, 112, and 116 (Perch-Nielsen, 1972), but was absent at more northerly sites in the Norwegian-Greenland Sea (Müller, 1976).

Younger coccolith assemblages from Cores 1 to 5 (0 to 48 m) lack diagnostic forms and have abundant *Coccolithus pelagicus*.

Silicoflagellate assemblages at Site 408 are exceptional because of the long range of *Mesocena circulus* s. ampl. through the middle and upper Miocene, the common occurrence of cool-water *Distephanus speculum speculum* throughout, and the common occurrence of *Distephanus jimlingii* specimens with small symmetric rosettes of apical openings (Figures 5 and 6). *Distephanus jimlingii* and *D. frugalis* from middle latitudes (37°N to 41°N), at abundances of 1 to 6 per cent, were reported for North Pacific Deep Sea Drilling Sites 303, 304, and 310. They were said to be possible cold-water guide species because they were absent in the equatorial Pacific. These species are especially common (up to 75%) at Site 408. They are sparser at other, more southerly, middle-latitude sites in the Atlantic, where abun-

Series or Subseries	Pliocene		Lower Miocene									Olig?
Depth (m)	56	125	163	170	179	198	215	217	220	224	265	278
Site 407 Sample (Interval in cm) / Species	7-2, 59-60	14-4, 15-17	18-4, 50-52	19-2, 50-52	20-2, 5-7	22-2, 20-22	24-1, 25-27	24-2, 50-52	24-4, 50-52	24-6, 119-121	29-4, 20-22	30-4, 103-105
Cannopilus sp. cf. *C. ernestinae*				2	<1							
Corbisema flexuosa					<1	2	17	5	7	5	X	X
C. triacantha s. ampl.					1	7	35	53	48	33	X	X
Dictyocha brevispina ausonia							1					
D. brevispina brevispina							2					
D. fibula						2	1					
D. pentagona						6	2	3				
D. sp.								1				
Distephanus boliviensis	3	15										
D. boliviensis (cannopilean)	1											
D. boliviensis (pentagonal)												
D. crux s. ampl.	<1	28										
D. frugalis		1	62	60	34	29	7	15	24	25	X	X
D. jimlingii	6											
D. sp. cf. *D. hannai*	31							1				
D. longispinus			9	4								
D. sp. cf. *D. longispinus*			4	4	6				1			
D. sp. cf. *D. schauinslandii*								1				
D. speculum diommata				6	3		4	3	2			
D. speculum haliomma			4		25	4	10	9	3	1		X
D. speculum hemisphaericus			1		11	5	6	4	3	2		
D. speculum minutus	4	55										
D. speculum pentagonus					1							
D. speculum speculum	30	3	11	12	5	1	4	2	1	3		X
D. speculum triommata			5	8	8	5	6	5	5	1		
D. sp. cf. *D. staurodon*					<1	1		1		4		
D. sulcatus	6											
D. varians	<1									<1		
Mesocena apiculata apiculata			3								X	X
M. apiculata curvata			1	2	2	4		2	6	11	X	
M. apiculata glabra					<1							
M. circulus s. ampl.	18											
M. elliptica					<1							
M. pappii										1		
Naviculopsis sp. cf. *N. biapiculata*						1	3					X
N. sp. cf. *N. constricta* (elongate)												X
N. lata						11		1	3			
N. sp. cf. *N. lata* (angular)										14		
N. sp. cf. *N. lata* (elongate)						8						
N. navicula					1							
N. ponticula				2								
N. quadrata s. str.						19	5					
(Macrora stella)					(2)		(1)					
(Rocella gelida)											(1)	
(Rocella schraderi)												(2)
Total specimens	300	200	160	50	300	200	200	200	200	300	16	40

Figure 4. *Silicoflagellates, recorded as per cents, in Pliocene, lower Miocene, and Oligocene? samples from Cores 7 to 30 at Site 407. (X = present, too scarce to count. Sparse specimens of problematic diatoms* Macrora stella, Rocella gelida, *and* R. schraderi *are tabulated as actual numbers encountered during the silicoflagellate counts.)*

dances are only 1 to 3 per cent. High ratios of these two taxa to other silicoflagellates are therefore used as an indication of cool paleotemperatures for Miocene and Pliocene siliceous marine sediment at Site 408.

Site 409
(lat 62°36.98′N, long 25°57.17′W, depth 832 m)

Site 409, in the western crest region of the Reykjanes Ridge near the boundary of the Gauss and Matuyama polarity

Series	Site 408 Sample (Interval in cm)	Depth (m)	Total specimens	*Dictyocha aspera*	*D. brevispina*	*D. calida ampliata*	*D.* sp. cf. *D. perlaevis ornata*	*D. perlaevis perlaevis*	*D.* sp. (mesocenoid)	*D.* spp. (variants)	*Distephanus boliviensis*	*D. boliviensis* (cannopilean)	*D. crux* s. ampl.	*D. frugalis*	*D. jimlingii*	*D. polyactis*	*D. pseudocrux*	*D. speculum elongata*	*D. speculum haliomma*	*D. speculum minutus*	*D. speculum pentagonus*	*D. speculum speculum*	*D. speculum triommata*	*D. varians*	*Mesocena circulus* s. ampl.	*M. diodon nodosa*	*M.* sp. aff. *M. diodon nodosa* (4-, 6-sided)	*M. quadrangula*
Pliocene	5-1, 74-76	39	300			<1	<1	1		1				4	22					3	1	67			<1			
	5-3, 51-53	42	300								6			76	6		1			3		8		<1				
	8-2, 80-82	69	300	2							1	14		1	12		1					50			2		9	8
	9-2, 60-62	78	300	<1	2			<1	1		1	2			47	8				4		32						3
	11-4, 121-123	101	200								2	9			18				2	52	1	15	1					
	12-2, 84-86	107	300								20	1			<1					68		10	<1					
Miocene	13-2, 60-62	116	300								4		1	1				<1		43	<1	36	<1	<1		14		

Figure 5. *Miocene and Pliocene silicoflagellates, recorded as per cents, from Cores 5 to 13 at Site 408.*

epochs (approximately 2.3 m.y.), contains poorly age-diagnostic Pliocene or Quaternary coccolith assemblages. Three samples from Cores 4, 6, and 7 are barren of silicoflagellates.

Coccolithus pelagicus is predominant, indicating cool-water conditions for the short 80-meter sedimentary section. *Gephyrocapsa caribbeanica* in Cores 2 and 4 (25 to 53 m) establishes their Quaternary age. Samples from Cores 5 to 7 (53 to 82 m) are not clearly diagnostic for either Pliocene or Quaternary because of low diversity of the coccolith assemblages. The absence of *Discoaster, Gephyrocapsa,* and *Helicosphaera sellii* in Sample 409-7-2, 31-33 cm (74 m) and the trace of *Cyclococcolithina macintyrei* make assignment to basal Quaternary or Pliocene questionable.

Site 410
(lat 45°30.51′N, long 29°28.56′W, depth 2975 m)

Site 410, on the western flank of the Mid-Atlantic Ridge at the position of the older part of magnetic anomaly 5 (approximately 10 m.y.), contains coccolith assemblages ranging from upper middle Miocene or lower upper Miocene to Quaternary in Cores 1 to 34 (0 to 321 m). Silicoflagellates are sparse to common in the upper Pliocene and Quaternary of Cores 1 to 14 (0 to 131 m).

The oldest coccolith assemblages are in close age agreement with the indicated magnetic anomaly 5 at Site 410. A nearly complete upper Miocene zonal sequence is present in the samples examined from Cores 18 to 32 (160 to 302 m), ranging from the *Discoaster bellus* Subzone (possibly *D. hamatus* Zone in the lowest Core 34) to *Amaurolithus primus* Subzone. The coccolith assemblage of Sample 410-34-2, 59-61 cm (314 m) contains abundant *Cyclococcolithina macintyrei* and *Reticulofenestra pseudoumbilica,* and sparse *Discoaster bellus, D. variabilis,* and *Triquetrorhabdulus rugosus.* Discoasters are less abundant than in higher samples, and no specimens of *D. hamatus* occur, but *D.* sp. cf. *D. bollii* occurs in Core 32 and *Minylitha convallis,* which typically ranges through the *D. neohamatus* Zone, is present in Core 30. Both occurrences suggest the lower *D. neohamatus* Zone.

Key discoaster species present in the *D. neohamatus* Zone samples include *D. bellus, D. braarudii,* and *D. variabilis* in Core 32; *D. brouweri* s. ampl., *D.* sp. cf. *D. neohamatus, D.* sp. cf. *D. pentaradiatus,* and *D.* sp. cf. *D. prepentaradiatus* in Core 30; *D.* sp. cf. *D. bellus* (small knob), *D. braarudii, D. challengeri, D. icarus, D. pentaradiatus,* and *D. variabilis* (some mimic *D. loeblichii*) in Core 28. The small-knobbed discoaster forms of *D.* sp. cf. *D. bellus* in Core 28 presage the occurrence of *D. berggrenii* and *D. quinqueramus,* and indicate that the upper *D. neohamatus* Zone was sampled.

Discoaster berggrenii (Core 26) and *D. quinqueramus* (Core 24), without *Amaurolithus* or *Minylitha,* indicate the *Discoaster berggrenii* Subzone in Cores 24 to 26 (217 to 245 m). The overlapping ranges of *Amaurolithus delicatus, A. primus,* and *D. quinqueramus* in Cores 18 to 22 (160 to 207 m) indicate the next higher *Amaurolithus primus* Subzone.

Although discoasters are not abundant in upper Pliocene Cores 11 to 16 (93 to 150 m), typical low-latitude associations occur that permit assignment to subzones (Figure 2) (Bukry, 1975a). Ceratoliths are rare, but scyphospheres and discoliths are fairly common in Cores 14 to 16 (122 to 150 m); this suggests that dissolution was slight and that Site 410 was alternately near or beyond the northern range of ceratolith-bearing nannoplankton. Dissolution of coccoliths is most noticeable in upper Pliocene Cores 11 and 13, where scyphospheres are missing. Several specimens of *Gephyrocapsa* in Sample 410-16-3, 122-124 cm (145 m) may be the result of the same down-hole drilling contamina-

Subseries	Upper Miocene						Middle Miocene							
Depth (m)	179	182	195	200	211	213	220	236	237	240	249	258	268	278
Species / Site 408 Sample (Interval in cm)	19-6, 70-72	20-2, 35-37	21-4, 0-2	22-1, 51-53	23-2, 0-2	23-3, 70-72	24-2, 0-2	25-6, 14-16	25-CC	26-2, 50-52	27-2, 94-96	28-2, 5-7	29-2, 25-27	30-2, 104-106
Cannopilus depressus			2	2			1	1		4	2	3	6	X
C. ernestinae												1	11	
C. sp. cf. *C. schulzii*											1		1	
Corbisema triacantha s. ampl.								3						
Dictyocha aspera				7										
D. fibula									2	1	2	1		
D. pulchella		3	13	3		9	2	42	40	16	1			
D. sp. aff. *D. pulchella* (small, narrow)				8										
D. varia			1	2	2	1	2							
D. spp. (mixed variants)	1		3	2		3	1		2		26			
Distephanus boliviensis	6	7			2									
D. crux s. ampl.	47	34	9	25	32	44	19	13	13	16	16	38	8	X
D. sp. cf. *D. crux darwinii*														X
D. crux (dictyochoid)		6			2	1		3	2					
D. frugalis		1		1										
D. longispinus	<1	1	1				31							
D. sp. cf. *D. longispinus*	3	1	5		6		17			1				
D. polyactis			2						1					
D. pseudocrux				2										
D. speculum elongata	<1			2		4		1				2		
D. speculum haliomma						1				2		4		
D. speculum hemisphaericus								1		1	4	2	1	X
D. speculum minutus		1												
D. speculum pentagonus	<1	1										1		
D. speculum speculum	26	39	24	30	46	28	11	26	33	46	6	29	2	
D. speculum triommata							2	1		2		1		X
D. schauinslandii s. ampl.	1				2									X
D. stauracanthus s. str.								1						
D. stauracanthus (fibuloid)								1	1					
D. staurodon s. ampl.										1		11		
D. stradneri		2		2		3							1	
D. varians								1						
Mesocena apiculata curvata											2	2	2	
M. circulus s. ampl.	9	5	28	3	6	3	12	6	5	10	37	10	41	
M. diodon diodon									1		3		27	X
M. diodon nodosa	1	2	11	13	2	3	2	1						
M. quadrangula	2	1	1	2										
M. triodon	<1			1										
(*Macrora stella*)				(1)	(1)		(2)	(7)	(16)	(47)	(2)		(2)	
Total specimens	300	200	200	200	50	75	100	110	100	100	100	200	100	15

Figure 6. *Silicoflagellates, recorded as per cents, in Miocene samples from Cores 19 to 30 at Site 408. (X = present but too scarce to count. Actual counts of the problematic diatom* Macrora stella, *recorded during silicoflagellate traverses, show a local acme in Core 26.)*

tion noted in the foraminiferal assemblages of Site 410 (R.Z. Poore, oral communication, 1977). The alternative, an early appearance of *Gephyrocapsa* in nontropical marginal oceanic areas (Akers and Koeppel, 1973), is not supported by the relative ranges of this genus and other fossil groups at the other Leg 49 sites. A few specimens of small *Reticulofenestra* sp. cf. *R. pseudoumbilica* in Section 16-3 suggest proximity to the upper-lower Pliocene boundary.

Quaternary coccolith assemblages of Cores 1 to 10 (0 to 93 m) contain common *Coccolithus, Discolithina, Helicosphaera,* and *Rhabdosphaera. Ceratolithus* is absent. Several species of *Gephyrocapsa* are present but sparse. This is a temperate association which is fairly consistent in the five samples examined. Low percentages of *Distephanus speculum speculum* among the Quaternary silicoflagellates (Figure 7) also indicate temperate conditions at Site 410.

Site 411
(lat 36°45.97′N, long 33°23.30′W, depth 1935 m)

Site 411, in a basin on the west terrace of the rift valley of the Mid-Atlantic Ridge, at a position on the old side of the Jaramillo magnetic polarity event (approximately 1 m.y.),

System or Subseries	Zone	Site 410 Sample (Interval in cm)	Depth (m)	Total specimens	*Dictyocha aculeata*	*D.* sp. cf. *D. longispina* (asperoid)	*D. perlaevis flexatella*	*D, perlaevis ornata*	*D. perlaevis perlaevis*	*D.* sp. cf. *D. stapedia aspinosa*	*D. stapedia stapedia*	*Distephanus boliviensis*	*D. boliviensis* (cannopilcan)	*D. frugalis*	*D. jimlingii*	*D. octonarius* (of Ling)	*D. speculum pentagonus*	*D. speculum speculum* s. ampl.	*D.* sp. (cruxoid, large)	*D.* sp. (pentagonal, large)	*Mesocena circulus*	*Octactis pulchra*	*Ammodochium rectangulare*
Quaternary	– – – –	1-2, 43-45	2	0																			
	Dictyocha aculeata	3-4, 9-11	22	100	27				22		35					1		15					
		5-6, 115-117	45	0																			
		8-4, 91-93	69	100	16	54			13		3							8		3		3	
Upper Pliocene	*Dictyocha stapedia stapedia*	10-7, 11-13	93	100		6		1	46	11	16	3						10	2	2		3	
		11-3, 31-33	96	100		18			16	36	13	4						8				5	X
		14-2, 100-102	124	8			X	X		X								X					
		14-4, 96-98	127	100			3	7	3	19	12	3	8					42			3		X
		14-6, 100-102	130	300			3	21	4	4	2	4	3	1	<1		1	53	<1		4		

Figure 7. *Silicoflagellates, recorded as per cents, in Pliocene and Quaternary samples from Cores 1 to 14 at Site 410.* [X = *present, too scarce to count. Disappearance of the ebridian* Ammodochium rectangulare *is used to mark the top of the Pliocene in the North Pacific (Ling, 1973).*]

contains temperate middle Quaternary coccolith assemblages in Cores 2A to 3A (9 to 37 m). No silicoflagellates were observed.

Site 412
(lat 36°33.74′N, long 33°09.96′W, depth 2609 m)

Site 412, about 2 km south of the north wall of Fracture Zone B of the FAMOUS area (Heirtzler and van Andel, 1977; Aumento et al., 1977), contains diverse warm-water Quaternary coccolith assemblages ranging from the *Gephyrocapsa caribbeanica* Subzone (approximately 0.9 to 1.6 m.y.; Bukry, 1975a) to the *Emiliania huxleyi* Zone (approximately 0 to 268,000 years; Thierstein et al., 1977). Silicoflagellates are common throughout and indicate a warm-temperate regime in all but Cores 7 and 8 (90 to 109 m), where *Distephanus* is common (Figure 8). Diversity in Core 10 (118 to 128 m) is especially high because of reworking, as indicated by the conjunction of Pliocene *D.* sp. cf. *D. brevispina, D. perlaevis ornata,* and *Distephanus boliviensis* in a Quaternary assemblage. Shipboard scientists reported an unusual abundance of reworked discoasters in this core (see chapter for Site 412, this volume).

Mesocena quadrangula (synonym of *M. elliptica* reported in upper Miocene to Pleistocene) is reported for the first time to occur at the northern Mid-Atlantic Ridge, in Cores 6 and 7. Its presence was predicted but not established during study of DSDP Leg 37 cores from near the FAMOUS area (Bukry, 1977a). Pacific Ocean cores indicate that *M. quadrangula* had a Quaternary peak abundance from 0.85 to 0.95 m.y. ago, just before its extinction between 0.60 m.y. and 0.85 m.y. ago (Jousé and Mukhina, 1973). This peak abundance has been correlated with the Jaramillo polarity event (Hays et al., 1969), which is accorded an age of 0.89 to 0.95 m.y. (Klitgord et al., 1975; LaBrecque et al., 1977). The short range of *M. quadrangula* in Cores 6 and 7 at Site 412 is within the *Emiliania ovata* Subzone. Above in Core 5, an interval is present which contains abundant small placoliths and rare *Gephyrocapsa oceanica* sometimes observed within the *Gephyrocapsa oceanica* Zone. This short interval has been given a position directly below the Jaramillo event at 0.92 to 1.22 m.y. ago (Gartner, 1977). Although the sequence of these biostratigraphic occurrences is reversed at Site 412, the time framework is short and implies a generally close association of these biostratigraphic guides in the middle Quaternary. At Site 397 off northwest Africa, however, the ranges of *Mesocena quadrangula* and *Dictyocha lingii* define the *M. quadrangula* Zone within the *Gephyrocapsa caribbeanica* Subzone.

Coccolith assemblages from Cores 1 and 3 are diverse and contain both abundant *Coccolithus pelagicus* (barred), *Rhabdosphaera clavigera,* and sparse *Ceratolithus cristatus,* suggesting a mixture of warm- and cool-water taxa. *Gephyrocapsa lumina,* originally reported to occur in the *Gephyrocapsa caribbeanica* Subzone of Site 157 in the Panama Basin (Bukry, 1973a), is common in Core 10 and sparse in Cores 8 and 9 of Site 412 in the same *G. caribbeanica* Subzone of coccoliths and *Mesocena quadrangula* Zone of silicoflagellates. Because *G. lumina* is not a widespread species, it may prove useful for indicating special paleoecologic variables.

Site 413
(lat 36°32.59′N, long 33°10.50′W, depth 2598 m)

No samples available; see reports of shipboard scientists.

System	Zone	Site 412 Sample (Interval in cm)	Depth (m)	Total specimens	*Dictyocha aculeata*	*D.* sp. cf. *D. aculeata*	*D.* sp. cf. *D. brevispina*	*D. calida ampliata*	*D. calida calida*	*D. hessii*	*D. lingii*	*D. perlaevis ornata*	*D. perlaevis perlaevis*	*D. stapedia aspinosa* s. ampl.	*D. stapedia stapedia*	*D.* sp. cf. *D. vexativa*	*D.* sp. (fibuloid)	*D.* spp. (asperoid)	*Distephanus boliviensis*	*D. octonarius* (of Ling)	*D. speculum pentagonus*	*D. speculum quintus*	*D. speculum speculum*	*D.* sp. cf. *D. speculum speculum* (7-spined)	*D.* sp. (cruxoid, large)	*D.* sp. (pentagonal, large)	*Mesocena quadrangula*	*Octactis pulchra*	*O.* sp.	Opal phytoliths or fresh-water diatoms
Quaternary	*Dictyocha aculeata*	1-1, 99-101	1	300	16	1								3	74		2						5							•
		2-3, 99-101	8	300	13	<1								2	82	<1					<1		2							•
		3-3, 39-41	14	300	10	<1								3	84								6	1				<1	<1	
		4-6, 36-38	31	300	64	1								<1	34			<1												
		5-3, 130-132	56	300	25	1		2	1				1	36	30	<1		1		<1			1	1				1		
	Mesocena quadrangula?	6-2, 109-111	83	300	3	31		3	11	31	2		1		9				2				3			1	2			
		7-2, 30-32	91	200	12	23		1	7	1	7		3		21	1							16			1	9			•
		8-5, 130-132	106	200		23		2		13	19		1		1					1			36			1		6		
		9-4, 12-14	113	100		29		2	11	21	8		5		10	1							7			5		1		
		10-4, 129-131	124	200	1	53	1	7	6	16	2	2	2	2	5	1			1	1		1	3		1	1				•
		12-2, 39-41	139	100		69		2	6	16	2		2		2							1								
		14-1, 59-61	157	300		6	3	<1	3	78	1				6			1	<1				3					<1		
		14-4, 85-87	161	150	10	9		4	5	53			2	1	13			2					1							•

Figure 8. *Silicoflagellates, recorded as per cents, in Quaternary samples from Cores 1 to 14 at Site 412.* [*• = presence of rare freshwater diatoms* Melosira granulata, Epithemia sp., Diploneis sp., *or panicoid and elongate opal phytoliths denoting eolian sediment source (Folger, 1970).*]

Site 414
(lat 32°03.00′N, long 27°30.10′W, depth 1538 m)

Hurricane Emmy forced abandonment of Site 414 before any coring was accomplished.

SILICEOUS SPONGE SPICULES

Siliceous sponge spicules occur in many samples from Leg 49. At Sites 407 and 408 they are most diverse and abundant in the lower and middle Miocene and sparse or absent in the Pliocene and Quaternary. At southern Site 412 (Figure 1) they are most abundant in the lower cores, but persist through the entire Quaternary. Shallow depths, new diverse terrains, and associated bottom currents favoring sponge productivity, could all contribute to the abundance of sponge spicules in near-basement sediment at the mid-ocean ridge sites of Leg 49. Differences between coeval spicule assemblages, such as those in the lower and middle Miocene at Site 391 (Bukry, in press a) and Sites 407 and 408, should be established to determine if fossil spicule assemblages can be used for benthic paleoecologic interpretations. Some of the different forms of spicules observed during silicoflagellate studies are illustrated in Plates 6 through 8.

SILICOFLAGELLATE ZONATION

Silicoflagellate zones of the same name that different authors identify by different species are not uncommon. Ecologic conditions that favored a consistent or common presence of a species in one region were sometimes less favorable or unfavorable in other regions; this makes correlation difficult and leads to establishment of alternate zonal guide species. Therefore, zonal criteria are indicated, below, and abundance charts are provided so silicoflagellate stratigraphy of Leg 49 sites can be related to other regions.

Naviculopsis biapiculata Zone (Bukry, 1974)

A sparse silicoflagellate assemblage of the *Naviculopsis biapiculata* Zone at Site 407 includes *Mesocena apiculata apiculata* (no *M. apiculata curvata*), *Naviculopsis* sp. cf. *N. biapiculata*, and *N.* sp. cf. *N. constricta*. Together with the diatoms *Coscinodiscus lewisianus* and *Rocella schraderi*, and the silicoflagellate *Distephanus speculum haliomma*, this array suggests the upper *N. biapiculata* Zone (Bukry, 1977b).

Naviculopsis lata Zone (Martini, 1972; emended, Bukry 1977b)

The interval of the *Naviculopsis lata* Zone at Site 407 contains *Naviculopsis lata* above the range of *Rocella* and below the first *N. quadrata*. This relationship is considered diagnostic for the *Naviculopsis lata* Zone. *Corbisema* is common at Site 407 in this interval, suggesting warmer temperatures during the early Miocene than prevailed later at the site.

Naviculopsis quadrata Zone (Bukry and Foster, 1974)

The range of *Naviculopsis quadrata* is used to identify an upper lower Miocene *Naviculopsis quadrata* Zone which lies between the *Naviculopsis lata* Zone below and the *Corbisema triacantha* Zone above. Withdrawal of previously used marker species for this interval, such as first *Distephanus stauracanthus* (Bukry and Foster, 1974) and first *Naviculopsis navicula* (Martini, 1972), is suggested because *N. quadrata* has been found to be more common and easily identified in deep-sea sediments (Figure 4). *N. navicula* is common in marginal marine areas, for example Site 415 off northwest Africa. Owing to the limited number of studies and the abbreviated sections available, the detailed geographic and temporal relations between *N. lata, N. navicula, N. quadrata,* and *N. ponticula* in the upper lower Miocene are not fully established. But their potential as zone markers is good (Sanfilippo et al., 1973; Martini and Müller, 1976).

Corbisema triacantha Zone (Martini, 1971, 1972)

Local paleoecologic conditions at Site 407 changed abruptly, as indicated by the decrease in *Corbisema triacantha* (Figure 4). The coincident disappearance of *Dictyocha* and increase of *Distephanus* indicates a significant cooling in the late early Miocene. Therefore, the last occurrence of *C. triacantha*, used to define the top of the *Corbisema triacantha* Zone in the tropics, cannot be relied upon at Site 407. The upper ranges of *Mesocena apiculata curvata* (in particular), *Distephanus speculum haliomma*, and *D. speculum triommata* are used as auxiliary markers to indicate the extent of the *Corbisema triacantha* Zone in Cores 18 to 20 at Site 407.

Specimens of *Distephanus longispinus* in this zone are considered to be cool-water phenotypes derived from the *D. crux* group. The low- to mid-latitude sequence of *C. triacantha* disappearance followed by *D. longispinus* acme in the middle to late Miocene (Bukry and Foster, 1973) appears to have occurred earlier at Site 407 — in the late early Miocene, on the basis of relative ranges of other silicoflagellates and associated coccoliths of the *Sphenolithus belemnos* Zone and *Helicosphaera ampliaperta* Zone. This dramatic paleoecologic shift in the silicoflagellate population is not reflected in the coccolith assemblages. Erosion has removed the middle Miocene and lower upper Miocene sedimentary record at Site 407.

At Site 408, in Cores 25 to 30, *Corbisema triacantha* is rare, *Distephanus* abundant, and *Dictyocha* and *Mesocena* common. Auxiliary species are again useful, but the *Distephanus longispinus* acme of the late middle Miocene occurs in Core 24 of Site 408 in its anticipated sequence with *Mesocena circulus,* but above the range of *M. apiculata curvata*.

Distephanus longispinus Zone (Bukry and Foster, 1973)

The *Distephanus longispinus* Zone was defined as the interval from the last *Corbisema triacantha* to the last *Distephanus longispinus,* characterized by the common occurrence of *D. longispinus*. The absence of *Mesocena apiculata curvata* and *Distephanus speculum triommata,* which characterize older Miocene zones, helps to identify the *D. longispinus* Zone. Also, *Mesocena circulus* usually appears in this zone (John Barron, oral communication, 1977). *M. circulus* is exceptionally common in several cores below the *D. longispinus* Zone at Site 408. It should be noted that Cores 27 to 29 contain middle middle Miocene coccoliths of the *Discoaster exilis* Zone, which is compatible with the earliest *M. circulus* in California (Barron, 1976).

Distephanus speculum speculum Zone (Bukry 1973b)

Cold-water silicoflagellate assemblages of upper Miocene Cores 13 to 23, Site 408, are tabulated as the *Mesocena circulus* Subzone (Bukry, 1975b) of the *Distephanus speculum speculum* Zone, because of the common occurrence of *Distephanus speculum speculum, Mesocena diodon nodosa,* and *M. circulus*. Mid-latitude marker species *Distephanus pseudofibula* was not observed at Site 408, and occurrences in the Atlantic are rarely reported (Bukry, 1976 a,b), so the last common *D. longispinus* was used as the base of the subzone. The disappearance of consistent *M. diodon nodosa* in Core 13 marks the top of the subzone. The top of the *D. speculum speculum* Zone was not observed at either Site 407 or Site 408.

Dictyocha stapedia stapedia Zone (Bukry, 1977a)

The *Dictyocha stapedia stapedia* Zone was defined for DSDP Leg 37 on the Mid-Atlantic Ridge as the interval from the first *D. stapedia stapedia* to the first Quaternary *Mesocena quadrangula,* more appropriately the appearance of the *M. quadrangula* acme. The upper Pliocene portion of this zone, identified off northwest Africa at Site 397 (lat 27°N), contains short-ranged *Dictyocha perlaevis flexatella, D. perlaevis ornata,* and dwindling *Distephanus boliviensis*. All three taxa occur in a similar stratigraphic sequence at Site 410 (Figure 7). At both sites, associated coccoliths show that the *D. stapedia stapedia* Zone straddles the Pliocene/Pleistocene boundary. The top of the zone was not observed, because of a sampling gap.

Mesocena quadrangula Zone (Bukry and Foster, 1973)

Mesocena quadrangula occurs in only two of the seven lower Quaternary cores assigned to the *Mesocena quadrangula* Zone at Site 412. The other cores were assigned because of (1) a general paucity of Quaternary *M. quadrangula* at high latitudes (Bukry, 1977a), (2) the presence of *Dictyocha lingii*—a companion species of *M. quadrangula* (Dumitrică, 1973b; Bukry, in press d), and (3) the presence of *Dictyocha aculeata* or compared species throughout (Bukry, in press d).

Dictyocha aculeata Zone (Bukry and Foster, 1973; emended, Bukry, in press d)

The common occurrence of *Dictyocha aculeata* above the Quaternary acme of *Mesocena quadrangula* is used to identify the *Dictyocha aculeata* Zone (Bukry, in press d). The assemblages at Sites 410 and 412 both show reduced diversity compared with the lower Quaternary, and *D. aculeata* and *D. stapedia stapedia* often dominate assemblages. The reduced silicoflagellate diversity in the upper Quaternary is also typical of other DSDP sites, such as Sites 310 and 362. A general reduction of size and thickness of silicoflagellate skeletons, compared with previous epochs, also indicates less than optimum conditions.

SILICOFLAGELLATE TAXONOMY

Selected silicoflagellates are discussed below. Other silicoflagellate taxonomy has previously been described and discussed in the Deep Sea Drilling Project volumes, especially those for Legs 44 and 47. See also Loeblich et al., (1968) for original references prior to 1968.

Genus CORBISEMA Hanna, 1928

Corbisema triacantha (Ehrenberg)
(Plate 1, Figure 1)

Dictyocha triacantha Ehrenberg, 1844, p. 80.
Dictyocha triacantha Ehrenberg, Lemmermann, 1901, p. 258, pl. 10, fig. 18.
Corbisema triacantha (Ehrenberg), Dumitrică, 1973b, p. 846, pl. 2, fig. 1-3.
Corbisema triacantha (Ehrenberg), Bukry, in press a, pl. 1, fig. 18.

Remarks: Rounded specimens like the lectotype (Locker, 1974) and angular specimens (Lemmermann, 1901) are tabulated together at Sites 407 and 408.

Genus DICTYOCHA Ehrenberg, 1837

Dictyocha aculeata (Lemmermann)
(Plate 1, Figure 2)

Dictyocha fibula var. *aculeata* Lemmermann, 1901, p. 261, pl. 11, fig. 1, 2.
Dictyocha aculeata (Lemmermann) Dumitrică, 1973b, p. 849, pl. 4, fig. 9-11.
Dictyocha aculeata (Lemmermann), Bukry, 1977a, p. 921.

Remarks: Rounded specimens that lack the full peripheral development of the basal ring are tabulated separately as compared specimens of *Dictyocha aculeata* (see Bukry, in press d, pl. 1, fig. 5-9). The rounded forms predominate in the lower Quaternary at Site 412 (Plate 1, Figures 3, 4).

Dumitrică (1973a) illustrated *D.* sp. cf. *D. aculeata* (rounded) as *D. messanensis* Haeckel (in part) (pl. 8, fig. 11-13) from an occurrence in the lower Quaternary of Mediterranean Sea Site 128. Comparison of these forms with the type figures of *D. aculeata* and *D. messanensis* (see Loeblich et al., 1968, pl. 9, fig. 1, 2; and pl. 17, fig. 24-27), indicates greater affinity with *D. aculeata*, based on the form, attitude, and proportions of the basal ring and apical bar. Strictly speaking, neither of the type specimens of Lemmermann (1901) has a basal ring with an eight-sided internal margin. They also lack the canted apical bar which characterizes upper Quaternary populations that have been assigned to *D. aculeata*. Emendation or splitting of the *D. aculeata* plexus could clarify this situation.

Dictyocha calida ampliata Bukry
(Plate 1, Figures 5, 6)

Dictyocha calida ampliata Bukry, in press d, pl. 2, fig. 1, 2, 9.

Remarks: *Dictyocha calida ampliata* having distinct pinched outlines is a minor part of lower Quaternary assemblages at Site 412. It occurs with *D. calida calida* at Site 412.

Dictyocha calida calida Poelchau
(Plate 1, Figure 7)

Dictyocha calida Poelchau, 1976, p. 169, pl. 1, fig. c, d; pl. 3, fig. a-f.
Dictyocha calida calida Poelchau, Bukry, in press d, pl. 2, fig. 3, 4.

Remarks: *Dictyocha calida calida* is smaller and has more equant axes than *D. perlaevis perlaevis*. Its periphery is less lobed than *D. perlaevis perlaevis* and less pinched than *D. calida ampliata*. It occurs in the lower Quaternary of southern Site 412.

Dictyocha hessii Bukry
(Plate 1, Figures 8-12)

?*Dictyocha* cf. *ausonia* Deflandre, Ling, 1970 (in part), p. 88, pl. 18, fig. 2.
Dictyocha sp. cf. *D. aspera* Lemmermann, Dumitrică, 1973a, (in part), p. 907, pl. 7, fig. 4-7.
Dictyocha lingi Dumitrică, Dumitrică, 1973b (in part), p. 848, pl. 3, fig. 4.
Dictyocha lingi Dumitrică, Ling, 1975, p. 768, pl. 1, fig. 11.
Dictyocha hessii Bukry, in press b.

Remarks: The *Dictyocha hessii-Dictyocha lingii* group was illustrated by Ling (1970) from occurrences in North Pacific cores. *D. lingii,* a highly modified, specific offshoot of the more common and generalized *D. hessii* stock, was differentiated by Dumitrică (1973 a, b) in DSDP cores from the Mediterranean and southwestern Pacific. *D. lingii* is distinguished by thinner apical bar and struts, basal pikes located directly on the struts, and more continuous elliptical outline (Dumitrică, 1973a; Bukry, in press d).

The populations of *Dictyocha hessii* at Site 412 have the same apiculated, scalloped ring and proportionally thick bar as populations tabulated or illustrated from occurrences at DSDP Sites 128, 206, and 310. As suggested by Dumitrică (1973a) for Site 128, the stratigraphic range of *D. lingii* is similar to that of *Mesocena quadrangula* in the Quaternary at Sites 310 and 397. The similar ranges of *D. hessii* and *D. lingii* at Site 412 therefore suggest a thicker *Mesocena quadrangula* Zone than does the range of *M. quadrangula* alone.

Dictyocha lingii Dumitrică
(Plate 1, Figure 13; Plate 2, Figures 1-4)

Dictyocha cf. *ausonia* Deflandre, Ling, 1970 (in part), p. 88, pl. 18, fig. 1, 3.
Dictyocha lingi Dumitrică, 1973a, p. 906, pl. 8, fig. 1-7.
Dictyocha lingi Dumitrică, Dumitrică, 1973b (in part), p. 848, pl. 3, fig. 5-7.
Dictyocha lingii Dumitrică, Bukry, in press d, pl. 2, fig. 5-8.
Remarks: See the remarks for *Dictyocha hessii*.

Dictyocha longispina (Lemmermann)

Dictyocha fibula var. *longispina* Lemmermann, 1901, p. 260, pl. 10, fig. 26.
Remarks: Most of the compared specimens of *Dictyocha longispina* at Site 410 are small to moderate, smooth, and slightly asperoid specimens. The type specimen of *D. longispina* is ambiguous. It is asperoid, on the basis of spine length and fibuloid on the basis of basal ring dimensions. This is unusual because silicoflagellates typically have the longer spine set aligned with the major axis of the basal ring. Since the basal ring form is considered more conservative for classification purposes, *D. longispina* would be judged slightly fibuloid (Bukry, in press d). The compared specimens are slightly asperoid by both criteria, but are tabulated as *D.* sp. cf. *D. longispina* because of their similar size, ornamentation, and stratigraphy (Plate 2, Figures 5, 6). Analysis of asperoid silicoflagellates of the Quaternary is still incomplete.

Dictyocha perlaevis flexatella Bukry
(Plate 2, Figures 7-10)

Dictyocha sp. cf. *D. perlaevis* Frenguelli (Lopsided form) Bukry, in press b, pl. 1, fig. 5, 6.
Dictyocha perlaevis flexatella Bukry, in press d, pl. 3, fig. 1-3.
Remarks: *Dictyocha perlaevis flexatella* occurs in the upper Pliocene of Core 14 at Site 410. It is missing in the Quaternary section at Site 412. This occurrence for Leg 49 matches the range of *D. perlaevis flexatella* at more southerly Sites 397 and 362 in the Atlantic. Although it appears to be a guide taxon for the upper Pliocene, it should be noted that definite lower Pliocene silicoflagellate assemblages have not been encountered in DSDP coring in the Atlantic (calcareous deposits predominate). Therefore, *D. perlaevis flexatella* may range lower.

Dictyocha perlaevis ornata Bukry
(Plate 2, Figures 11-14)

Dictyocha perlaevis ornata Bukry, 1977a, p. 922, pl. 1, fig. 1-6.
Remarks: *Dictyocha perlaevis ornata* is typically part of upper Pliocene assemblages, but occurs sporadically (reworked?) in the Quaternary. It is rather widespread in the Atlantic, and occurs at DSDP Sites 412, 410, 397, 362, 335, and 333. Two phenotypic groups of *D. perlaevis ornata* exist. The original mid-Atlantic group (Bukry, 1977a) has a shorter bar, more elongate minor-axis portals, and smaller peripheral pikes. The western-Africa group (Bukry, in press b, d) has the major axis predominant, long bar, and short minor-axis spines. At Site 410, the mid-Atlantic group predominates; only 2 of 64 studied specimens approach the form of the western-Africa group in Sample 410-14-6, 100-102 cm (130 m). The reworked specimens at Site 412 are all from the mid-Atlantic group.

Dictyocha vexativa Bukry

Dictyocha vexativa Bukry, in press b, pl. 1, fig. 10-14.
Remarks: Sparse, small specimens of *Dictyocha* sp. cf. *D. vexativa* occur in the Quaternary at Site 412. The bars are short and the struts may have pikes (Plate 2, Figures 15, 16).

Genus DISTEPHANUS Stöhr, 1880

Distephanus boliviensis (Frenguelli)

Dictyocha boliviensis Frenguelli, 1940 (in part), p. 44, fig. 4a (not 4b-d).
Distephanus boliviensis (Frenguelli) Bukry and Foster, 1973, p. 827, pl. 4, fig. 1-3.
Distephanus boliviensis boliviensis (Frenguelli), Bukry, in press d, pl. 4, fig. 12; pl. 5, fig. 1.
Remarks: The non-cannopilean specimen (p. 44, fig. 4a) of Frenguelli's (1940) type suite is herein designated the lectotype of *Distephanus boliviensis*. Because of their short equant spines and subdivided apical rings, fig. 4b and 4c of Frenguelli (1940) are assigned to *Distephanus boliviensis major* s. str. The specimen shown as fig. 4d of Frenguelli (1940) can be referred to *Distephanus jimlingii* because of the small, subdivided apical ring and spine and basal ring pattern that differs from *D. boliviensis major*. Cannopilean specimens of *D. boliviensis* that do not match the form of *D. boliviensis major* or *D. jimlingii* are tabulated as *D. boliviensis* (cannopilean) for Leg 49 (see Plate 3, Figures 1, 2).
The spines of large *Distephanus boliviensis* are sometimes not axially aligned (see Bukry and Foster, 1973).

Distephanus boliviensis major (Frenguelli)

Dictyocha boliviensis Frenguelli, 1940 (in part), p. 44, fig. 4b, 4c (not 4a, 4d).
Dictyocha boliviensis var. *major* Frenguelli, 1951, p. 277, fig. 3a-c.
Cannopilus major (Frenguelli) Bukry and Foster, 1973, p. 826, pl. 1, fig. 4-7.
not *Distephanus boliviensis* var. *major* (Frenguelli) Ciesielski, 1975, p. 660, pl. 8, fig. 1-5.
Remarks: Inspection of Frenguelli (1940, fig. 4b, 4c; 1951, fig. 3a-c) and Bukry and Foster (1973, pl. 1, fig. 4, 5?, 6, 7) shows that these specimens differ from the cannopilean form of *Distephanus boliviensis* (see Ling, 1970, pl. 20, fig. 2-6) by their shorter more equant spines and by their more equant basal ring. Although the name *D. boliviensis major* has been applied to all specimens of *D. boliviensis* having large subdivided apical rings, the short-spined specimens from South America and the Panama Basin area seem to represent a distinct form. Therefore, Cannopilean specimens of *D. boliviensis* with large apical subdivisions are tabulated as *D. boliviensis* (cannopilean) for this report. Figure 4b of Frenguelli (1951) is herein designated the lectotype of *D. boliviensis major*.

Distephanus crux Ehrenberg
(Plate 3, Figure 3)

Dictyocha crux Ehrenberg, 1840, p. 207; Ehrenberg, 1854, pl. 18, fig. 56; pl. 20 (1), fig. 46; pl. 33 (15), fig. 9; pl. 33 (16), fig. 9; pl. 33 (17), fig. 5.
Distephanus crux (Ehrenberg), Locker, 1974 (in part), p. 637, pl. 3, fig. 8 (not fig. 10).
Remarks: *Distephanus crux* s. ampl. is variable in the proportions of spines, pikes, basal ring, and apical ring. This variability may be seen to change the form of the taxon from sample to sample—as in Cores 25 to 29 at Site 408—in a manner similar to changes observed elsewhere in the coccolith *Discoaster variabilis*. The basal ring of *D. crux* s. ampl. may be elliptic, square, or elongate rhomboid. Some specimens at Site 408 have dictyochoid apical structures (Plate 3, Figure 4); otherwise their morphology matches associated normal specimens with apical rings.

Distephanus frugalis (Bukry) n. comb.
(Plate 3, Figures 5, 6)

Distephanus boliviensis frugalis Bukry, 1975a, p. 688, pl. 2, fig. 2-7.
Distephanus boliviensis frugalis Bukry, Barron, 1976, p. 60, pl. 3, fig. 25-27.
Remarks: *Distephanus frugalis* is abundant (76%) in Pliocene Sample 408-5-3, 51-53 cm (42 m).

Distephanus hannai (Bukry) n. comb.

Distephanus crux hannai Bukry, 1975b, p. 855, pl. 4, fig. 4-6.
Remarks: A single compared specimen of this lobed, quadrate taxon was noted in lower Miocene Sample 407-24-2, 50-52 cm (217 m).

Distephanus jimlingii (Bukry) n. comb.
(Plate 3, Figures 7-12)

Cannopilus hemisphaericus (Ehrenberg), Ling, 1973 (in part), p. 751, pl. 1, fig. 1, 2.
Cannopilus himisphaericus (Ehrenberg), Ling, 1975, p. 768, pl. 1, fig. 1, 2.
Distephanus boliviensis jimlingii Bukry, 1975a, p. 688, pl. 1, fig. 6, 7; pl. 2, fig. 1.
Distephanus boliviensis jimlingii Bukry, Barron, 1976, p. 60, pl. 3, fig. 31.
Remarks: *Distephanus jimlingii* is characterized by its holotype as having an apical structure of small, rounded openings that are regularly arranged in the manner of *Distephanus speculum hemisphaericus* (Locker, 1974, pl.

4, fig. 1; Bukry, 1977b, pl. 2, fig. 11-13), with a central opening surrounded by a regular cycle of 5 to 7 openings. In regular specimens the openings are essentially the same size. *D. jimlingii* is distinguished from *D. speculum hemisphaericus* by its smaller openings, longer spines, large boliviensis-style basal ring, and relatively smaller apical structure. Lower and middle Miocene *D. speculum hemisphaericus* is the same size as coeval *D. speculum* s. ampl., and the apical structure virtually fills the inter-ring area (see Ling, 1972, pl. 23, fig. 1-3; Locker, 1974, pl. 4, fig. 1, 8). *D. jimlingii* is larger than coeval *D. speculum* s. ampl., and even non-symmetric forms with larger apical structures still show the character of equant small openings.

Distephanus longispinus (Schulz)
(Plate 3, Figures 13, 14)

Distephanus crux f. *longispina* Schulz, 1928, p. 256, fig. 44.
Distephanus crux var. *longispina* Schulz, Ling, 1972, p. 165, pl. 26, fig. 17-19.
Distephanus longispinus (Schulz) Bukry and Foster, 1973, p. 828, pl. 4, fig. 7, 8.

Remarks: The distribution of *Distephanus longispinus* at Sites 407 and 408 in the lower and middle Miocene suggests that its occurrence may be paleoecologically determined, thus reducing the area of its stratigraphic use. All of the quadrate *Distephanus* taxa (nearly extinct since the late Miocene) need further analysis to establish their geologic significance.

Distephanus polyactis (Ehrenberg)
(Plate 3, Figures 15, 16; Plate 4, Figure 1)

Dictyocha polyactis Ehrenberg, 1839, p. 129; Ehrenberg, 1854, pl. 22, fig. 50.
Distephanus polyactis (Ehrenberg), Bukry and Foster, 1973, p. 828, pl. 5, fig. 6, 7.
Distephanus polyactis (Ehrenberg), Dumitrică, 1973 b, p. 851, pl. 7, fig. 10-13; pl. 8, fig. 1-10; pl. 9, fig. 2.

Remarks: A population of 8- to 11-sided, regular specimens occurs in Pliocene Sample 408-9-2, 60-62 cm (78 m).

Distephanus pseudocrux (Schulz) n. comb.

Distephanus speculum f. *pseudocrux* Schulz, 1928, p. 263, fig. 52a, b.
Distephanus pseudocrux (Schulz), Bukry, 1973b, p. 828, pl. 2, fig. 2, 3.

Distephanus speculum diommata (Ehrenberg) n. comb.

Dictyocha diommata Ehrenberg, 1845, p. 56, 76; Ehrenberg 1854, pl. 33 (17), fig. 6.
Dictyocha diommata Ehrenberg, Locker, 1974, p. 641, pl. 4, fig. 4.

Remarks: The original illustration of *Distephanus speculum diommata* resembles *D. speculum binoculus*. Locker's refigured holotype shows a regular subdivided apical structure having two large and two slightly smaller openings. This regular four-opening pattern is accepted for use in describing *D. speculum diommata* as a member of the lower and middle Miocene *D. speculum* plexus.

Distephanus speculum hemisphaericus (Ehrenberg)

Dictyocha hemisphaerica Ehrenberg, 1844, pl. 17, fig. 5.
Cannopilus hemisphaericus (Ehrenberg) Locker, 1974 (in part), p. 639, pl. 4, fig. 1, 8.
Distephanus speculum hemisphaericus (Ehrenberg) Bukry, 1975b, p. 855, pl. 4, fig. 8.

Remarks: See remarks for *Distephanus jimlingii*.

Distephanus speculum speculum (Ehrenberg)

Dictyocha speculum Ehrenberg, 1839, p. 150; Ehrenberg, 1854, pl. 18, fig. 57; pl. 19, fig. 41; pl. 21, fig. 44; pl. 22, fig. 47.

Remarks: *Distephanus speculum speculum* and *D. speculum minutus* were tabulated as *D. speculum* for Site 410. At Site 412, *D. speculum speculum* specimens are notably smaller than associated silicoflagellates.

Distephanus stauracanthus (Ehrenberg)
(Plate 4, Figures 2, 3)

Dictyocha stauracanthus Ehrenberg, 1845, p. 56, 57, 76; Ehrenberg, 1854, pl. 33 (14), fig. 5; pl. 33 (15), fig. 10.
Distephanus stauracanthus (Ehrenberg), Dumitrică, 1973b, p. 850, pl. 6, fig. 14, 15.
Distephanus stauracanthus (Ehrenberg), Locker, 1974, p. 638, pl. 3, fig. 12.
Distephanus stauracanthus (Ehrenberg), Bukry, in press d, pl. 5, fig. 6.

Remarks: Rare specimens of *Distephanus stauracanthus* occur only in middle Miocene Core 25 at Site 408. Associated coccoliths are assigned to the *Discoaster exilis* Zone or *Catinaster coalitus* Zone of coccoliths. This correlation supports conclusions on the relative ranges of the fossils in the Atlantic Coast Plain (Ernissee et al., 1977).

Distephanus sulcatus n. sp.
(Plate 4, Figures 4-12)

Description: *Distephanus sulcatus* has a large sulcate basal ring—indented at strut junctions and rounded at spine junctions. Spines and pikes are moderate and tubular elements are narrow relative to the large overall size of the ring. The major-axis spines are the longest and the major-axis portals are often distinctive for their greater elongation, giving a pinched appearance. The small apical structure is a group of small, rounded, irregularly sized openings, typically three to five in number. One or two are relatively large.

Remarks: *Distephanus sulcatus* is distinguished from associated *Distephanus jimlingii* by its larger size, narrower tubes, more sulcate basal ring, elongate major-axis portals, and irregularly sized and spaced apical openings. Its size and proportions make *D. sulcatus* a distinctive member of its associated silicoflagellate assemblage.

Occurrence: *Distephanus sulcatus* occurs in the upper Pliocene of Sample 407-7-2, 59-60 cm (56 m) at an abundance of 6 per cent for a count of 300 silicoflagellates. It is not known from other DSDP sites and is probably a high-latitude species.

Size: Maximum internal diameter, 60 to 80 μm.

Holotype: USNM 250479 (Plate 4, Figures 4, 5).

Isotypes: USNM 250480 to 250483.

Type locality: North Atlantic Ocean, Sample 407-7-2, 59-60 cm (56 m).

Distephanus sp. (cruxoid)

Remarks: Large specimens of uncertain origin that resemble extinct *Distephanus crux crux* are tabulated as *Distephanus* sp. (cruxoid) for Leg 49. These specimens occur in the Quaternary of southern Sites 410 and 412.

Distephanus sp. (pentagonal)

Remarks: Large pentagonal specimens resembling *Distephanus boliviensis* (see Bukry, in press d, *Distephanus* sp. A., pl. 5, fig. 7-10) occur in the Quaternary of southern Sites 410 and 412.

Genus MESOCENA Ehrenberg, 1843

Mesocena apiculata curvata Bukry
(Plate 4, Figure 13)

Mesocena apiculata curvata Bukry, 1976b, p. 849, pl. 2, fig. 15, 16.
Mesocena apiculata (Schulz), Martini and Müller, 1976, p. 872, pl. 11, fig. 2.

Remarks: *Mesocena apiculata curvata* greatly outnumbers *M. apiculata apiculata* in the lower and middle Miocene of Sites 407 and 408.

Mesocena circulus (Ehrenberg)
(Plate 4, Figures 14, 15)

Mesocena circulus (Ehrenberg) Ehrenberg, 1844, p. 65.
Mesocena circulus (Ehrenberg) Ling, 1972, p. 175, pl. 28, fig. 5, 6.
Mesocena circulus (Ehrenberg), Bukry, 1975b, p. 868, pl. 6, fig. 1, 2.
Mesocena circulus Ehrenberg, Martini and Müller, 1976, p. 872, pl. 11, fig. 4.

Remarks: Various styles of the *Mesocena circulus* group have been tabulated together. Variations pointed out by Dumitrică (1973 b), and other variations present, include: pointed and blunt spines, small or large spines, spines at one or two levels, spines at two levels being appressed or separated, and evenly or irregularly separated around the periphery. Future study should determine the possible geologic significance of these variations.

Mesocena diodon nodosa Bukry
(Plate 4, Figure 18; Plate 5, Figures 1-4)

Mesocena diodon nodosa Bukry, in press a, pl. 5, fig. 14, 15; pl. 6, fig. 1-5.

Remarks: Nearly hexagonal and quadrate specimens of *Mesocena diodon nodosa* occur together in Sample 408-8-2, 80-82 cm (69 m).

Genus NAVICULOPSIS Frenguelli, 1940

Naviculopsis lata (Deflandre)
(Plate 5, Figures 7-9)

Dictyocha biapiculata lata Deflandre, 1932, p. 500, fig. 30, 31.
Naviculopsis lata (Deflandre) Frenguelli, 1940, p. 61, fig. 11h.

Naviculopsis robusta Deflandre, Stradner, 1961, p. 89, pl. 2, fig. 39-43, 44?, 45.
Naviculopsis lata (Deflandre), Bukry, in press a, pl. 9, fig. 1, 2.
Remarks: *Naviculopsis lata* and angular and elongate varieties occur in the lower Miocene of Cores 22 to 24 at Site 407.

ACKNOWLEDGMENT

I thank John Barron and Dick Poore, U.S. Geological Survey, for valuable discussions on Leg 49 biostratigraphic correlations. The manuscript was improved by the critical reviews of Naja Mikkelsen, Scripps Institution of Oceanography, and John Barron, U.S. Geological Survey. Typing, collating, and proofing of the manuscript was smoothly done by Dorothy Blackstock, U.S. Geological Survey.

REFERENCES

Akers, H. W. and Koeppel, P. E., 1973. Age of some Neogene formations, Atlantic Coastal Plains, United States and Mexico. *In* Smith, L. E. and Hardenbol, J. (Eds.), *Proceedings of symposium on calcareous nannofossils*: Houston (Gulf Coast Sect. Soc. Econom. Paleontologists and Mineralogists), p. 80-93.

Aumento, F., Melson, W. G., and Robinson, P. T., 1977. Introduction. *In* Aumento, F., Melson, W. G., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 37: Washington (U.S. Government Printing Office), p. 3-13.

Barron, J. A., 1976. Revised Miocene and Pliocene diatom biostratigraphy of Upper Newport Bay, Newport Beach, California, *Marine Micropaleontology,* v. 1, p. 27-63.

Berggren, W. A., 1971. Tertiary boundaries and correlations, *In* Funnel, B. M. and Riedel, W. R (Eds.), *The micropaleontology of oceans:* Cambridge (Cambridge Univ. Press), p. 693-809.

Berggren, W. A., 1972, A Cenozoic time-scale--some implications for regional geology and paleobiogeography, *Lethaia*, v.5, p.195-215.

Berggren, W. A. and Van Couvering, J., 1973, Late Neogene chronostratigraphy, biostratigraphy, biochronology, and paleoclimatology, *Woods Hole Oceanog. Inst. Tech. Rept.* 73-40, p.275.

Bramlette, M. N. and Wilcoxon, J. A., 1967, Middle Tertiary calcareous nannoplankton of the Cipero Section, Trinidad, W. I., *Tulane Studies Geology,* v. 5, p. 93-131.

Bukry, D., 1973a. Coccolith stratigraphy, eastern equatorial Pacific, Leg 16 Deep Sea Drilling Project. *In* van Andel, T. H., Heath, G. R., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 16: Washington (U.S. Government Printing Office), p. 653-711.

________, 1973b. Coccolith and silicoflagellate stratigraphy, Deep Sea Drilling Project Leg 18, eastern North Pacific. *In* Kulm, L. D., von Huene, R., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 18: Washington (U.S. Government Printing Office), p. 871-831.

________, 1974. Stratigraphic value of silicoflagellates in nontropical regions: *Geol. Soc. America Bull.,* v. 85, p. 1905-1906.

________, 1975a. Coccolith and silicoflagellate stratigraphy, northwestern Pacific Ocean, Deep Sea Drilling Project Leg 32. *In* Larson, R. L., Moberly, R., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 32: Washington (U.S. Government Printing Office), p. 677-701.

________, 1975b. Silicoflagellate and coccolith stratigraphy, Deep Sea Drilling Project Leg 29. *In* Kennett, J. P., Houtz, R. E., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 29: Washington (U.S. Government Printing Office), p. 845-872.

________, 1976a. Cenozoic silicoflagellate and coccolith stratigraphy, South Atlantic Ocean, Deep Sea Drilling Project Leg 36. *In* Hollister, C.D., Craddock, C., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 35: Washington (U.S. Government Printing Office), p. 885-917.

________, 1976b. Silicoflagellate and coccolith stratigraphy, Norwegian-Greenland Sea, Deep Sea Drilling Project Leg 38. *In* Talwani, M., Udintsev, G., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 38: Washington (U.S. Government Printing Office), p. 843-855.

________, 1977a. Coccolith and silicoflagellate stratigraphy, central North Atlantic Ocean, Deep Sea Drilling Project Leg 37. *In* Aumento, F., Melson, W. G., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 37: Washington (U.S. Government Printing Office), p. 917-927.

________, 1977b. Cenozoic coccolith and silicoflagellate stratigraphy, offshore northwest Africa, Deep Sea Drilling Project Leg 41. *In* Lancelot, Y., Seibold, E., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 41: Washington (U.S. Government Printing Office), p. 689-708.

________, in press a. Cenozoic coccolith and silicoflagellate stratigraphy, Deep Sea Drilling Project Leg 44. *In* Benson, W. E., Sheridan, R. E., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 44: Washington (U.S. Government Printing Office), p. 807-864.

________, in press b. Cenozoic silicoflagellate and coccolith stratigraphy, southeastern Atlantic Ocean, Deep Sea Drilling Project Leg 40. *In* Bolli, H. M., Ryan, W. B. F., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 40: Washington (U.S. Government Printing Office), p. 635-650.

________, in press c. Cenozoic silicoflagellate and coccolith stratigraphy, northwestern Atlantic Ocean, Deep Sea Drilling Project, Leg 43. *In* Benson, W.E., Sheridan, R.E., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 44: Washington (U.S. Government Printing Office), p. 775-806.

________, in press d. Comments on opal phytoliths and stratigraphy of Neogene silicoflagellates and coccoliths at Deep Sea Drilling Project Site 397 off northwest Africa. *In* Ryan, W. B. F., von Rad, U., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 47: Washington (U.S. Government Printing Office).

Bukry, D. and Foster, J. H., 1973. Silicoflagellate and diatom stratigraphy, Leg 16, Deep Sea Drilling Project. *In* van Andel, T. H., Heath, G. R., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 16: Washington (U.S. Government Printing Office), p. 815-871.

________, 1974. Silicoflagellate zonation of Upper Cretaceous to lower Miocene deep-sea sediment *U.S. Geol. Survey J. Research,* v. 2, p. 303-310.

Ciesielski, P. F., 1975. Biostratigraphy and paleoecology of Neogene and Oligocene silicoflagellates from cores recovered during Antarctic Leg 28, Deep Sea Drilling Project. *In* Hayes, D. E., Frakes, L. A., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 28: Washington (U.S. Government Printing Office), p. 625-691.

Deflandre, G., 1932. Sur la systématique des Silicoflagellés, *Soc. Bot. France Bull.,* v. 79, p. 494-506.

Dumitrică, P., 1973a. Miocene and Quaternary silicoflagellates in sediments from the Mediterranean Sea. *In* Ryan, W. B. F., Hsü K. J., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 13: Washington (U.S. Government Printing Office), p. 902-933.

________, 1973b. Paleocene, late Oligocene and post-Oligicene silicoflagellates in southwestern Pacific sediments cored on DSDP Leg 21. *In* Burns, R. E., Andrews, J. E., et al., *Initial Reports of the Deep Sea Drilling Project,* v. 21: Washington (U.S. Government Printing Office), p. 837-883.

Ehrenberg, C. G., 1839. Über die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen, *K. Preuss. Akad. Wiss. Berlin Ber.*, Jahrg. 1838, p. 59-148.

———, 1840. 274 Blätter von ihm selbst ausgeführter Zeichnungen von ebenso vielen Arten, *K. Preuss. Akad. Wiss. Berlin Ber.*, Jahrg. 1840, p. 197-219 (Nov.).

———, 1844. Untersuchungen über die kleinsten Lebensformen im Quellenlande des Euphrats und Araxes, so wie über eine an neuen Formen sehr reiche marine Tripelbildung von den Bermuda-Inseln vor., *K. Preuss. Akad. Wiss. Berlin Ber.*, Jahrg. 1844, p. 253-275.

———, 1845. Neue Untersuchungen über das kleinste Leben als geologisches Moment., *K. Preuss. Akad. Wiss. Berlin Ber.*, Jahrg. 1845, p. 53-87.

———, 1854. *Mikrogeologie:* Leipzig (Leopold Voss), p. 1-374.

Ernissee, J. J., Abbott, W. H., and Huddlestun, P. F., 1977. Microfossil correlation of the Coosawhatchie Clay (Hawthorn Formation, Miocene) of South Carolina, and its equivalent in Georgia, *Marine Micropaleontology*, v. 2, p. 105-119.

Ewing, M., Worzel, J. L., Beall, A. O., Berggren, W. A., Bukry, D., Burk, C. A., Fischer, A. G., and Pessagno, E. A., Jr., 1969. Appendix I: Time stratigraphic framework. *In* Ewing, M., Worzel, J. L., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 1: Washington (U.S. Government Printing Office), p. 643-651.

Folger, D. W., 1970. Wind transport of land-derived mineral, biogenic, and industrial matter over the North Atlantic, *Deep-Sea Research*, v. 17, p. 337-352.

Frenguelli, J., 1940. Consideraciones sobre los silicoflagelados fósiles, *Mus. La Plata Rev., Paleontol.*, v. 2, no. 7, p. 37-112.

———, 1951. Silicoflagelados del Trîpoli de Mejillones (Chile), *Physis* (Buenos Aires), v. 20, p. 272-284.

Gartner, S., 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene, *Marine Micropaleontology*, v. 2, p. 1-25.

Hays, J. D., Saito, T., Opdyke, N. D., and Burckle, L. H., 1969. Pliocene-Pleistocene sediments of the equatorial Pacific: their paleomagnetic, biostratigraphic, and climatic record, *Geol. Soc. America Bull.*, v. 80, p. 1481-1514.

Heirtzler, J. R. and van Andel, T. H., 1977. Project FAMOUS: Its origin, programs, and setting, *Geol. Soc. America Bull.*, v. 88, p. 481-487.

Jousé, A.P. and Mukhina, V.V., 1973. The *Mesocena elliptica* Ehr. Zone in the Pleistocene sediments of the Pacific Ocean, *Oceanology* (AGU Translation), v. 13, p. 386-394.

Klitgord, K. D., Huestis, S. P., Mudie, J. D., and Parker, R. L., 1975. An analysis of near-bottom magnetic anomalies: Sea-floor spreading and the magnetized layer, *Geophys. J. Royal Astron. Soc.*, v. 43, p. 387-424.

LaBrecque, J. L., Kent, D. V., and Cande, S. C., 1977. Revised magnetic polarity time scale for Late Cretaceous and Cenozoic time, *Geology*, v. 5, p. 330-335.

Lemmermann, E., 1901. Silicoflagellatae, *Deutsche. Bot. Gesell. Ber.*, v. 19, p. 247-271.

Ling, H. Y., 1970. Silicoflagellates from central North Pacific core sediments, *Am. Paleontology Bull.*, v. 58, p. 85-129.

———, 1972. Upper Cretaceous and Cenozoic silicoflagellates and ebridians, *Am. Paleontology Bull.*, v. 62, p. 135-229.

———, 1973. Silicoflagellates and ebridians from Leg 19. *In* Creager, J. S., Scholl, D. W., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 19: Washington (U.S. Government Printing Office), p. 751-775.

———, 1975. Silicoflagellates and ebridians from Leg 31. *In* Ingle, J. C., Karig, D. E., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 31: Washington (U.S. Government Printing Office), p. 763-777.

Locker, S., 1974. Revision der Silicoflagellaten aus der Mikrogeologischen Sammlung von C. G. Ehrenberg, *Ecologae Geol. Helvetiae*, v. 67, p. 631-646.

Loeblich, A. R., 3d, Loeblich, L. A., Tappan, H., and Loeblich, A. R., 1968. Annotated index of fossil and recent silicoflagellates and ebridians with descriptions and illustrations of validly proposed taxa, *Geol. Soc. America Mem.*, 106, 319 p.

Martini, E., 1971. Neogene silicoflagellates from the equatorial Pacific. *In* Winterer, E. L., Riedel, W. R., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 7: Washington (U.S. Government Printing Office), p. 1695-1708.

———, 1972. Silicoflagellate zones in the late Oligocene and early Miocene of Europe, *Senckenbergiana Lethaea*, v. 53, p. 119-122.

———, 1976. Cretaceous to recent calcareous nannoplankton from the central Pacific Ocean (DSDP Leg 33). *In* Schlanger, S. O., Jackson, E. D., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 33: Washington (U.S. Government Printing Office), p. 383-423.

Martini, E. and Müller, C., 1976. Eocene to Pleistocene silicoflagellates from the Norwegian-Greenland Sea (DSDP Leg 38). *In* Talwani, M., Udintsev, G., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 38: Washington (U.S. Government Printing Office), p. 857-895.

Müller, C., 1976. Tertiary and Quaternary calcareous nannoplankton in the Norwegian-Greenland Sea, DSDP Leg 38. *In* Talwani, M., Udintsev, G., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 38: Washington (U.S. Government Printing Office, p. 823-841.

Nakagawa, H. Niitsuma, N., Kitamura, N., Matoba, Y., Takayama, T., and Asano, K., 1974. Preliminary results on magnetostratigraphy of Neogene stage stratotype sections in Italy, *Riv. Italiana Paleontologia*, v.80, p.615-630.

Perch-Nielsen, K., 1972. Remarks on Late Cretaceous to Pleistocene coccoliths from the North Atlantic. *In* Berggren, W. A., Laughton, A. S., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 12: Washington (U.S. Government Printing Office), p. 1003-1069.

Poelchau, H. S., 1976. Distribution of Holocene silicoflagellates in North Pacific sediments, *Micropaleontology*, v. 22, p. 164-193.

Roth, P. H. and Berger, W. H., 1975. Distribution and dissolution of coccoliths in the south and central Pacific, *Cushman. Found. Foram. Research Spec. Publ. 13*, p. 87-113.

Ryan, W. B. F., Cita, M. B., Dreyfus Rawson, M. Burckle, L. H., and Saito, T., 1974. A paleomagnetic assignment of Neogene stage boundaries and the development of isochronous datum planes between the Mediterranean, the Pacific and Indian Oceans in order to investigate the response of the world ocean to the Mediterranean "salinity crisis," *Riv. Italiana Paleontologia*, v. 80, p. 631-688.

Sanfilippo, A., Burckle, L.H., Martini, E., and Riedel, W.R., 1973. Radiolarians, diatoms, silicoflagellates and calcareous nannofossils in the Mediterranean Neogene, *Micropaleontology*, v. 19, p. 209-234.

Schulz, P., 1928. Beiträge zur Kenntnis fossiler und rezenter Silicoflagellaten, *Bot. Archiv.* v. 21, p. 225-292.

Stradner, H., 1961. Über fossile Silicoflagelliden und die Möglichkeit ihrer Verwendung in der Erdölstratigraphie, *Erdöl Kohle*, v. 14, p. 87-92.

Thierstein, H. R., Geitzenauer, K. R., Molfino, B., and Shackleton, N. J., 1977. Global synchroneity of late Quaternary coccolith datum levels: Validation by oxygen isotopes, *Geology*, v. 5, p. 400-404.

PLATE 1
Neogene Silicoflagellates From DSDP Leg 49
All figures magnified 800×; scale bar equals 10 μm.

Figure 1	*Corbisema triacantha* (Ehrenberg) s. ampl. Swirled apical structure, Sample 407-22-2, 20-22 cm (198 m).
Figure 2	*Dictyocha aculeata* (Lemmermann). Sample 412-4-6, 36-38 cm (31 m).
Figures 3,4	*Dictyocha* sp. cf. *D. aculeata* (Lemmermann). 3. Sample 412-6-2, 109-111 cm (83 m). 4. Sample 412-10-4, 129-131 cm (124 m).
Figures 5,6	*Dictyocha calida ampliata* Bukry. Sample 412-8-5, 130-132 cm (106 m).
Figure 7	*Dictyocha calida calida* Poelchau. Sample 412-10-4, 129-131 cm (124 m).
Figures 8-12	*Dictyocha hessii* Bukry. 8. Sample 412-6-2, 109-111 cm (83 m). 9, 10. Sample 412-8-5, 130-132 cm (106 m). 11, 12. Sample 412-14-1, 59-61 cm (157 m).
Figure 13	*Dictyocha lingii* Dumitrică. Sample 412-8-5, 130-132 cm (106 m).

PLATE 1

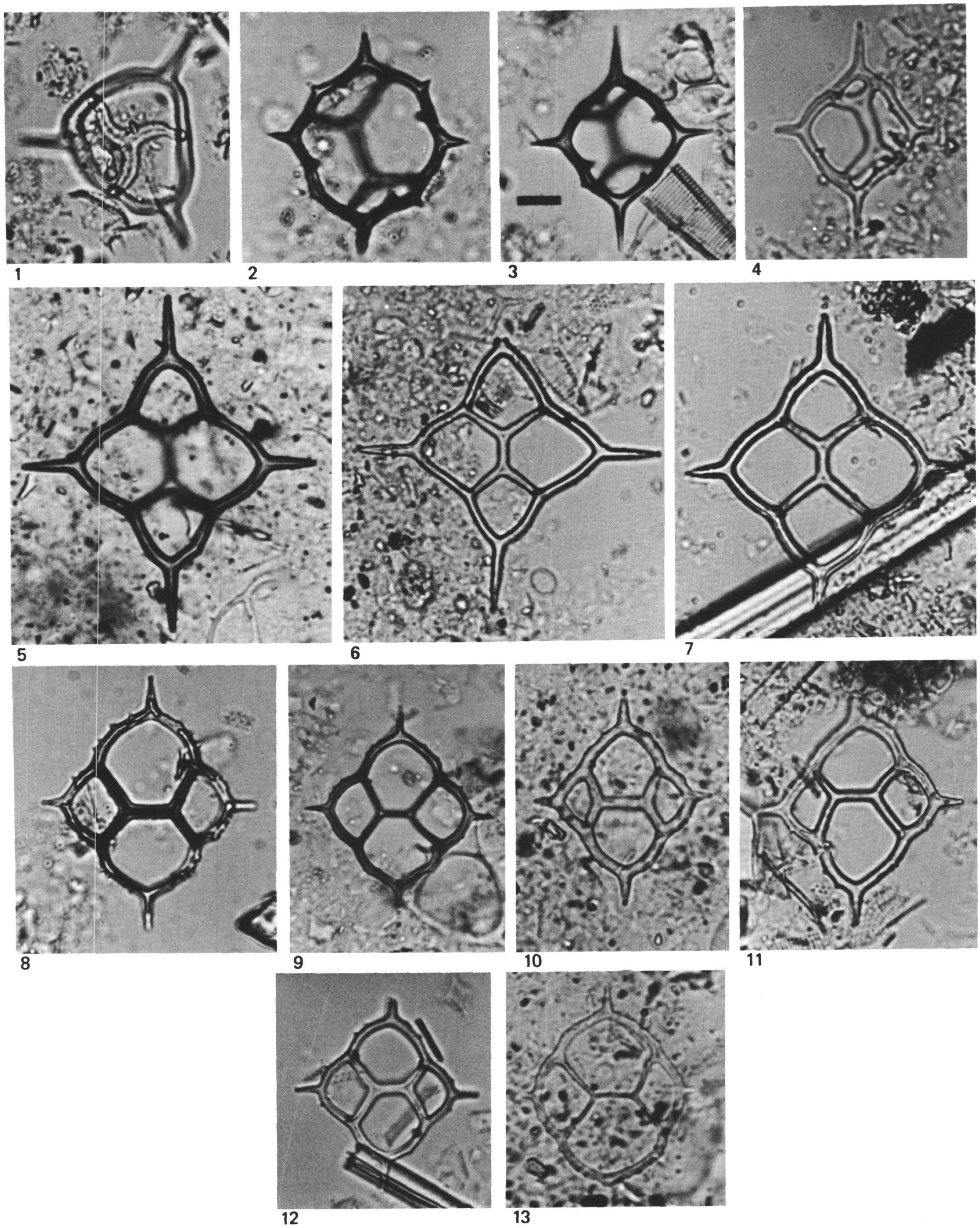


PLATE 2

Neogene Silicoflagellates From DSDP Leg 49
All figures magnified 800×; scale bar equals 10 μm.

Figures 1-4 *Dictyocha lingii* Dumitrică.
1. Sample 412-6-2, 109-111 cm (83 m).
2. Sample 412-7-2, 30-32 cm (91 m).
3,4. Sample 412-8-5, 130-132 cm (106 m).

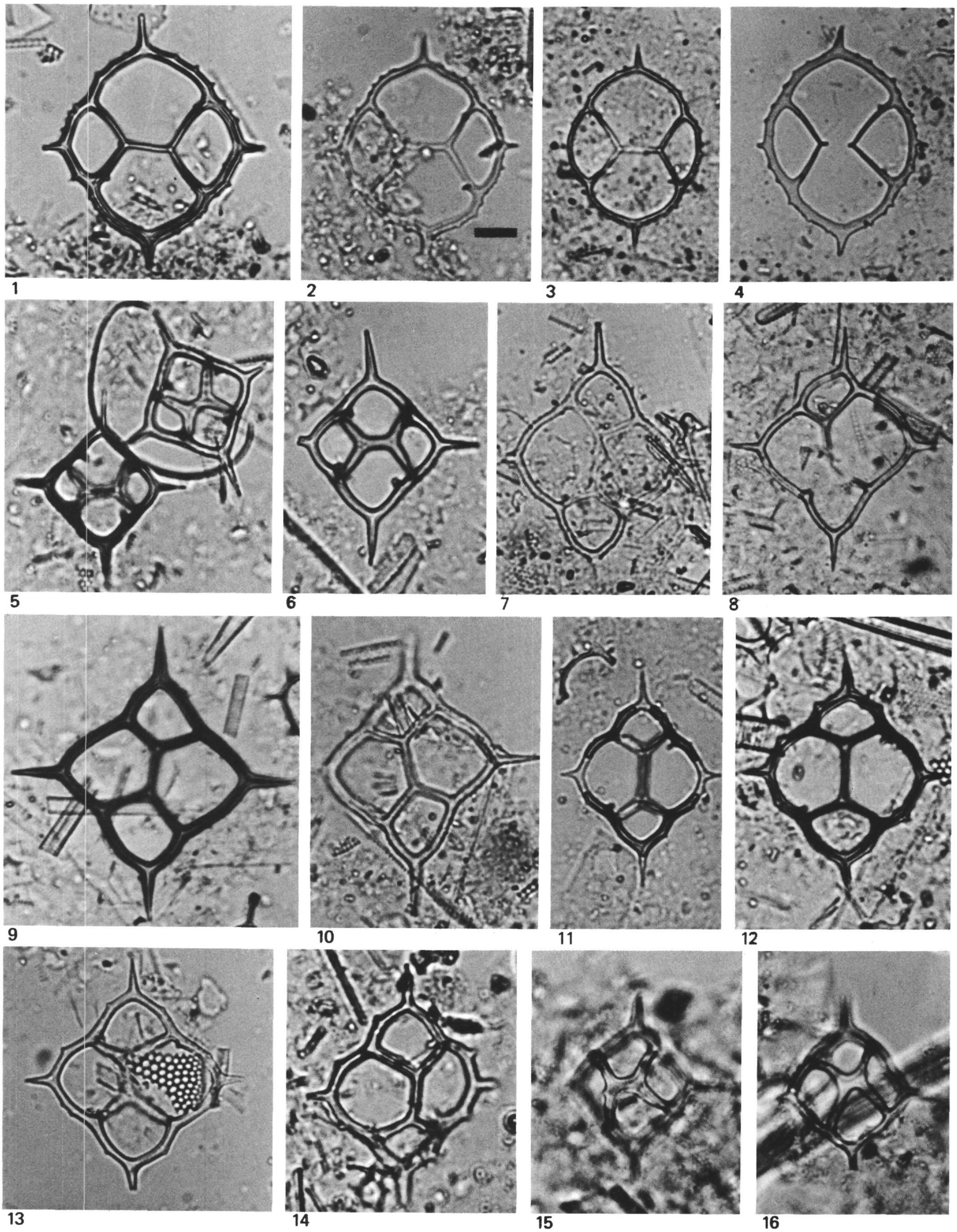
Figures 5,6 *Dictyocha* sp. cf. *D. longispina* (Lemmermann) asperoid.
Sample 410-8-4, 91-93 cm (69 m).

Figures 7-10 *Dictyocha perlaevis flexatella* Bukry.
Sample 410-14-6, 100-102 cm (130 m).

Figures 11-14 *Dictyocha perlaevis ornata* Bukry.
11. Sample 410-14-4, 96-98 cm (127 m).
12-14. Sample 410-14-6, 100-102 cm (130 m).

Figures 15,16 *Dictyocha* sp. cf. *D. vexativa* Bukry.
15. Sample 412-7-2, 30-32 cm (91 m).
16. Sample 412-10-4, 129-131 cm (124 m).

PLATE 2



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

PLATE 3
Neogene Silicoflagellates From DSDP Leg 49
Figures 3-6, 14 magnified 800×; scale bar equals 10 μm.
Figures 1, 2, 7-13, 15-16 magnified 400×; scale bar equals 20 μm.

Figures 1, 2	*Distephanus boliviensis* (Frenguelli) [cannopilean]. Sample 408-11-4, 121-123 cm (101 m).
Figure 3	*Distephanus crux* (Ehrenberg) s. ampl. Sample 408-29-2, 25-27 cm (288 m).
Figure 4	*Distephanus crux* (Ehrenberg) [dictyochoid]. Sample 408-25-6, 14-16 cm (236 m).
Figures 5, 6	*Distephanus frugalis* (Bukry). 5. Sample 408-5-3, 51-53 cm (42 m). 6. Sample 407-7-2, 59-60 cm (56 m).
Figures 7-12	*Distephanus jimlingii* (Bukry). Sample 408-9-2, 60-62 cm (78 m).
Figures 13, 14	*Distephanus longispinus* (Schulz). 13. Sample 408-24-2, 0-2 cm (220 m). 14. Sample 407-19-2, 50-52 cm (170 m).
Figures 15, 16	*Distephanus polyactis* (Ehrenberg). Sample 408-9-2, 60-62 cm (78 m). 15. Basal focus. 16. Apical ring piked; small *Distephanus speculum minutus* (Bachmann) to right.

PLATE 3

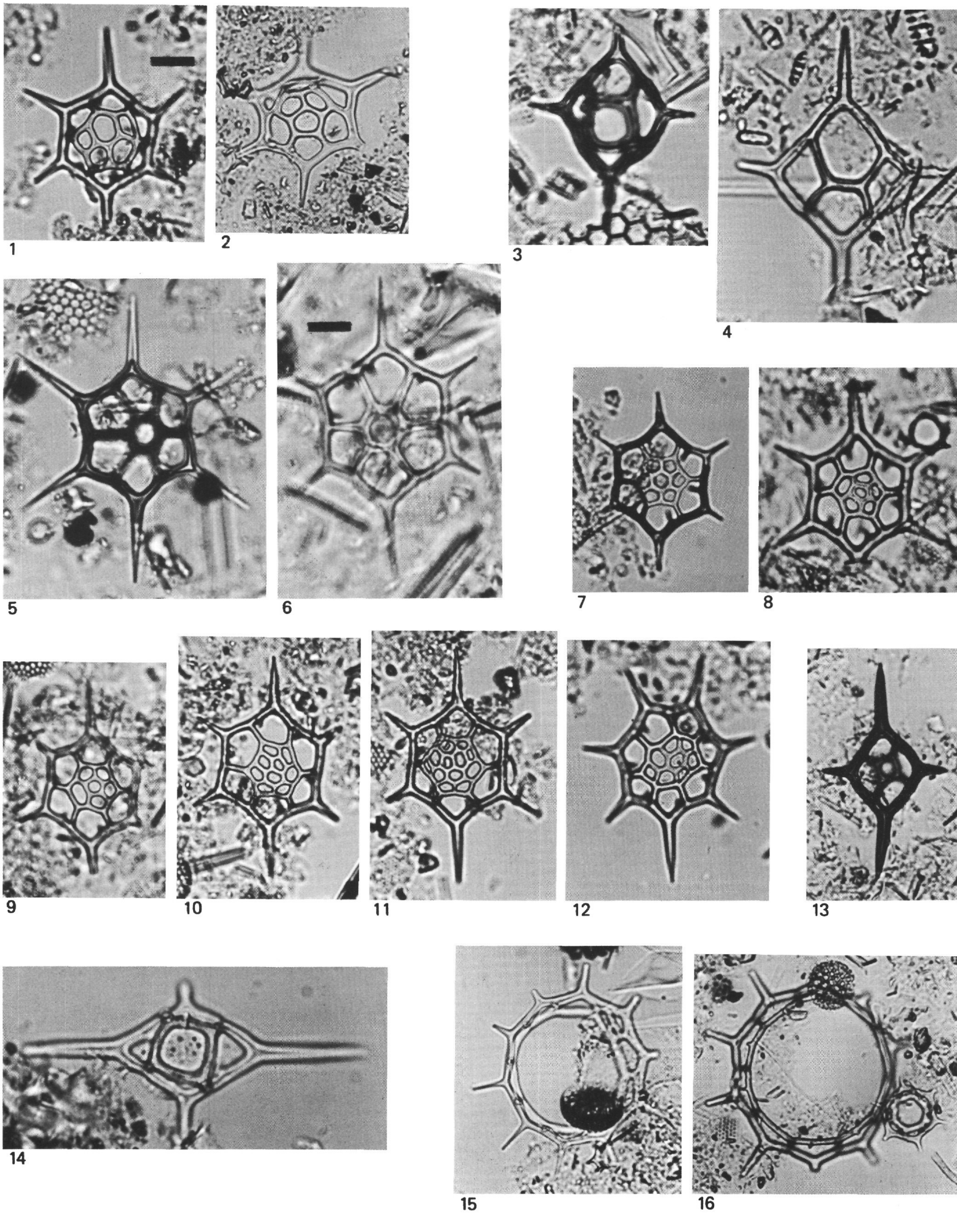


PLATE 4

Neogene Silicoflagellates From DSDP Leg 49
Figures 2, 3, 13, 15, 18 magnified 800×; scale bar equals 10 μm.
Figures 1, 14, 16, 17 magnified 400×; scale bar equals 20 μm.Figures 4-12 magnified 350×; scale bar equals 20 μm.

Figure 1	*Distephanus polyactis* (Ehrenberg). Sample 408-9-2, 60-62 cm (78 m).
Figures 2, 3	*Distephanus stauracanthus* (Ehrenberg). Sample 408-25-6, 14-16 cm (236 m).
Figures 4-12	*Distephanus sulcatus* n. sp. Sample 407-7-2, 59-60 cm (56 m). 4, 5. Holotype, USNM 250479. 6, 7. USNM 250480. 8, 9. USNM 250481. 10. USNM 250482. 11, 12. USNM 250483.
Figure 13	*Mesocena apiculata curvata* Bukry. Sample 407-24-6, 119-121 cm (224 m).
Figures 14, 15	*Mesocena circulus* (Ehrenberg) s. ampl. 14. Sample 408-24-2, 0-2 cm (220 m). 15. Sample 407-7-2, 59-60 cm (56 m).
Figures 16, 17	*Mesocena diodon diodon* (Ehrenberg). 16. Sample 408-27-2, 94-96 cm (249 m). 17. Sample 408-29-2, 25-27 cm (268 m).
Figure 18	*Mesocena diodon nodosa* Bukry. Sample 408-22-1, 51-53 cm (200 m).

PLATE 4

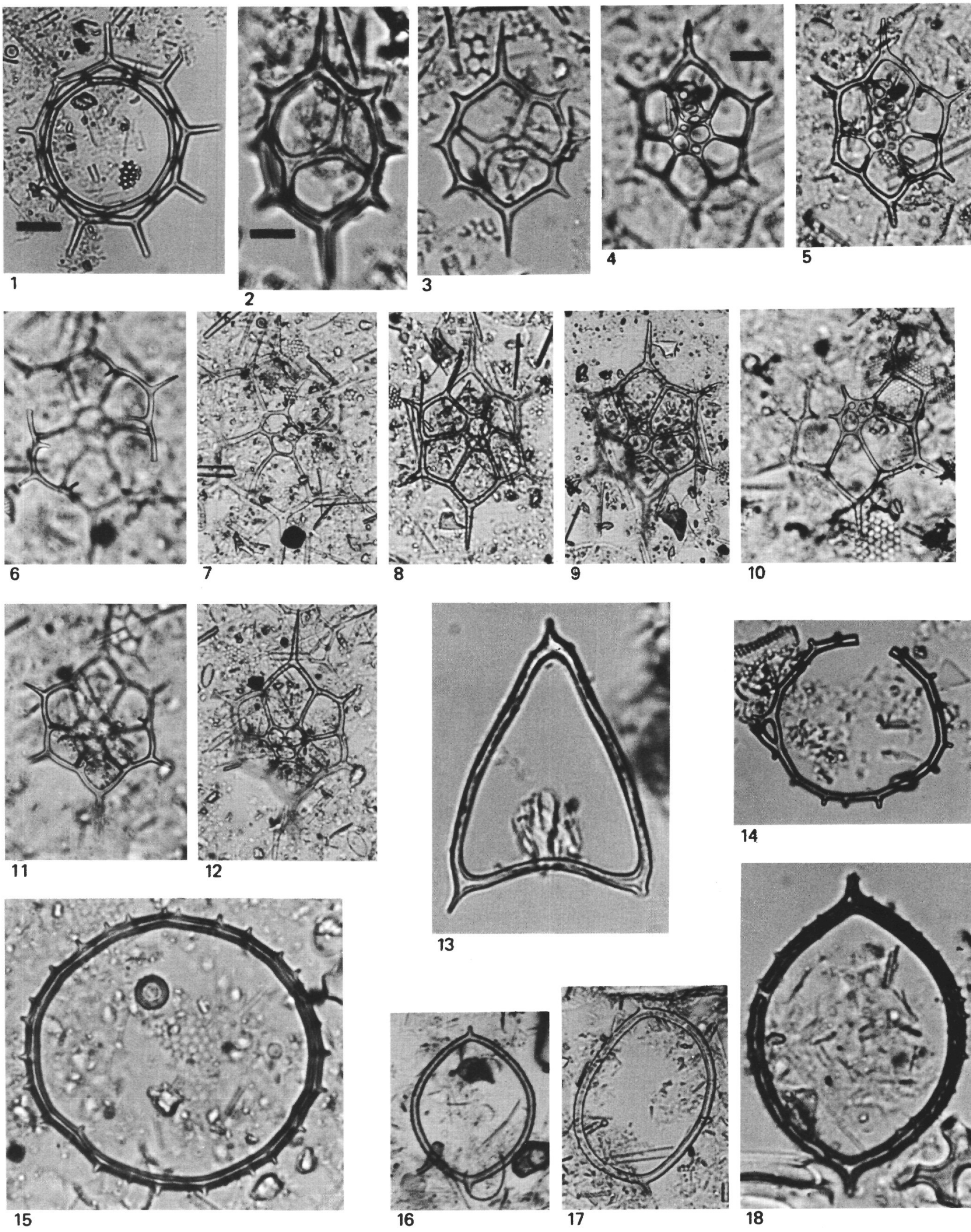


PLATE 5

Neogene Silicoflagellates and *Macrora* From DSDP Leg 49
Figure 16 magnified 1050×; scale bar equals 10 μm.
Figures 1, 2, 4, 6, 7, 10, 12-15 magnified 800×; scale bar equals 10 μm.
Figures 3, 5, 8, 9, 11 magnified 400×; scale bar equals 20 μm.

Figure 1	*Mesocena diodon nodosa* Bukry. Normal, Sample 408-22-1, 51-53 cm (200 m).
Figures 2-4	*Mesocena* sp. aff. *M. diodon nodosa* Bukry. 2. Four-sided, Sample 408-8-2, 80-82 cm (69 m). 3, 4. Six-sided, Sample 408-8-2, 80-82 cm (69 m).
Figures 5, 6	*Mesocena quadrangula* Ehrenberg ex Haeckel. 5. Sample 412-7-2, 30-32 cm (91 m). 6. Sample 408-8-2, 80-82 cm (69 m).
Figures 7-9	*Naviculopsis lata* (Deflandre). Sample 407-22-2, 20-22 cm (198 m). 7. Normal. 8. Elongate. 9. Elongate; *Dictyocha pentagona* (Schulz) below.
Figures 10-11	*Naviculopsis quadrata* (Ehrenberg). Sample 407-22-2, 20-22 cm (198 m).
Figures 12-15	*Octactis pulchra* Schiller. 12, 13. Sample 410-8-4, 91-93 cm (69 m). 14, 15. Sample 412-5-3, 130-132 cm (56 m).
Figure 16	*Macrora stella* (Azpeitia). Sample 408-25-6, 14-16 cm (236 m).

PLATE 5

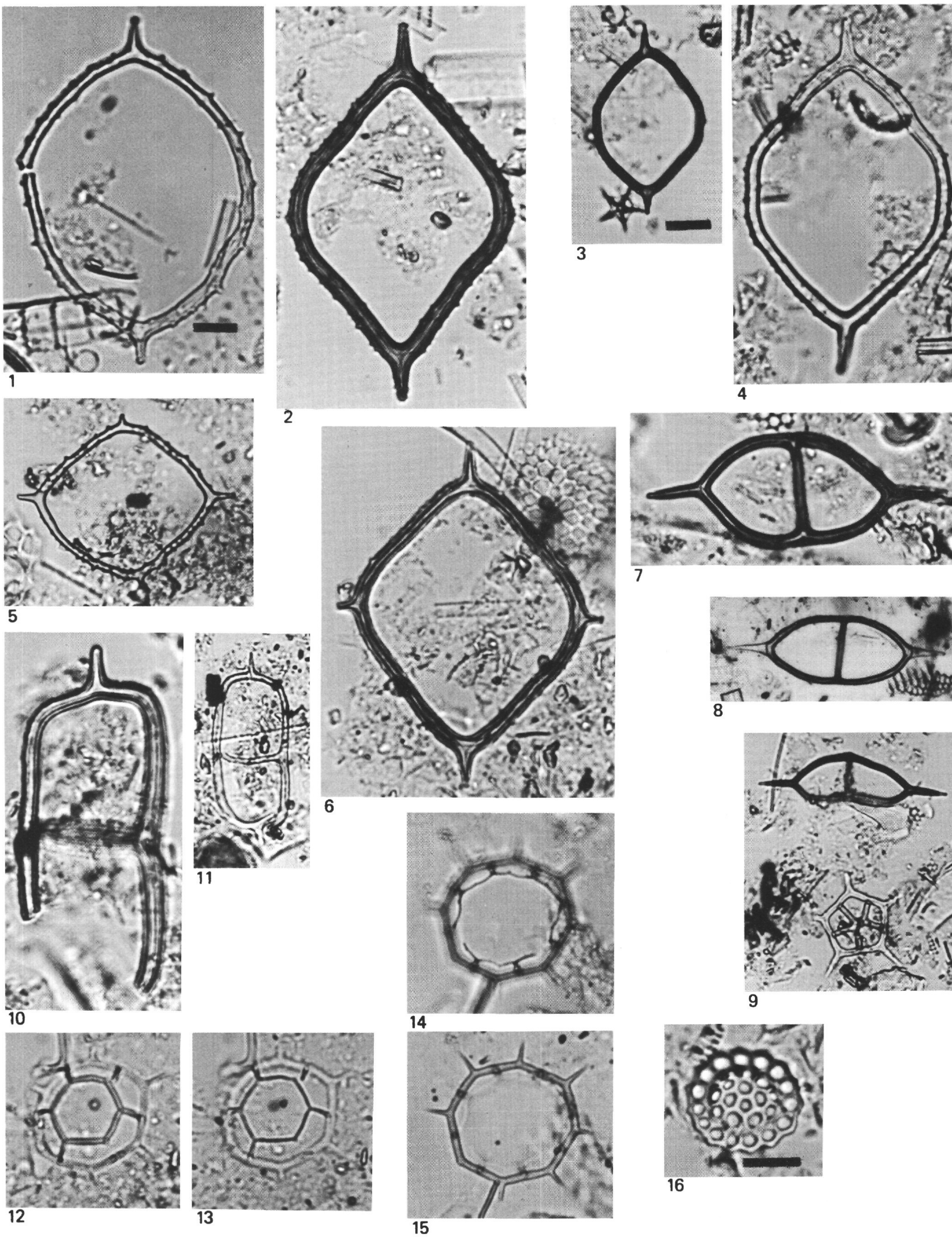


PLATE 6

Neogene Diatoms, Opal Phytoliths, and
Siliceous Sponge Spicules From Leg 49
Figures 1, 2 magnified 1050×; scale bar equals 10 μm.
Figures 3-10, 15 magnified 800×; scale bar equals 10 μm.
Figures 12-13 magnified 400×; scale bar equals 20 μm.
Figures 11, 14 magnified 350×; scale bar equals 20 μm.

Figures 1, 2 — *Macrora stella* (Azpeitia).
Sample 408-25-6, 14-16 cm (236 m).

Figures 3 — *Rhizosolenia* frustule.
Sample 412-1-1, 99-101 cm (1 m).

Figures 4, 5 — *Rocella gelida* (Mann).
Sample 407-29-4, 20-22 cm (265 m).
4. Abapical focus.
5. Apical focus.

Figures 6, 7 — Panicoid opal phytoliths.
6. Sample 410-14-4, 96-98 cm (127 m).
7. Sample 410-14-6, 100-102 cm (130 m).

Figure 8 — Elongate opal phytoliths.
Sample 408-5-3, 51-53 cm (42 m).

Figure 9 — Diatom sp.
Sample 407-18-4, 50-52 cm (163 m).

Sponge Spicules

Figure 10 — Amphidisc.
Sample 407-24-6, 119-121 cm (224 m).

Figure 11 — Diancistron (one hook elevated).
Sample 407-24-4, 50-52 cm (220 m).

Figures 12-15
12. Sample 408-19-2, 114-116 cm (174 m).
13. Sample 408-21-4, 0-2 cm (195 m).
14. Sample 408-27-2, 94-96 cm (249 m).
15. Sample 407-29-4, 20-22 cm (265 m).

PLATE 6

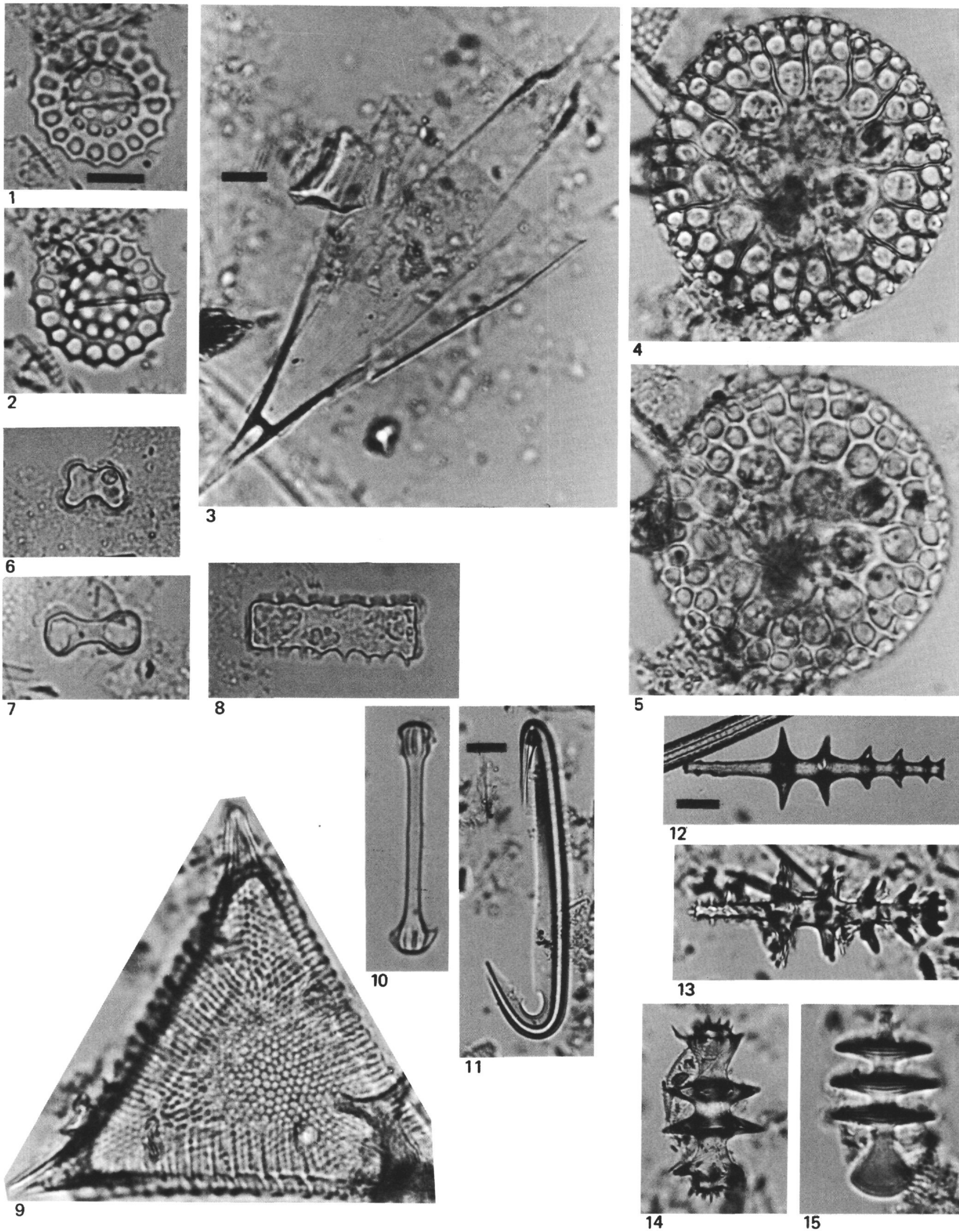


PLATE 7

Neogene Siliceous Sponge Spicules From Leg 49
Figures 2, 4, 14 magnified 800×; scale bar equals 10 μm.
Figures 5, 10, 16 magnified 400×; scale bar equals 20 μm.
Figures 1, 3, 6-9, 11-13, 15, 17-20 magnified 350×; scale bar equals 20 μm.

Figures 1-5	Isochelas. 1. Sample 408-25-6, 14-16 cm (236 m). 2. Sample 408-21-4, 0-2 cm (195 m). 3. Sample 408-23-2, 0-2 cm (211 m). 4. Sample 412-12-2, 39-41 cm (139 m). 5. Sample 407-19-2, 50-52 cm (170 m).
Figures 6, 14, 15	Oxeas 6. Sample 408-22-1, 51-53 cm (200 m). 14. Sample 407-30-4, 103-105 cm (278 m). 15. Sample 409-7-2, 31-33 cm (74 m).
Figures 7-13	Oxeas. 7. Sample 408-20-2, 35-37 cm (182 m). 8. Sample 408-27-2, 94-96 cm (249 m). 9. Sample 408-24-2, 0-2 cm (220 m). 10. Sample 412-3-3, 39-41 cm (14 m). 11. Sample 407-31-4, 91-93 cm (287 m). 12, 13. Sample 407-29-4, 20-22 cm (265 m).
Figure 16	Sterraster. Sample 409-7-2, 31-33 cm (74 m).
Figure 17	Streptaster. Sample 407-18-4, 50-52 cm (163 m).
Figures 18, 19	Spherasters. 18. Sample 407-18-4, 50-52 cm (163 m). 19. Sample 407-31-4, 91-93 cm (287 m).
Figure 20	Strongyle, spined. Sample 407-18-4, 50-52 cm (163 m).

PLATE 7

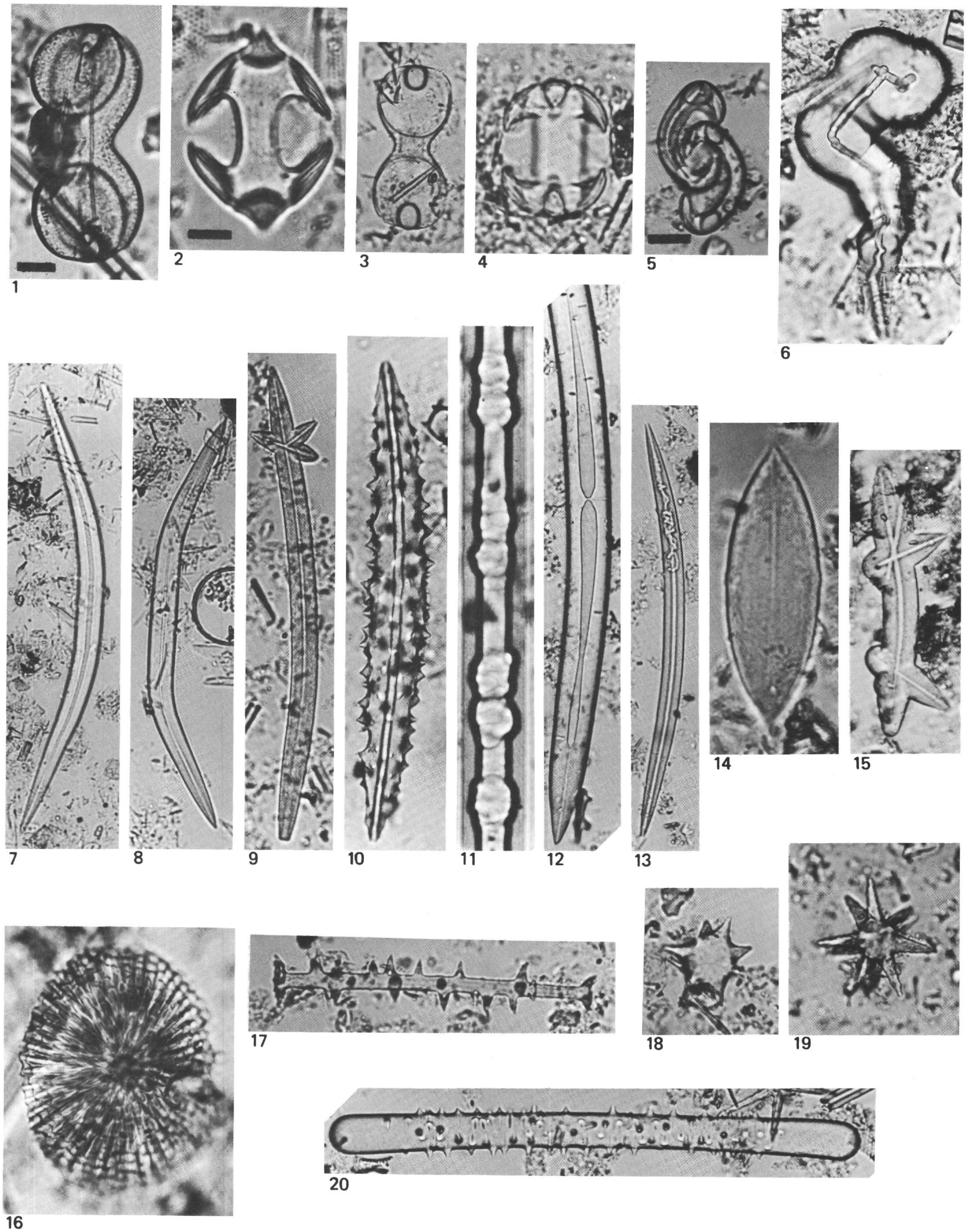


PLATE 8

Neogene Siliceous Sponge Spicules From Leg 49

Figure 16 magnified 800×; scale bar equals 10 μm.
Figures 5, 7, 11, 14, 15 magnified 400×; scale bar equals 20 μm.
Figures 1-4, 6, 8-10, 12, 13 magnified 350×; scale bar equals 20 μm.

Figures 1-6 Tylostyles.
1. 3, 4. Sample 407-18-4, 50-52 cm (163 m).
2. Sample 408-24-2, 0-2 cm (220 m).
5. Sample 407-24-6, 119-121 cm (224 m).
6. Sample 407-24-1, 25-27 cm (215 m).

Figure 7 Trichotriaene, spiney.
Sample 408-21-4, 0-2 cm (195 m).

Figures 8-16 Miscellaneous spicules.
8. Sample 408-22-1, 51-53 cm (200 m).
9. Sample 409-7-2, 31-33 cm (74 m).
10. Sample 408-29-2, 25-27 cm (268 m).
11. Sample 408-10-4, 120-122 cm (91 m).
12. Sample 407-18-4, 50-52 cm (163 m).
13. Sample 407-29-4, 20-22 cm (265 m).
14. Sample 407-24-1, 25-27 cm (215 m).
15. Sample 407-19-2, 50-52 cm (170 m).
16. Sample 408-27-2, 94-96 cm (249 m).

PLATE 8