14. SILICOFLAGELLATE STRATIGRAPHY OF OFFSHORE CALIFORNIA AND BAJA CALIFORNIA, DEEP SEA DRILLING PROJECT LEG 63[1]

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ABSTRACT

Quantitative study of middle and upper Miocene silicoflagellate assemblages from Pacific Coast Sites 467 and 469 to 472 has permitted identification of warm- and temperate-water biostratigraphic zones and the formulation of a model for relative paleotemperature values (*Ts*) on the basis of warm- and temperate-genera abundances. Geographic and temporal trends in *Ts* for Pacific Coast assemblages are indicated. Three new taxa are described: *Dictyocha subclinata* Bukry n. sp., *Mesocena diodon borderlandensis* Bukry n. subsp., and *M. hexalitha* Bukry, n. sp. The ranges in space and time for several species, such as *Dictyocha neonautica* var. *cocosensis* and *Distephanus mesophthalmus*, are increased. Regionally, barred forms of *Distephanus stauracanthus* become predominant over ringed forms in the upper part of the middle Miocene *Distephanus stauracanthus* Subzone.

INTRODUCTION

Leg 63 drilling along the Pacific Coast from Site 467 near Pt. Conception, California, to Site 473 near Trés Marias Islands, Mexico, provides a latitudinal transect of the California Current region (Fig. 1). From a set of 61 mostly middle and upper Miocene samples, silicoflagellates were examined in detail. Specimens were counted from these samples to establish biostratigraphic boundaries and paleoecologic trends. Preliminary nonquantitative work on other samples was done aboard ship. Results show the anticipated warmer conditions in southern sites and major fluctuations in species dominance in the late Miocene. The cool-temperate zonation developed at Site 173 for the northern part of the California Current (Bukry, 1973b) is most easily recognized at Site 467 and 469, whereas its guide species are less consistent at southern Sites 470 to 472. Sites 468 and 473 contain few silicoflagellate-bearing intervals. Where it was possible, both cool-temperate and warm-water zones (Bukry, in press) were identified. Silicoflagellate zonal assignments for Leg 63 are presented in a summary figure on the basis of those samples for which numerical data are available (Fig. 2). Coccolith zones for the sections studied are provided for reference through the use of a coded system (Okada and Bukry, 1980; Bukry, this volume).

RELATIVE PALEOTEMPERATURE VALUES (*Ts*)

Quantitative distribution data for silicoflagellate assemblages permitted selection of a model for identifying relative paleotemperatures off the Pacific Coast. Because north–south gradients of sea temperature can be expected and certain geological intervals are known to be generally cooler or warmer in the Pacific (Ingle, 1973), a mix of silicoflagellate indicator taxa from the California Current area can be proposed to show temperature gradients in space and time. The relative paleotemperature technique developed for diatoms by Kanaya and Koizumi (1966) has been used for silicoflagellate studies of fossil and extinct assemblages by Ciesielski (1975) and Dumoulin (personal communication, 1979). The silicoflagellate paleotemperature values that have been determined are less detailed than are the diatom values of Kanaya and Koizumi, because the taxa used to indicate warm and cool conditions for silicoflagellates are only at the level of genera, not species.

General paleotemperature trends of silicoflagellates can be seen in the relative abundances of warm-water *Dictyocha* and cool-water *Distephanus* (hexagonal). This basic relationship indicated by Gemeinhardt (1930), Mandra (1969), and Lipps (1970) has been augmented by Ciesielski and by Dumoulin with the assignment of temperature characteristics to other silicoflagellate genera. For example, *Cannopilus* is considered cool and *Corbisema* warm.

The silicoflagellate paleotemperature values (*Ts*) for this Leg 63 report are calculated on a broad generic basis, but a value based on species or subspecies distributions can be developed when more sample determinations are completed. The general formula

$$Ts = X_w + 0.5\, X_t$$

where

X_w = warm-indicating genera: *Corbisema* and *Dictyocha*

and

X_t = temperate-indicating genus: *Distephanus* (quadrate)

employs percentages calculated for the whole assemblage. I derived this relation empirically after comparing results with those derived from the relative paleo-

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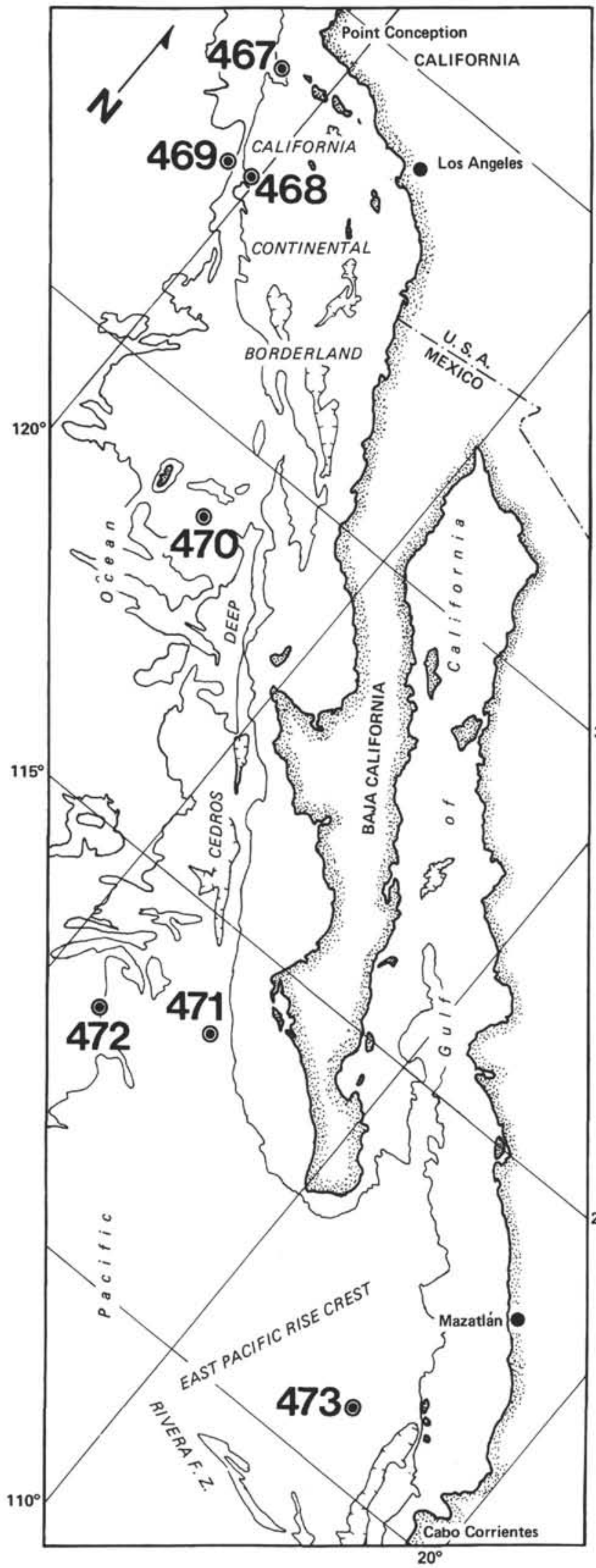

Figure 1. Location of DSDP Leg 63 sites.

temperature technique developed for diatoms by Kanaya and Koizumi (1966) and from the *Dictyocha/Distephanus* ratio (Lipps, 1970). Cool-indicating genera such as *Cannopilus, Distephanus* (hexagonal), and *Mesocena* are not used.

The quadrate *Distephanus* (*D. crux, D. longispinus, D. schauinslandii*, and *D. staurodon*) are considered temperate. This assignment supports an assumed north-to-south latitudinal trend from cooler to warmer assemblages between Site 173 at 39°57.71′N and Site 472 at 23°00.35′N. The general mid-latitude acme of *D. crux* in the lower and middle Miocene is widespread and coincides with a warming trend and Miocene thermal high in the Pacific. However, *D. crux* is very sparse in coeval assemblages of equatorial Pacific Site 66 (Martini, 1971), which suggests that somewhat cooler, upwelled waters were more favorable. Further, *D. crux* ranged from tropical areas such as the Gulf of Panama to cooler areas in the Gulf of Alaska. Quadrate forms of *Distephanus* largely disappear in the upper Miocene.

Corbisema is most closely related to *Dictyocha* and is by stratigraphic range and distribution a warm-water genus. The long-ranged genus *Mesocena* is mainly represented by *M. circulus* and *M. diodon* in Leg 63 middle Miocene to Pliocene assemblages. Both species are most abundant at high-latitude, cool-water sites (Stadum and Burckle, 1973; Bukry, 1976b), with diminishing numbers in mid-latitudes and scarcity at low latitudes (Bukry and Foster, 1973).

Figure 3 summarizes the *Ts* for all of the enumerated samples shown in Figure 4 and at the bottom of the distribution figures (Figs. 5-9). A comparison of the *Ts* at the sites along the Pacific Coast shows a north-to-south gradient toward warmer assemblages for each of three major Miocene to Pliocene time intervals. Further, the gradient becomes more extreme in successively younger intervals as the northern sites apparently cooled and the southern sites remained warm. Similarly, the sample-to-sample variation at a given site becomes larger upsection, reflecting less stable environments.

An unusually persistent decline in *Ts* from 76 to 26 occurs from Cores 15 to 12 at Site 470 (from the *Corbisema triacantha* Zone upward into the *Distephanus longispinus* Zone of the middle Miocene). A similar decline in Cores 20 to 21 at Site 173 is indicated by planktonic foraminiferal indices (Ingle, 1973, fig. 3). Silicoflagellate *Ts* for Core 21 is 43 but falls to 17 in Core 20 (Fig. 4) and continues at low levels: Core 19 (*Ts* = 12), Core 18 (*Ts* = 4), Core 17 (*Ts* = 15). A brief warming recorded in Core 16 (*Ts* = 40) (Bukry, 1973b, fig. 5; Fig. 4, this chapter) is also indicated by foraminifer studies (Ingle, 1973, fig. 3).

SITE SUMMARIES

Site 467
(33°50.97′N, 120°45.47′W, depth 2128 m)

The older silicoflagellate assemblages in Pliocene and Miocene Cores 36 to 52 contain common cool-water *Di-*

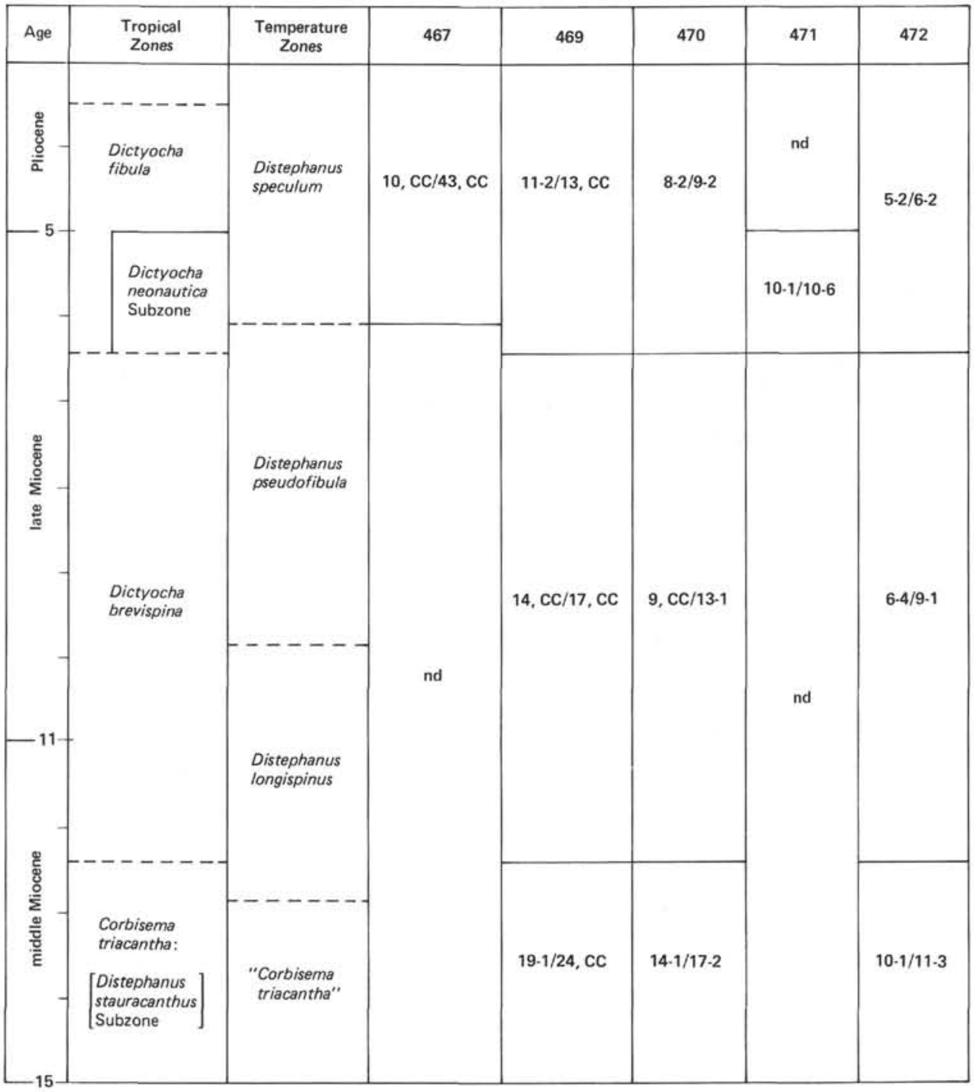

Figure 2. Local correlations of Leg 63 silicoflagellate samples for which species abundances were enumerated. (Tropical zonation [Martini, 1971; Bukry, in press] and temperate zonation [Bukry, 1973b] are shown; nd = no numerical data determined.)

stephanus frugalis, D. speculum minutus, and *D. speculum speculum* (Fig. 5). *Dictyocha aspera clinata* in Core 47 is the highest occurrence of a Miocene indicator silicoflagellate. Quaternary *Distephanus octangulatus* in Cores 3 to 8 is a guide to the cool-water *Distephanus octangulatus* Zone (Bukry, 1973b).

Abundant Pliocene assemblages are mainly restricted to Cores 9 to 13 and 18, where the *Distephanus speculum* group predominates. Silicoflagellates are sparse or absent from most Pliocene samples and are also missing from Miocene Cores 53 to 110.

Cool-water *Mesocena circulus* (Stadum and Burckle, 1973) is notably sparse at Site 467 relative to its meager to common abundances at Leg 32, Site 310 in the northwestern Pacific (Bukry, 1978c). A diminished abundance of warm-water coccoliths of *Ceratolithus* and *Discoaster* in all but the mid-Pliocene, coupled with the greater dominance of cool-water *Distephanus* at Site 467, suggests that cool waters were present but were not the controlling factor here. Although *Mesocena circulus* was generally numerous in temperate areas, perhaps coastal factors such as increased sediment turbidity in the waters or selective grazing limited populations of the Pacific Coast.

Site 468 (Hole 468) (32°37.03′N, 120°07.07′W, depth 1849 m) (Holes 468A, B) (32°37.41′N, 120°06.55′W, depth 1737 m)

Silicoflagellates are well preserved but sparse at Site 468 and are essentially restricted to the middle Miocene. The assemblages associated with the coccolith *Discoaster exilis* Zone are characterized by *Distephanus crux, D. longispinus* s. ampl., and *D. speculum speculum*, with sporadic *Corbisema triacantha* and *Dictyocha pulchella*. In the coccolith *Sphenolithus heteromorphus* Zone, *Distephanus crux, Dictyocha fibula* s. ampl., and *Distephanus speculum hemisphaericus* are typical, with

Age	Tropical Zones	Temperature Zones	173	467	469	470	471	472
Pliocene		*Distephanus speculum*	3	0				
	Dictyocha fibula		13	20				
				6	25		48	94
late Miocene					15	59	57	58
					42	60	61	84
		Dictyocha pseudofibula and *Distephanus longispinus*	10		31	61		85
			40		12	27		59
			15		46	51		74
			4		13	35		50
			12		46	42		58
	Dictyocha brevispina		17			36		74
						61		71
						80		69
						44		79
middle Miocene						57		72
						26		
						50		
						46		
			43			54		
			31			57		
	Corbisema triacantha	"*Corbisema triacantha*"	24		48	63		81
			42		51	70		79
			50		51	72		75
			42		29	76		75
			50			37		
			29			47		
			47			57		
			43					

Figure 3. Summary of relative paleotemperature values calculated for silicoflagellate assemblages at Pacific Coast DSDP Sites 173, 467, and 469 to 472.

Age	Zone	Site 173 Sample (interval in cm)	Sub-bottom Depth (m)	Total Specimens	*Ts*
Pliocene	*Distephanus speculum*	14-3, 20–21	123	93	3
		15-2, 25–26	130	173	13
late Miocene	*Distephanus pseudofibula*	16-1, 53–54	139	300	10
		16-3, 20–21	141	300	40
		17-1, 104–105	148	300	15
		18-1, 140–141	158	300	4
		19-4, 20–21	170	300	12
middle Miocene	*Distephanus longispinus*	20-3, 20–21	179	300	17
		21-3, 20–21	188	206	43
		22-1, 102–103	195	300	31
	Corbisema triacantha	23-3, 20–21	207	35	24
		24-5, 20–21	220	156	42
		25-5, 20–21	230	84	50
		26-4, 20–21	237	84	42
		27-4, 20–22	247	300	50
		28-3, 20–21	255	300	29
		29-2, 20–21	263	300	47
		30-1, 4–5	272	220	43

Figure 4. Relative paleotemperature values (*Ts*) for silicoflagellate assemblages at temperate Site 173, calculated from previously reported silicoflagellate counts (Bukry, 1973b) using the formula presented in this chapter.

sporadic *Cannopilus depressus* and *Mesocena apiculata curvata*. In Sample 468B-30,CC, the unique appearances of *Corbisema flexuosa* and *Mesocena apiculata apiculata* suggest probable reworking into the lowermost middle Miocene, because the typical range of these species is upper Eocene to lower Miocene.

A count of 300 specimens for Sample 468B-12,CC shows 88% *Distephanus crux*, 9% *D.* sp. cf. *D. longispinus*, and 1% each for *D. speculum, Cannopilus depressus*, and *Dictyocha brevispina*. This assemblage may represent a transition between or a physical mixture of the middle Miocene *Corbisema triacantha* Zone and *Distephanus longispinus* Zone or *Dictyocha brevispina*

Series	Pliocene		
Silicoflagellate Zone	*D. speculum*		
Coccolith Zones	CN12	CN10	
Depth (m)	80	348	396
Species \ Site 467 Sample (interval in cm)	10, CC	38, CC	43, CC
Cannopilus depressus			<1r
Dictyocha brevispina		2	2
D. sp. aff. *D. brevispina* [mesocenoid]		2	
D. fibula		1	3
D. pentagona		13	
D. pulchella			1
Distephanus boliviensis	<1		
D. crux		3	
D. frugalis		11	45
D. frugalis [pentagonal]		2	
D. jimlingii		1	
D. quinquangellus	<1	30	
D. speculum hemisphaericus		<1r	
D. speculum minutus	55	23	43
D. speculum speculum	44	12	6
Total Specimens	400	300	300
Relative Paleotemperature Value	0	20	6

Figure 5. Pliocene silicoflagellates (recorded as percentages) from Site 467 Cores 10, 38, and 43 (r = specimen reworked from older strata).

Zone. The sediments are burrowed and rich in terrigenous detritus, probably accounting for the sporadic occurrence of marker species. For example, *Corbisema triacantha* occurs upsection in Sample 468B-9,CC.

Site 469
(32°37.00′N, 120°32.90′W, depth 3790 m)

Middle and late Miocene silicoflagellate trends were studied in a set of 12 samples from Cores 11 to 25. Relatively high abundances of cool and temperate indicator taxa of *Cannopilus* and *Distephanus* suggest rather steady temperature conditions in the middle Miocene (Fig. 6), whereas fluctuations characterize the upper Miocene record in Cores 11 to 17.

The dominance of *Distephanus frugalis* in Core 11 indicates that a potentially widespread event occurred in the borderland at about the Miocene/Pliocene boundary, because this species also dominates the Malaga Mudstone sample collected ashore from Malaga Cove by the shipboard party. Although Ling (1977) did not use *D. frugalis* in his documentation of the Malaga Cove assemblages, he did record a dramatic appearance of abundant *D. boliviensis* (probably including *D. frugalis*) at the Miocene/Pliocene boundary. The abundance of *D. frugalis* in the borderland may constitute a stratigraphic horizon in the manner of Martini (1971) or it may mark the beginning of a local subzone at the Miocene/Pliocene boundary, because *D. frugalis* is also persistent in Cores 40 to 45 at Site 467.

The upper Miocene strata contain conspicuously reworked taxa from older Miocene assemblages. This reworking began after *Corbisema triacantha* Zone deposition. Other highlights of the assemblages at Site 469 include: (1) 11% to 24% abundance of *Cannopilus* near the top of the *Corbisema triacantha* Zone; (2) the overlap of common *Distephanus longispinus* and *Corbisema triacantha* in Core 19; (3) the occurrence of a *D. longispinus* population within the *C. triacantha* Zone; and

Series or Subseries	Plio. or Up. Mio.		Upper Miocene					Middle Miocene				
Silicoflagellate Zones	*D. fibula?*			*D. brevispina*				*C. triacantha*				–
	D. speculum			*D. pseudofibula*			*D. longispinus?*		"*C. triacantha*"			–
Coccolith Zones and Subzones	CN10 or CN9b		CN9b	CN8b	CN8		CN8a	CN5b	CN5a	–	CN4	
Depth (m)	95	96	120	125	134	141	151	169	186	212	225	228
Site 469 Sample (interval in cm) / Species	11-2, 50–51	11-2, 100–102	13, CC	14, CC	15, CC	16, CC	17, CC	19-1, 47–48	20, CC	23, CC	24, CC	25, CC
Cannopilus depressus								11	24			
Corbisema triacantha	1r	1r		1r			1r	4	1	6	3	1
C. triacantha [no bars]											1	
Dictyocha aspera aspera		<1	2	<1					4			
D. aspera clinata		<1	2									
D. aspera clinata [fibuloid]			3									
D. brevispina	14	7	2	10	3	4				4		
D. fibula	1		18	1				<1	3	1		
D. sp. aff. *D. neonautica neonautica*			1									
D. sp. aff. *D. perlaevis*	2	1										
D. pulchella	4	2	2	11	5	32		3	10			
D. pulchella [medusoid]				1					1			
D. pulchella [cruxoid]			2									
D. subclinata							5					
D. subclinata [fibuloid]							2					
D. varia		1										
D. spp. [fibuloid variants]		<1			1	3			3		1	1
Distephanus sp. aff. *D. boliviensis*	1		1			1						
D. crux	8	6	15	13	5	13	8	11	49	80	82	48
D. frugalis	53	72	1		1	1						
D. jimlingii	1											
D. longispinus	1r	1r		1			3	52	2		4	25
D. sp. cf. *D. longispinus*			1r				1	13			5	21
D. pseudocrux					2	1						
D. pseudofibula	1	<1	1	15	6	6						
D. quinquangellus		<1		<1		1	1		1			
D. quintus								1				
D. speculum diommata											<1	
D. speculum elongatus		<1										
D. speculum haliomma											<1	
D. speculum hemisphaericus	1r								1		<1	
D. speculum hemisphaericus [elongate]						1r						
D. speculum minutus	1	2	7	1	4	1		<1				
D. speculum speculum	15	5	40	35	56	23	4	<1	6	7	1	1
D. speculum triommata												3
D. speculum varians [symmetric]	1			<1								
D. stauracanthus				<1r								
D. staurodon			4								1	
Mesocena apiculata curvata		<1r										
M. circulus s. ampl.		1	2	3	6	8	74	<1				
M. diodon borderlandensis				5	6							
M. diodon nodosa				1	1	5		3	1			
M. elliptica				<1r								
M. hexalitha?		<1r	1r				1					
M. quadrangula			1								<1	
M. sp. [triangular]										2		
Naviculopsis? sp.											<1	
Total Specimens	200	300	200	300	200	100	100	300	200	100	300	300
Relative Paleotemperature Value	25	15	42	31	12	46	13	46	48	51	51	49

Figure 6. Neogene silicoflagellates (recorded as percentages) from Site 469 Cores 11 to 25 (r = specimen reworked from older strata; tropical zones are listed on the line above temperate zones).

(4) the rather precise correlation of the range of *Mesocena diodon borderlandensis* to the *Distephanus pseudofibula* Zone and CN8 Zone in the upper Miocene. *M. diodon borderlandensis* was previously known only from short dart core samples.

Site 470
(28°54.46′N, 117°31.11′W, depth 3549 m)

Silicoflagellates are common through the middle and upper Miocene of Cores 8 to 17 at Site 470 on the Guadalupe Arrugado east of Isla Guadalupe, Mexico. There is generally good agreement between previously determined silicoflagellate sequences at the nearby Experimental Mohole (EM) site (Ling, 1972; Martini, 1972; Bukry and Foster, 1973) and those of Site 470, suggesting uncomplicated stratigraphic relations in the area.

The oldest silicoflagellates of Site 470 are from the lower middle Miocene *Distephanus stauracanthus* Subzone, which correlates to the coccolith *Coccolithus miopelagicus* Subzone. The stratigraphic association is characteristic, with prominent *Dictyocha pulchella* and *Distephanus crux* and consistent or common *Corbisema triacantha, Distephanus speculum speculum*, and *Mesocena circulus*. Noteworthy occurrences in the *D. stauracanthus* Subzone include an isolated horizon of abundant *Distephanus longispinus* in Core 17 and a reversal in dominance of ring and bar forms of *D. stauracanthus* between Cores 16 and 14.

Samples 470-13-2, 21–23 cm and 470-14-1, 7 cm contain transitional assemblages (Fig. 7A) at the top of the range of *Corbisema triacantha* and at the beginning of the flourishing of *Distephanus longispinus*, following the disappearance of *D. stauracanthus*. Using the *C.*

Subseries	Middle Miocene													
Silicoflagellate Zones and Subzone	*D. brevispina*					–		*C. triacantha*						
	D. longispinus					–		*D. stauracanthus*						
Coccolith Zone and Subzones	CN7			–			CN5b?		CN5a					
Depth (m)	105	106	108	109	114	116	124	125	126	136	140	145	153	155
Site 470 Sample (interval in cm) / Species	12-1, 10–11	12-2, 100–102	12-3, 100–102	12-4, 100–102	13-1, 23	13-2, 21–23	14-1, 7	14-1, 111	14-2, 100–102	15-2, 100–102	15, CC	16-2, 100–102	17-1, 100–102	17-2, 100–102
Cannopilus depressus								3	<1	<1	1		<1	
Corbisema triacantha						2	4	5	14	7	10	4		23
Dictyocha sp. aff. *D. aspera*		2												3
D. brevispina		1												
D. fibula				1	1	1		3	6	6	5	4		1
D. pentagona														
D. sp. cf. *D. perlaevis* [elongate]														
D. pulchella	2	23	5	9	5	7	21	50	43	44	48	13	<1	11
D. pulchella [medusoid]								1			1	1		
D. subclinata														
D. varia														
D. spp. [fibuloid variants]		1								1				
Distephanus crux	4	8	37	5	1	3	26	7	13	22	21	30	17	37
D. sp. cf. *D. crux* [long spined]														
D. frugalis														
D. longispinus	76	37	3	59	75	72	16			<1			69	
D. sp. aff. *D. longispinus*	7	14	1	7										
D. sp. cf. *D. longispinus*			1	9	3	13	18			5	3		6	
D. polyactis										<1				
D. pseudofibula														
D. quinquangellus										<1	1	1		
D. schauinslandii														
D. sp. aff. *D. schauinslandii*							4							
D. sp. cf. *D. schauinslandii*											1			
D. speculum diommata														1
D. speculum giganteus														
D. speculum haliomma										<1			<1	2
D. speculum hemisphaericus			1	1								3		
D. speculum hemisphaericus [elongate]								<1				7		11
D. speculum minutus														
D. speculum polyommata												1		
D. speculum speculum		3		4	7	1	10	6	9	5	4	2	2	4
D. speculum speculum [large]	3		4		1				1					
D. speculum triommata							1			<1		2		<1
D. speculum varians					<1									
D. speculum varians [symmetric]		1			<1									
D. stauracanthus								3	<1		1	20		6
D. stauracanthus [bar]			1					21		2	1	11	3	
D. spp.	<1							<1				1		
Mesocena circulus s. ampl.	5	7	45	5	9	1		<1	3	3	3	5	1	<1
M. diodon borderlandensis														
M. diodon nodosa		1							9	2	2			
M. sp. aff. *M. elliptica*			1					<1		1				1
M. hexalitha	1	5	1											
M. sp. aff. *M. quadrangula*		1			1						1		<1	
M. triodon									1		1			
M. sp. [dictyochoid]										<1				
Naviculopsis sp. aff. *N. lata*					<1									
Total Specimens	300	200	100	100	300	100	100	300	300	300	200	200	300	300
Relative Paleotemperature Value	44	57	26	50	46	54	57	63	70	72	76	37	47	57

Figure 7A. Middle Miocene silicoflagellates (recorded as percentages) from Site 470 Cores 12 to 17 (tropical zones appear on the line above temperate zones).

triacantha disappearance criterion, these two transition samples can still be assigned to the *C. triacantha* Zone (Martini, 1971; Bukry and Foster, 1973).

Distephanus longispinus is abundant and consistent in Cores 12 and 13 above the last *C. triacantha*. The only major reduction in the *D. longispinus* plexus is in Sample 470-12-3, 100–102 cm, where *D. crux* and *M. circulus* predominate. This sample also contains the beginning of the brief *Mesocena hexalitha* range that is associated with the *Distephanus longispinus* Zone, a relationship first presented by Barron (1976a).

Correlation between the EM site and Site 470 is facilitated by the new species *Dictyocha subclinata*, which occurs (2%–5%) through Core 11 of Site 470 (Fig. 7B) in the *Dictyocha brevispina* Zone. Specimens of *D. subclinata* were illustrated as part of *Dictyocha* sp. by Ling (1972) from Sample EM 8-11, 69–70 cm. A comparison of coccolith assemblages between the sites shows both occurrences of *D. subclinata* are within lower CN8.

The reversal in dominance between asperoid and fibuloid populations of *Dictyocha* that is used to distinguish the top of the tropical *Dictyocha brevispina* Zone occurs within the temperate *Distephanus pseudofibula* Zone in Core 9, Site 470. The reversal is dramatic, with asperoid/fibuloid ratios of 3.2 in lower Core 9 and only 0.18 at the top. *Ts* values increase from 27 to 61 in Core 9, suggesting the ratio change is related to the beginning of a warming event in low or lower mid-latitudes. Core 8 is assigned to the tropical *Dictyocha fibula* Zone; higher cores were not studied because silicoflagellates are too sparse and fragmented.

Subseries	Upper Miocene									Middle Miocene	
Silicoflagellate Zones	*D. fibula*				*D. brevispina*						
	—		*D. pseudofibula*			—					
Coccolith Zones	CN9		—	CN8						CN7	
Depth (m)	69	70	77	79	80	96	98	99	101	104	104
Site 470 Sample (interval in cm) / Species	8-2, 75	8, CC	9-1, 100–102	9-2, 100–102	9, CC	11-1, 100–102	11-2, 100–102	11-3, 100–102	11-4, 100–102	11-6, 100–102	11-7, 20–22
Cannopilus depressus											
Corbisema triacantha									<1		
Dictyocha sp. aff. *D. aspera*	2		<1			1					
D. brevispina	1	<1	1	X		1	3				
D. fibula	50	52	47	X	6	2	3		3	2	5
D. pentagona			<1			<1					
D. sp. cf. *D. perlaevis* [elongate]	X	X									
D. pulchella			7	X	19	21	19	21	14	35	69
D. pulchella [medusoid]								<1	<1		
D. subclinata						2	5	4	5		
D. varia			<1								
D. spp. [fibuloid variants]			2			<1					
Distephanus crux			5	X	3	21	7	27	12	38	4
D. sp. cf. *D. crux* [long spined]											4
D. frugalis	2	X	1	X							
D. longispinus		<1				19	1		1		1
D. sp. aff. *D. longispinus*											
D. sp. cf. *D. longispinus*				X		5	1	6	12	9	2
D. polyactis											
D. pseudofibula	1	1	19	X	33						
D. quinquangellus	1					<1	1	1	<1	3	3
D. schauinslandii	1										
D. sp. aff. *D. schauinslandii*									1		
D. sp. cf. *D. schauinslandii*	11	12									
D. speculum diommata						1			1		
D. speculum giganteus										2	2
D. speculum haliomma											
D. speculum hemisphaericus											
D. speculum hemisphaericus [elongate]											
D. speculum minutus	3	1	3		4		5				
D. speculum polyommata											
D. speculum speculum	19	31	13	X		20		5	9		
D. speculum speculum [large]	3	1			31		22		1	10	7
D. speculum triommata									1		1
D. speculum varians					3						
D. speculum varians [symmetric]			1								
D. stauracanthus											
D. stauracanthus [bar]											
D. spp.											
Mesocena circulus s. ampl.		<1		X	2	5	14	32	39	1	4
M. diodon borderlandensis						?					
M. diodon nodosa		<1			2	1	20		<1		
M. sp. aff. *M. elliptica*											
M. hexalitha											
M. sp. aff. *M. quadrangula*											
M. triodon							3				
M. sp. [dictyochoid]											
Naviculopsis sp. aff. *N. lata*									<1		
Total Specimens	200	300	300	25	100	300	200	300	300	100	200
Relative Paleotemperature Value	59	60	61	X	27	51	35	42	36	61	80

Figure 7B. Miocene silicoflagellates, recorded as percentages, from Site 470 Cores 8 to 11 (X = present but too scarce for meaningful percentages; tropical zones appear on the line above temperate zones).

Site 471
(23°28.93′N, 112°29.78′W, depth 3101 m)

Lower Pliocene and upper Miocene silicoflagellates are sparse to common and well preserved in Cores 6 to 18. They are missing in the calcareous Quaternary and Pliocene of Cores 1 to 5 and in the Miocene silty clays of Cores 19 to 78, although sparse fragments of diatoms *Coscinodiscus marginatus* and *Thalassiothrix longissima* as well as pyritized centric diatoms occur through Cores 20 to 28. The silicoflagellate assemblages of Cores 8 and 9 are especially diverse. Although silicoflagellates are generally common in Cores 10 to 18, diversity is low and assemblages are composed mainly of *Dictyocha brevispina, D. fibula*, and *Distephanus speculum*. In most samples *Dictyocha fibula* predominates over *D. brevispina*, suggesting the warm-water *Dictyocha fibula* Zone of Martini (1971). Samples 471-13,CC and 471-15,CC, however, have more *D. brevispina* than *D. fibula*, possibly indicating the top of the *Dictyocha brevispina* Zone.

Counts of silicoflagellates for Core 10 show moderate asperoid/fibuloid ratios from 0.1 to 0.7, suggesting *Dictyocha fibula* Zone assemblages (Fig. 8). The most age-diagnostic taxa present are short-ranged *Dictyocha neonautica* var. *cocosensis* and *D. neonautica neonautica*, which mark the *Dictyocha neonautica* Subzone of the upper upper Miocene. *D. neonautica* correlates to the coccolith *Amaurolithus primus* Subzone or equivalents at other Pacific DSDP Sites (77, 157, 158, 303,

Subseries	Upper Miocene		
Silicoflagellate Zone	*D. fibula*		
Silicoflagellate Subzone	*D. neonautica*		
Depth (m)	86	89	93
Site 471 Sample (interval in cm) / Species	10-1, 20–22	10-3, 33	10-6, 1
Dictyocha aspera aspera	1	1	
D. aspera clinata	1	1	
D. brevispina	6	7	3
D. fibula [elongate]	16	30	40
D. sp. aff. *D. fibula* [spired]		3	6
D. perlaevis	2		6
D. pulchella	5		
D. neonautica cocosensis	8		
D. neonautica neonautica	1	1	
D. sp. aff. *D. varia*		1	2
Distephanus boliviensis	3	1	1
D. frugalis		6	1
D. mesophthalmus	15	25	8
D. quinquangellus			3
D. speculum elongatus	1		
D. speculum minutus	4	8	3
D. speculum minutus [pentagonal]	3		1
D. speculum speculum	37	14	28
Total Specimens	200	200	200
Relative Paleotemperature Value	48	57	61

Figure 8. Upper Miocene silicoflagellates (recorded as percentages) from Site 471 Core 10.

304, and 310) (Bukry, in press). A few specimens of *Dictyocha aspera clinata* s. str. also support the upper upper Miocene correlation.

The assemblages of Core 10 also contain the only significant population of *Distephanus mesophthalmus* yet recorded from offshore California and Baja California. The late late Miocene age of the assemblage extends the previously recorded early late Miocene (Dumitrică, 1973) upper range for *D. mesophthalmus.*

Site 472
(23°00.35′N, 113°59.71′W, depth 3831 m)

Silicoflagellates are sparse to common and well preserved in Miocene Cores 3 to 12 at Hole 472. The low-diversity assemblages of the *Dictyocha fibula* Zone in Cores 3 to 6 correlate with Site 471 Cores 10 to 17 to the east; on the basis of radiolarian dates at Site 471 (upper upper Miocene *Stichocorys peregrina* Zone), these assemblages are therefore probably upper Miocene. The assemblages are dominated by *Dictyocha fibula, D. brevispina*, and *Distephanus speculum*. Older *Dictyocha pulchella* is common in Cores 6 to 12. Mid-latitude guide *Distephanus pseudofibula* occurs in Core 6; elsewhere low-latitude assemblages prevail. Panicoid and elongate opal phytoliths (microfossils from terrestrial grasses) also occur in Core 6.

The silicoflagellate assemblages at Site 472 (Fig. 9) are similar to those at Site 470 in the middle Miocene, differing mainly in the somewhat lower numbers of *Distephanus crux*. In the middle to upper Miocene *Distephanus longispinus* Zone interval, the abundance of *D. longispinus* is much lower than at Site 470. In the upper Miocene, Site 472 is distinguished by the continued high abundances of *Dictyocha pulchella* and the lack of a substantial *Distephanus pseudofibula* population. It is also distinguished by moderate to common populations of small *Distephanus speculum speculum*. These differences, in addition to the general constancy of the upper Miocene assemblages (except for Sample 472-6-1), indicate a more uniform environment.

The predominance of bar forms of *Distephanus stauracanthus* near the end of the species range in Site 472 (Core 11) supports the regional relation discovered at Site 470. This trend may be useful for biostratigraphy within borderland *D. stauracanthus* Subzone strata.

Site 473
(20°57.92′N, 107°03.81′W, depth 3249 m)

Silicoflagellates are sparse to few in upper Quaternary Cores 1 to 4 (0–29 m). The upper assemblages lack *Dictyocha aculeata*, but it occurs in Core 4 without *Mesocena quadrangula*, indicating the *Dictyocha aculeata* Zone. Cores 5 to 15 (29–133.5 m) are barren. Lower Pliocene Cores 16 to 18 (133.5–162 m) contain few to common *Dictyocha* sp. aff. *D. perlaevis*, and few *D. brevispina, Distephanus speculum*, and *D. boliviensis*. Silicoflagellates are most common in Sample 473-16,CC and are absent in Pliocene and upper Miocene Cores 19 to 29.

Elongate and panicoid opal phytoliths from terrestrial grasses occur in Cores 1, 3, 4, 9, 10, 11, and 16.

A count of 100 silicoflagellates from Sample 473-16, CC shows 70% *Dictyocha* sp. aff. *D. perlaevis* (small), and 10% each for *D. brevispina, Distephanus speculum speculum*, and *D. speculum minutus*. The assemblage is abundant but of limited diversity, similar to assemblages from the Gulf of California. The assemblage belongs to the upper Miocene and lower Pliocene *Dictyocha fibula* Zone.

NEW TAXONOMY

Genus *DICTYOCHA* Ehrenberg, 1837

Dictyocha subclinata Bukry, n. sp.
(Plate 1, Figs. 4–8; Plate 2, Figs. 1–10)

Dictyocha sp., Ling, 1972 (in part), p. 164, pl. 26, figs. 7 and ?8 (not figs. 4–6).

Description. *Dictyocha subclinata* has a rounded rhomboid to nearly elliptic basal ring with very long major-axis spines. Minor-axis spines are short or vestigial. The moderate to long bar is very slightly inclined to the minor axis in the majority of specimens. A minority of specimens (fibuloid) have the bar in line with the major axis. Basal pikes are not observed on either form. Major/minor spine ratios range from 3 to 12. The ratio of basal ring length to maximum spine length varies from 1.2 to 1.7.

Remarks. *Dictyocha subclinata* is distinguished from *D. aspera clinata* by the greater predominance of major-axis spines, more elliptic

Subseries	Upper Miocene													Middle Miocene			
Silicoflagellate Zones	*D. fibula*			*D. brevispina*										*C. triacantha*			
				–						*D. longispinus*				–			
Coccolith Subzone	–														CN5a		
Depth (m)	37	45	46	48	50	53	56	60	62	63	65	67	72	82	92	92	94
Site 472 Sample (interval in cm) / Species	5-2, 120–122	6-1, 130–132	6-2, 130–132	6-4, 20–22	6-5, 10–12	7-1, 10–12	7-3, 38–40	7-5, 90–92	7-7, 36–38	8-1, 30–32	8-2, 120–122	8-3, 120–122	9-1, 10–11	10-1, 100–102	11-1, 52–54	11-1, 100–102	11-3, 35–37
Cannopilus depressus														1	<1		
C. spp.															1		2
Corbisema triacantha														6	4	10	6
C. sp.						<1											
Dictyocha aspera aspera				1	1	1	5							<1			
D. sp.aff. *D. aspera aspera* [small]		<1						<1	1				<1		2	2	2
D. sp. cf. *D. aspera clinata*			1											<1			
D. brevispina	2	16	2	6	5	9	1	3	2	3						2	
D. concavata										1							
D. fibula fibula	86	16	76	3	3	7	1	4	2	6	1	3	8	7	11	7	12
D. sp. aff. *D. fibula augusta*							9	1	4								
D. pulchella	5	23	4	74	36	47	28	40	47	38	52	70	47	54	50	42	41
D. pulchella [medusoid]	1	1				1	<1	1	1					1		1	1
D. subclinata								1	7	1	1		3				
D. subclinata [fibuloid]									4		1		5				
D. varia					8	5	1	1									
D. sp. cf. *D. varia*										2							
D. spp. [fibuloid variants]			1														1
Distephanus sp. aff. *D. boliviensis*		1		<1		<1											
D. crux s. ampl.		1		2	12	5	7	12	8	37	5	7	13	15	22	17	22
D. longispinus								<1		2	23	1	2	4	1		
D. sp. cf. *D. longispinus*								1	4		9	4		4	1	5	2
D. pseudofibula s. ampl.		5	<1		<1			<1									
D. quinquangellus		<1	<1	<1	1	1	1		4	2	1	1	5		<1		
D. speculum diommata									<1				<1				
D. speculum giganteus												2					
D. speculum hemisphaericus								<1									
D. speculum minutus								3	1								
D. speculum speculum	6	36	14	13	21	21	48	25	15	6	6	10	18	5	4	4	4
D. speculum speculum [large]			1		9	1	1	<1		1			<1		1		
D. stauracanthus																	6
D. stauracanthus [bar]															3	4	2
Mesocena circulus		<1		<1	3	3	4	1	<1	2	2	2	1				
M. diodon borderlandensis					<1												
M. diodon diodon														1			
M. diodon nodosa					1			1	<1				1	<1		5	1
M. quadrangula								<1		1				<1		2	
M. triodon														1		3	
Total Specimens	300	300	300	300	300	300	300	300	300	200	200	100	300	300	300	200	200
Relative Paleotemperature Value	94	58	84	85	59	74	50	58	74	71	69	79	72	81	79	75	75

Figure 9. Miocene silicoflagellates (recorded as percentages) from Site 472 Cores 5 to 11 (tropical zones appear on the line above temperate zones).

basal ring, less canted bar, and distinctly smaller size. *D. subclinata* is distinguished from *D. pulchella*, from which it may have evolved, by longer disparate spines, more elliptic basal ring, and less obvious or absent basal pikes.

Occurrence. *Dictyocha subclinata* occurs in the lower upper Miocene, below *D. aspera clinata* at Site 469 and 472. *D. subclinata* is part of the warm-water *Dictyocha brevispina* Zone and temperate-water *Distephanus longispinus* Zone at Sites 469, 470, and 472. Associated coccoliths belong to Zone CN8. Fibuloid variants show the same range. The two specimens of *D. subclinata* illustrated by Ling (1972) are from Sample EM 8-11, 69–70 cm, which belongs to the *Denticula hustedtii-D. lauta* Zone of diatoms (Barron, this volume) and *Distephanus longispinus* Zone (Bukry and Foster, 1973). This occurrence helps support the correlation of Cores 11 at both sites.

Size. 45 to 56 μm, maximum length.

Holotype. USNM 304796 (Plate 1, Fig. 4).

Isotypes. USNM 304797 to 304810.

Type locality. Northeastern Pacific Ocean, east of Isla Guadalupe, DSDP Sample 470-11-3, 100–102 cm (99 m).

Genus *MESOCENA* Ehrenberg, 1843

Mesocena diodon borderlandensis Bukry, n. subsp.

(Plate 4, Figs. 5–9; Plate 5, Figs. 1, 2)

Mesocena diodon nodosa Bukry, 1978b (in part), p. 818, pl. 6, figs. 4, 5 (not figs. 1–3).

Description. *Mesocena diodon borderlandensis* has a noded ring with two moderate spines along the major axis. The apices at the major axis are relatively acute (compared to the broadly curved segments intersecting the minor axis). The elongate form of the ring is derived from high ratios of major axis/minor axis ranging from 2.1 to 2.6.

Remarks. *Mesocena diodon borderlandensis* is distinguished from *M. diodon diodon* by narrower shape, longer spines, and more acute and equant major-axis apices. It is distinguished from *M. diodon nodosa* by the extreme elongation along the major axis, giving axis ratio values over 2.0 instead of 1.1 to 1.3 (Bukry, 1978b, pls. 5 and 6).

Occurrence. *Mesocena diodon borderlandensis* is prominent (5% and 6%) in upper Miocene (CN8 and *Distephanus pseudofibula* Zone) samples from Cores 14 and 15 at Site 469 in the California Continental Borderland. It also occurs in USGS Sample LEE-2-76-SC-161 from the upper Miocene of the borderland.

Size. 60 to 85 μm, maximum inner diameter.

Holotype. USNM 304811 (Plate 4, Fig. 8).

Isotypes. USNM 304812 to 304817.

Type locality. Northeastern Pacific Ocean, DSDP Sample 469-14,CC (125 m).

Mesocena hexalitha Bukry, n. sp.

(Plate 5, Figs. 5–10)

non *Mesocena hexagona* Haeckel, 1887, p. 1556.

Mesocena cf. *elliptica* Ehrenberg, Ling, 1972 (in part), p. 177, pl. 29, fig. 2 (not figs. 1 or 3).

Mesocena hexagona Haeckel, Barron, 1976b, p. 60, pl. 3, figs. 28, 33.
Mesocena hexagona Haeckel, Barron, 1976a, p. 348, fig. 8d, e.
"*Mesocena polymorpha* Lemmermann," Bukry, 1976c, pl. 3, fig. 12; pl. 4, fig. 1.
Mesocena hexagona Haeckel, Ling, 1977, p. 208, pl. 3, fig. 3.

Description. *Mesocena hexalitha* has a rounded hexagonal basal ring bearing peripheral spines. The major/minor axis ratio is 1.2 to 1.3 and the major-axis spines are about twice as long as the side spines. Surface nodes are small and not prominent. Spines are commonly not situated symmetrically; for example, side spines on one side can be closer together than the opposite set. Rare aberrant forms may have a small, asymmetrically located seventh spine.

Remarks. *Mesocena hexalitha* is distinguished from *Mesocena elliptica pentagona* Bachmann and Ichikawa by the more rounded basal ring and fairly consistent hexagonal symmetry. Both may have evolved from *Mesocena quadrangula*. *Mesocena*? *heptagona* Ehrenberg is from the Recent, beyond the range of *Mesocena*, and has a regular circular ring with seven equant, symmetrically located spines. This form could only superficially be compared to *M. hexalitha*.

Mesocena hexagona Haeckel (1887) is considered valid by Loeblich et al., however, it was never illustrated. Because the age of the species is Recent, and both synonymy species are Recent and invalid *nom. nud.* (Loeblich et al., 1968), the significance of the name *M. hexagona* is confused. True *Mesocena* became extinct in the mid-Quaternary, so there should be no Recent *Mesocena*. Mesocenoid specimens of *Distephanus speculum* are known and could provide the regular hexagonal rings that were described. It seems unlikely that sufficient numbers of extinct mid-Miocene *Mesocena hexalitha* could be reworked into the Recent to be detected, because they are so sparse in place. Instead of being regular hexagons, as *M. hexagona* was described, *M. hexalitha* specimens are rounded with six spines in somewhat irregular locations. Application of the name of Recent *M. hexagona* to the mid-Miocene population is too presumptive; the name *M. hexalitha* is therefore proposed for the Miocene population to avoid any ambiguity with the prescribed but unillustrated Recent specimens of *M. hexagona*.

Occurrence. *Mesocena hexalitha* is sparse in the upper Miocene *Distephanus longispinus* Zone at Sites 469 and 470. It is reworked into the *Distephanus speculum* Zone at 469. Elsewhere, it is recorded from the upper Miocene Puente Formation at Baldwin Park, California (Bukry, 1976c), the type Delmontian Stage of the Monterey Formation (Barron, 1976a), and the Newport Bay section of the Monterey Formation (Barron, 1976b), from DSDP Site 33, Core 13 (Ling, 1977), and from DSDP Site 438, Cores 60 to 63 (Barron, in press).

Size. 50 to 70 μm, maximum inner diameter.

Holotype. USNM 304818 (Plate 5, Fig. 5).

Isotype. USNM 304819 to 304823.

Type locality. Northeastern Pacific Ocean, east of Isla Guadalupe, DSDP Sample 470-12-1, 10–11 cm (105 m).

TAXONOMY

Genus *CANNOPILUS* Haeckel, 1887

Cannopilus depressus (Ehrenberg)

Halicalyptra depressa Ehrenberg, 1854, pl. 18, fig. 111.
Cannopilus depressus (Ehrenberg) Bukry, 1978b, p. 814, pl. 1, fig. 1.

Remarks. *Cannopilus depressus* is only common or consistent in the upper *Corbisema triacantha* Zone of Leg 63. It is most abundant at Site 469 in Core 19 (11%) and Core 20 (24%). It occurs in coccolith Subzone CN5a at Sites 469, 470, and 472 but extends upward into Subzone CN5b at Site 469.

Genus *CORBISEMA* Hanna, 1928

Corbisema triacantha (Ehrenberg)

Dictyocha triacantha Ehrenberg, 1844a, p. 80.
Corbisema triacantha (Ehrenberg), Dumitrică, 1973, p. 846, pl. 2, figs. 1–3.

Remarks. *Corbisema triacantha* ranges up to 14% in abundance in Leg 63 samples. It has consistent or common occurrences only in the middle Miocene, at least as high as coccolith Subzone CN5b. The sparse, sporadic occurrences in the upper Miocene at Site 469 result from reworking. Several unusual specimens without bar structure occur only in Sample 469-24,CC, where *Distephanus crux* predominates (82%) over all other silicoflagellates.

Genus *DICTYOCHA* Ehrenberg, 1837

Dictyocha aculeata (Lemmermann)

Dictyocha fibula var. *aculeata* Lemmermann, 1901, p. 261, pl. 11, figs. 1, 2.

Remarks. *Dictyocha aculeata* was recorded only from the Quaternary of Site 467 and 473.

Dictyocha aspera aspera (Lemmermann)

Dictyocha fibula aspera Lemmermann, 1901, p. 260, pl. 10, figs. 27, 28.

Remarks. Most of the tabulated specimens are smaller than normal and are too sparse to be useful.

Dictyocha aspera clinata Bukry

Dictyocha aspera clinata Bukry, 1975a, p. 695, pl. 1, figs. 1–5.

Remarks. This moderate to large, upper upper Miocene species is sparse for a short interval near the Miocene/Pliocene boundary at Sites 469 and 471. It has the same morphology as the type specimens from the western Pacific.

Dictyocha brevispina (Lemmermann)

Dictyocha fibula var. *brevispina* Lemmermann, 1901, p. 260; illustrated in Ehrenberg, 1854 (in part), pl. 21, fig. 42b and pl. 22, fig. 42a, b.
Dictyocha mutabilis Deflandre, 1950 (in part), p. 197, figs. 203–205, 210 (not 206–209).
Dictyocha brevispina (Lemmermann) Bukry, 1976c, p. 723.

Remarks. *Dictyocha brevispina* is most common (to 14%) near the Miocene/Pliocene boundary at Sites 469 and 471. In taxonomically differentiating a short-spined variety of *Dictyocha fibula* Ehrenberg s. ampl., Lemmermann (1901) selected a type suite of specimens that all have a bar aligned with the minor axis of the basal ring. This same morphology was later named *D. fibula* var. *aspera* fa. *rhombica* by Schulz (1928). Still later, Deflandre (1950) illustrated this morphology as part of the intraspecific variation in his species *D. mutabilis*. Lemmermann's type suite gives his named taxon priority over the similar holotypes for *D. mutabilis* and *D. fibula* var. *aspera* fa. *rhombica*.

Lemmermann listed three Ehrenberg (1854) figures in synonymy. Loeblich et al., (1968) validated these as the original illustrations. The lectotype for *Dictyocha brevispina* (Lemmermann) is, herein, designated to be pl. 22, fig. 42b of Ehrenberg (1854), which is the same as pl. 10, fig. 1 of Loeblich et al., (1968).

The maximum length of the minor portals in fig. 3 (of Loeblich et al.) is too long to be a typical specimen. The proportions in the other two specimens, including the lectotype, are typical.

Dictyocha concavata Dumitrică
(Plate 1, Figs. 1, 2)

Dictyocha concavata Dumitrică, 1978, p. 212, pl. 3, figs. 1–4.

Remarks. *Dictyocha concavata* is recorded in one sample of lower upper Miocene Core 8 at Site 472.

Dictyocha fibula augusta Bukry
(Plate 1, Fig. 3)

Dictyocha fibula augusta Bukry, 1976a, p. 893, pl. 6, figs. 1–5.

Remarks. Specimens related to this large, angular taxon are recorded from upper Miocene *Dictyocha brevispina* Zone cores at Site 472. Abundance ranges up to 9%.

Dictyocha fibula fibula Ehrenberg

Dictyocha fibula Ehrenberg, 1839, fide Loeblich et al., 1968, p. 90, pl. 9, figs. 9–12.
Dictyocha fibula fibula Ehrenberg, Bukry, 1978a, p. 697, pl. 2, figs. 1, 2.

Remarks. *Dictyocha fibula fibula* ranges through the Miocene sections of Leg 63 but is abundant in the *Dictyocha fibula* Zone. The elongate specimens at Site 471, Core 10, have a longer bar and more scallopped outline, probably indicating a transition stage between *D. fibula fibula* and *D. perlaevis*.

Dictyocha neonautica **var.** *cocosensis* **Bukry**
(Plate 3, Figs. 1-3)

Dictyocha navicula Ehrenberg, Bukry and Foster, 1973 (in part), p. 827, pl. 3, fig. 8.
Dictyocha neonautica var. *cocosensis* Bukry, in press.

Remarks. *Dictyocha neonautica* var. *cocosensis* is common (8%) in Core 10 at Site 471 off Baja California. The population shows the same narrow bar with uncentered bar position as in populations from other Pacific sites. Some specimens of *Dictyocha brevispina* in this core show an unusual degree of elongation, rounding, and reduction of minor-axis portals that suggests possible derivation of *D. neonautica* var. *cocosensis* from *D. brevispina*. Unlike the middle Miocene naviculopsoid population of *Dictyocha brevispina ausonia*, which also has off-center bars (Bukry, 1980), *D. neonautica* var. *cocosensis* lacks any minor-axis spines.

A short-ranged occurrence in the eastern Pacific during the late late Miocene makes *Dictyocha neonautica* var. *cocosensis* a potentially useful guide taxon, if its geographic range proves to be as large as presently suggested by the area of DSDP Sites 471, 158, and 77.

Dictyocha neonautica neonautica **Bukry**
(Plate 3, Fig. 4)

Dictyocha navicula Ehrenberg, Bukry and Foster, 1973 (in part), p. 827, pl. 3, figs. 6, 7.
Dictyocha neonautica Bukry, in press.

Remarks. *Dictyocha neonautica neonautica* and compared specimens are sparse in the upper Miocene at Sites 469 and 471.

Dictyocha pentagona **Schulz**

Dictyocha fibula var. *pentagona* Schulz, 1928, p. 225, fig. 41a, b.
Dictyocha pentagona (Schulz) Bukry and Foster, 1973, p. 827, pl. 3, fig. 10.
Dictyocha pentagona (Schulz), Bukry, 1976a, p. 894.

Dictyocha perlaevis **Frenguelli**

Dictyocha perlaevis Frenguelli, 1951, p. 279, fig. 4b, c.

Remarks. This relatively large, scalloped, fibuloid *Dictyocha* is mainly developed in warm-water Pliocene and Quaternary assemblages. It is sparse in the temperate and Miocene assemblages from the California Current region.

Dictyocha pulchella **Bukry**
(Plate 3, Figs. 5, 6)

Dictyocha pulchella Bukry, 1975a, p. 687, pl. 4, figs. 1-3.

Remarks. *Dictyocha pulchella* is one of the most common of the asperoid taxa of *Dictyocha* in the Miocene. Abundances (up to 74%) are greatest at southern Sites 470 and 472.

Dictyocha varia **Locker**

Dictyocha varia Locker, 1975, p. 7, text-figs. 1 and 3.

Remarks. *Dictyocha varia* is a small to moderate species that is distinguished from *Dictyocha brevispina* and *D. pulchella* by its shorter bar and more equant outline. These proportions make the portals of *D. varia* more nearly equant than in the other species. *D. aspera* has nearly equant portals but has a less rounded outline and is larger.

Dictyocha varia is a minor species in the *Dictyocha fibula* Zone and *Dictyocha brevispina* Zone of Leg 63 at abundances of 1% to 8%.

Genus *DISTEPHANUS* Stöhr, 1880

Distephanus boliviensis **(Frenguelli)**

Dictyocha boliviensis Frenguelli, 1940 (in part), p. 44, fig. 4, fide Loeblich et al., 1968, p. 83, pl. 9, fig. 3.
Distephanus boliviensis (Frenguelli) Bukry and Foster, 1973, p. 827, pl. 4, figs. 1-3.

Distephanus crux **(Ehrenberg)**

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), Bukry, 1979, p. 561, pl. 3, fig. 3.

Distephanus jimlingii **(Bukry)**

Distephanus boliviensis jimlingii Bukry, 1975a, p. 688, pl. 1, figs. 6, 7; pl. 2, fig. 1.
Distephanus jimlingii (Bukry) Bukry, 1979, p. 561, pl. 3, figs. 7-12.

Distephanus frugalis **(Bukry)**

Distephanus boliviensis frugalis Bukry, 1975a, p. 688, pl. 2, figs. 2-7.
Distephanus frugalis (Bukry) Bukry, 1979, p. 561, pl. 3, figs. 5, 6.

Remarks. *Distephanus frugalis* is most abundant in the upper Miocene cool-water assemblages at Site 467 (Cores 43 to 52). It is also prominent in an outcrop sample of the Malaga Mudstone collected ashore by the shipboard party prior to Leg 63.

Distephanus longispinus **(Schulz)**

Distephanus crux f. *longispina* Schulz, 1928, p. 256, fig. 44.
Distephanus longispinus (Schulz) Bukry and Foster, 1973, p. 828, pl. 4, figs. 7, 8.
Distephanus longispinus (Schulz), Bukry, 1979, p. 562, pl. 3, figs. 13, 14.

Remarks. Although populations of *Distephanus longispinus* were best developed in the late middle and early late Miocene, a disjunct older population with abundances up to 25% and 69% occurs at Sites 469 and 470. Because similar populations in the *Corbisema triacantha* Zone occur at Site 407 in the North Atlantic (Bukry, 1979), the disjunct populations of Leg 63 may represent an early expression of the *D. longispinus* morphology in response to short-lived environmental conditions. The more consistent and common occurrences later in the middle Miocene could reflect the re-establishment of a similar conducive environment. The apparent recurrence of some silicoflagellate taxa, while providing a potential paleoenvironmental tool, may lead to some uncertainties in taxonomic classification. An independent name, such as *D. longispinus*, is desirable to represent the main biostratigraphic population; however, the other possible ephemeral populations derived phenotypically from a root species (e.g., *Distephanus crux*) at other times or when certain environmental conditions prevailed could cause a problem if the *D. longispinus*-like species were designated as a biostratigraphic guide. The value of *D. longispinus* for long-range chronostratigraphy appears to be very low, on the basis of its occurrence pattern in Leg 49 and Leg 63 cores.

Distephanus mesophthalmus **(Ehrenberg)**

Dictyocha mesophthalma Ehrenberg, 1844a, p. 64, 80; Ehrenberg, 1854, pl. 22, fig. 43.
Distephanus mesophthalmus (Ehrenberg) Dumitrica, 1973, p. 850, pl. 6, figs. 9, 10, 12, 13.

Remarks. *Distephanus mesophthalmus* is a cruxoid species with a pike oriented peripherally midway on each of the four sides of the apical ring. Dumitrică (1973) noted a range from late middle to early late Miocene. The occurrence of *D. mesophthalmus* in Core 10 at Site 471 extends the range to the late late Miocene off Baja California.

Distephanus polyactis **(Ehrenberg)**
(Plate 3, Fig. 7)

Dictyocha polyactis Ehrenberg, 1839, p. 129; Ehrenberg, 1854, pl. 22, fig. 50.
Distephanus polyactis (Ehrenberg), Bukry, 1979, p. 562, pl. 3; figs. 15, 16; pl. 4, fig. 1.

Distephanus pseudocrux **(Schulz)**

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

Distephanus pseudocrux (Schulz), Ling, 1977, p. 207, pl. 2, figs. 16, 17.
Distephanus pseudocrux (Schulz), Bukry, 1979, p. 562.

Distephanus pseudofibula **(Schulz)**
(Plate 3, Figs. 8, 9)

Dictyocha speculum f. *pseudofibula* Schulz, 1928, p. 262, fig. 51a, b.
Distephanus pseudofibula (Schulz) Bukry, 1976b, p. 848.

Distephanus quinquangellus **Bukry and Foster**

Distephanus quinquangellus Bukry and Foster, 1973, p. 838, pl. 5, fig. 4.

Distephanus quintus **(Bukry and Foster) n. comb.**

Cannopilus quintus Bukry and Foster, 1973, p. 821, pl. 1, figs. 8, 9; pl. 2, fig. 1.
Distephanus speculum quintus (Bukry and Foster) Bukry, 1975b, p. 855.

Distephanus schauinslandii **Lemmermann**

Distephanus schauinslandii Lemmermann, 1901, p. 262, pl. 11, figs. 4, 5.

Distephanus speculum diommata **(Ehrenberg)**

Dictyocha diommata Ehrenberg, 1845, p. 56; Ehrenberg, 1854, pl. 33 (17), fig. 6.
Dictyocha diommata Ehrenberg, Locker, 1975, p. 641, pl. 4, fig. 4.

Distephanus speculum elongatus **Bukry**

Distephanus speculum elongatus Bukry, 1975a, p. 688, pl. 2, figs. 8, 9; pl. 3, figs. 1-3.

Distephanus speculum giganteus **Bukry**
(Plate 4, Figs. 1, 2)

Distephanus speculum giganteus Bukry, 1976b, p. 848, pl. 1, fig. 19; pl 2, figs. 1, 2.

Distephanus speculum haliomma **(Ehrenberg)**

Dictyocha haliomma Ehrenberg 1844a, p. 64, 80; Ehrenberg, 1854, pl. 21, fig. 46.
Distephanus speculum haliomma (Ehrenberg) Bukry, 1978a, p. 697, pl. 2, fig. 10.

Distephanus speculum hemisphaericus **(Ehrenberg)**
(Plate 4, Figs. 3, 4)

Dictyocha hemisphaerica Ehrenberg, 1844b, pl. 17, fig. 5.
Cannopilus hemisphaericus (Ehrenberg), Lemmermann, 1901, p. 268, pl. 11, fig. 21.
Distephanus speculum hemisphaericus (Ehrenberg) Bukry, 1975b, p. 855, pl. 4, fig. 8.
Distephanus speculum hemisphaericus (Ehrenberg), Bukry, 1978a, p. 697, pl. 2, figs. 11-13.

Distephanus speculum minutus **(Bachmann) emended**

Dictyocha speculum f. *minuta* Bachmann *in* Ichikawa, et al., 1967, p. 161, pl. 7, figs. 12-15.
Distephanus speculum minutus (Bachmann) Bukry, 1976a, p. 895, pl. 8, figs. 1-3.

Remarks. *Distephanus speculum minutus* is distinguished from *D. speculum speculum* by the generally larger diameter of the apical ring. *D. speculum minutus* is emended, herein, to include specimens with apical rings that have an inner diameter that is at least 50% of the inner diameter of the basal ring, measured along the major axis. Owing to similarity in tube widths, this proportion results in specimens which, in plan view, show the apical-ring corners at or overlapping the basal ring. The holotype of *D. speculum minutus* has a 55% ring ratio with apical-ring corners at the basal-ring inner periphery. The most visually diagnostic isotypes have 60% ring ratios with the apical ring slightly overlapping the basal ring. Aside from a few tilted or aberrant specimens, only one regular specimen falls below the emended 50% ring-ratio standard (Ichikawa, et al., pl. 7, fig. 15) with a 45% value. That specimen can be assigned to *D. speculum speculum*.

By its age and geographic distribution in Leg 63 cores, *D. speculum minutus* is a cool-water guide species. It has maximum abundances at northern Site 467 and is least common at southern Site 472.

Distephanus speculum polyommata **(Schulz)**

Cannopilus hemisphaericus f. *polyommata* Schulz, 1928, p. 268, 278, fig. 64a, b.
Distephanus speculum polyommata (Schulz) Bukry, 1979, p. 818.

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.

Distephanus speculum triommata **(Ehrenberg)**

Dictyocha triommata Ehrenberg, 1845, pp. 56, 76; Ehrenberg, 1854, pl. 33 (XV), fig. 11.

Distephanus speculum varians **Gran and Braarud**

Distephanus speculum f. *varians* Gran and Braarud, 1935, p. 390, figs. 68a, b.
Distephanus speculum varians Gran and Braarud, Bukry, 1976a, p. 896, pl. 8, figs. 7-10.

Distephanus stauracanthus **(Ehrenberg)**

Dictyocha stauracanthus Ehrenberg, 1845, pp. 56, 57, 76; Ehrenberg, 1854, pl. 33 (14), fig. 5; pl. 33 (15), fig. 10.
Distephanus stauracanthus (Ehrenberg) Dumitrică, 1973, p. 850, pl. 6, figs. 14, 15.

Remarks. Although few samples are involved, the *Distephanus stauracanthus* populations at both Sites 470 and 472 change from predominantly ring forms in older samples to predominantly bar forms in younger samples. This suggests a potential means to subdivide the *Distephanus stauracanthus* Subzone in this part of the Pacific.

Distephanus staurodon **(Ehrenberg)**

Dictyocha staurodon Ehrenberg, 1844a, p. 80; Ehrenberg, 1854, pl. 18, fig. 58.
Dictyocha staurodon (Ehrenberg), Locker, 1974, p. 637, pl. 3, fig. 10.
Distephanus staurodon (Ehrenberg), Bukry, 1978a, p. 697.

Genus *MESOCENA* Ehrenberg, 1843

Mesocena circulus **(Ehrenberg)**

Dictyocha (*Mesocena*) *circulus* Ehrenberg, 1840, p. 208, fide Loeblich et al., 1968, pp. 34, 84.
Paradictyocha apiculata (Lemmermann) Dumitrică, 1973, p. 852, pl. 9, figs. 3-6.
Paradictyocha circulus (Ehrenberg) Dumitrică, 1973, p. 853, pl. 9, figs. 7-10.
Mesocena circulus (Ehrenberg), Bukry, 1975b, p. 868, pl. 6, figs. 1, 2.

Remarks. No rigorous distinction was made between the various morphologies of the *Mesocena circulus* plexus for this study.

Mesocena diodon diodon **Ehrenberg**

Mesocena diodon Ehrenberg, 1844a, p. 71, 84; Ehrenberg, 1854, pl. 33 (15), fig. 18.
Mesocena diodon diodon Ehrenberg, Bukry, 1978b, p. 818, pl. 5, figs. 9-13.

Mesocena diodon nodosa **Bukry**
(Plate 5, Fig. 3)

Mesocena diodon nodosa Bukry (in part), 1978b, p. 818, pl. 5, figs. 14, 15; pl. 6, figs. 1-3 (not figs. 4, 5).

Mesocena elliptica (Ehrenberg)

Dictyocha (*Mesocena*) *elliptica* Ehrenberg, 1840, p. 208; Ehrenberg, 1854, pl. 20 (1), fig. 44a, b.
Mesocena elliptica (Ehrenberg), Bukry, 1978b, p. 819, pl. 6, figs. 6-13.

Mesocena quadrangula Ehrenberg ex Haeckel

Mesocena quadrangula Ehrenberg ex Haeckel, 1887, p. 1556; Lemmermann, 1901, pl. 10, figs. 5-7; fide Loeblich et al., 1968, p. 57.
Mesocena quadrangula Ehrenberg ex Haeckel, Martini, 1971, p. 1696, pl. 1, fig. 2.
Mesocena quadrangula Ehrenberg ex Haeckel, Bukry, 1978b, p. 819, pl. 7, figs. 1-5.

Mesocena triodon Bukry

Mesocena triodon Bukry, 1973a, p. 860, pl. 2, fig. 11.
Mesocena triodon Bukry, Bukry, 1978b, p. 819, pl. 7, figs. 9, 10.

Genus *NAVICULOPSIS* Frenguelli, 1940

Naviculopsis lata (Deflandre)

Dictyocha biapiculata lata Deflandre, 1932, p. 500, figs. 30, 31.
Naviculopsis lata (Deflandre) Frenguelli, 1940, p. 61, fig. 11h.
Naviculopsis lata (Deflandre), Bukry, 1978b, p. 820, pl. 9, figs. 1, 2; pl. 19, fig. 16.

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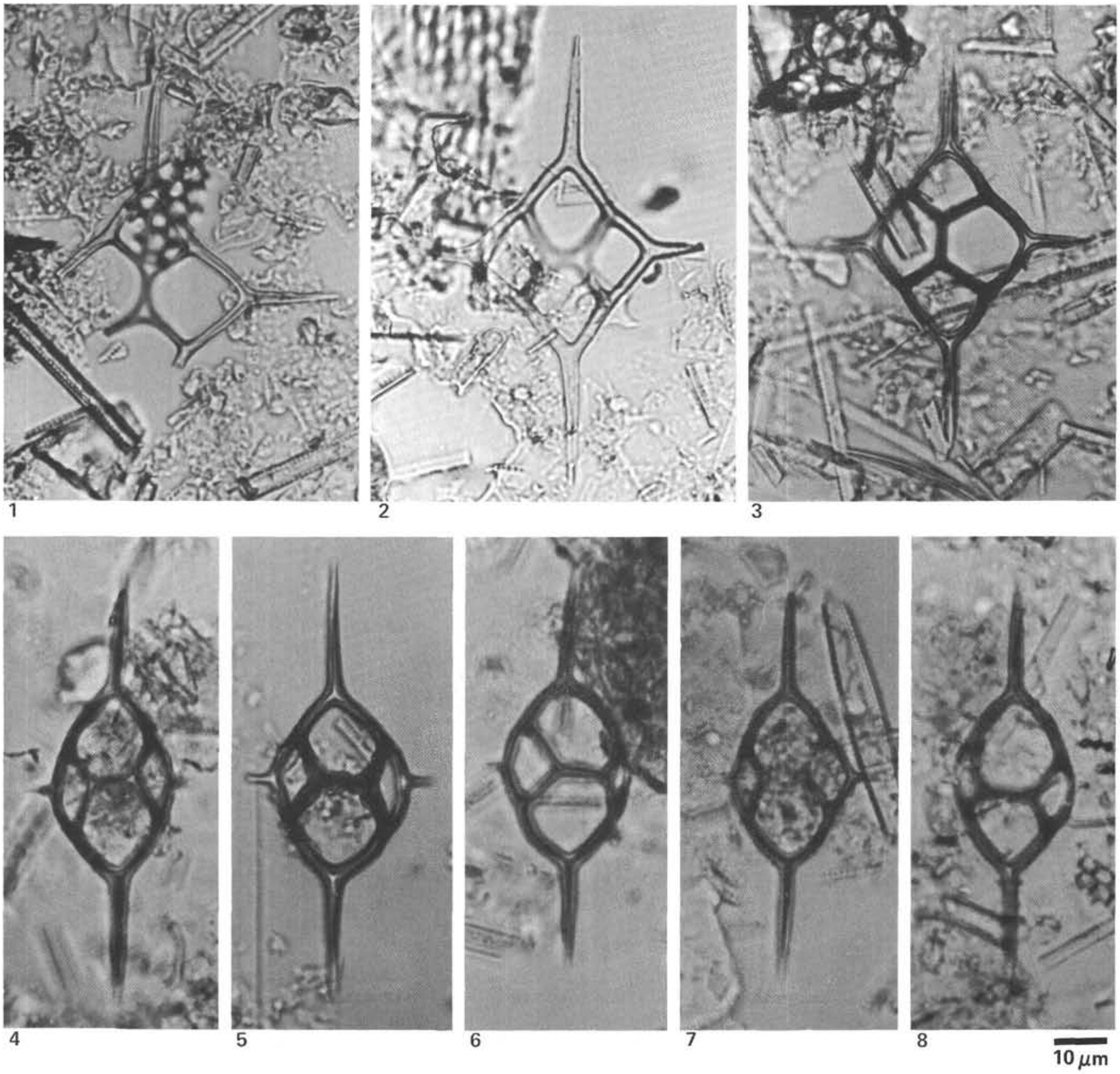

Plate 1. Silicoflagellates from DSDP Leg 63 (magnification 800×; scale bar equals 10 μm). 1, 2. *Dictyocha concavata* Dumitrică. (1) Sample 472-8-1, 30–32 cm. (2) Sample 472-7-3, 38–40 cm. 3. *Dictyocha* sp. aff. *D. fibula augusta* Bukry. Sample 472-7-7, 36–38 cm. 4–8. *Dictyocha subclinata* Bukry, n. sp. (4) Holotype, USNM 304796, Sample 470-11-3, 100–102 cm. (5) USNM 304797, Sample 472-9-1, 10–11 cm. (6) USNM 304798, Sample 470-11-4, 100–102 cm. (7) USNM 304799, Sample 470-11-2, 100–102 cm. (8) USNM 304800, Sample 469-17,CC.

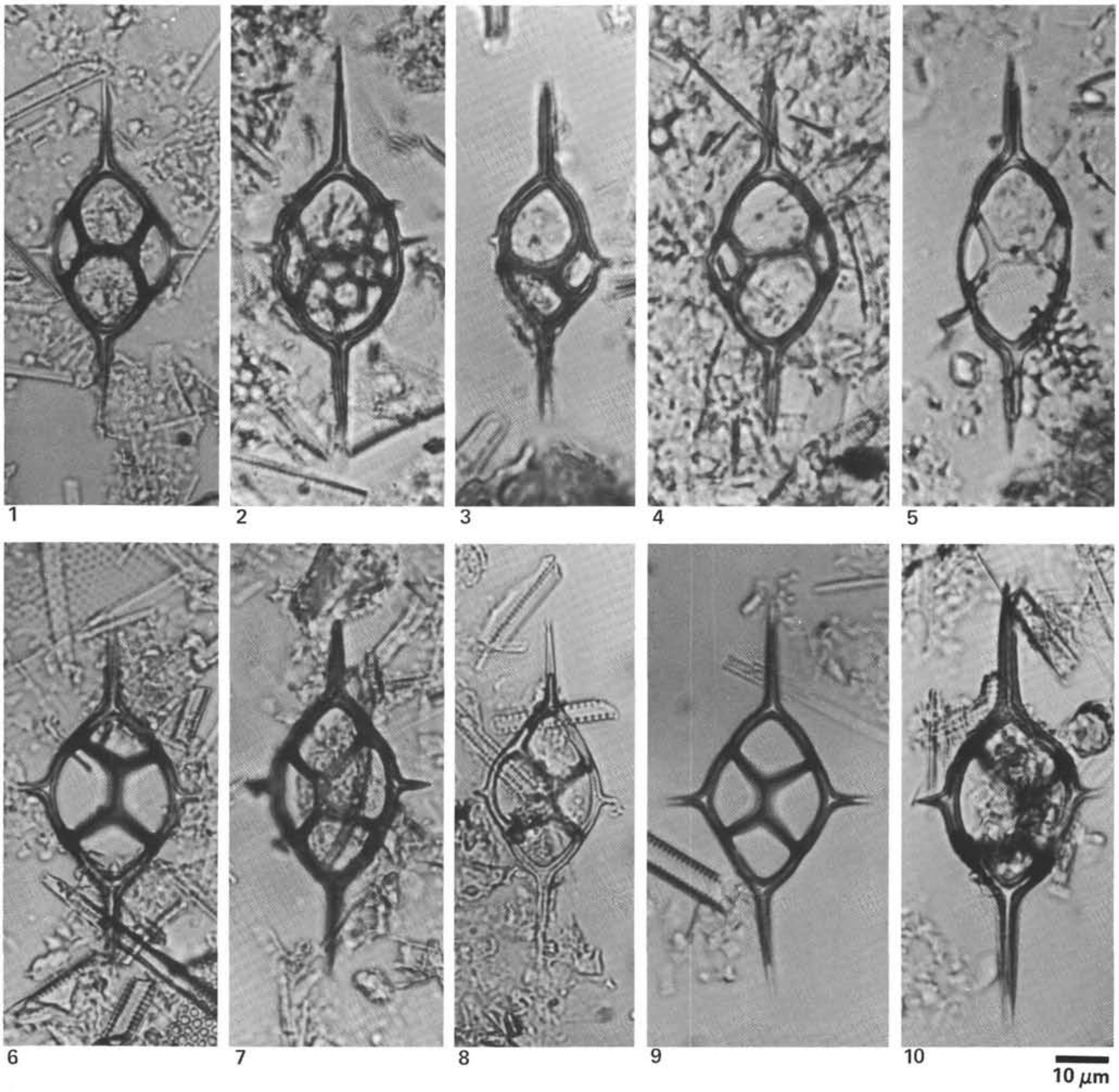

Plate 2. Silicoflagellates from DSDP Leg 63 (magnification 800×; scale bar equals 10 μm). 1–5. *Dictyocha subclinata* Bukry, n. sp. Normal forms. (1) USNM 304801, Sample 472-7-7, 36–38 cm. (2) USNM 304802, Sample 470-11-1, 100–102 cm. (3) USNM 304803, Sample 470-11-4, 100–102 cm. (4) USNM 304804, Sample 470-11-4, 100–102 cm. (5) USNM 304805, Sample 469-17,CC. 6–10. *Dictyocha subclinata* Bukry, n. sp. Fibuloid forms. (6) USNM 304806, Sample 472-9-1, 10–11 cm. (7) USNM 304807, Sample 472-7-7, 36–38 cm. (8) USNM 304808, Sample 472-9-1, 10–11 cm. (9) USNM 304809, Sample 472-9-1, 10–11 cm. (10) USNM 304810, Sample 472-8-2, 120–122 cm.

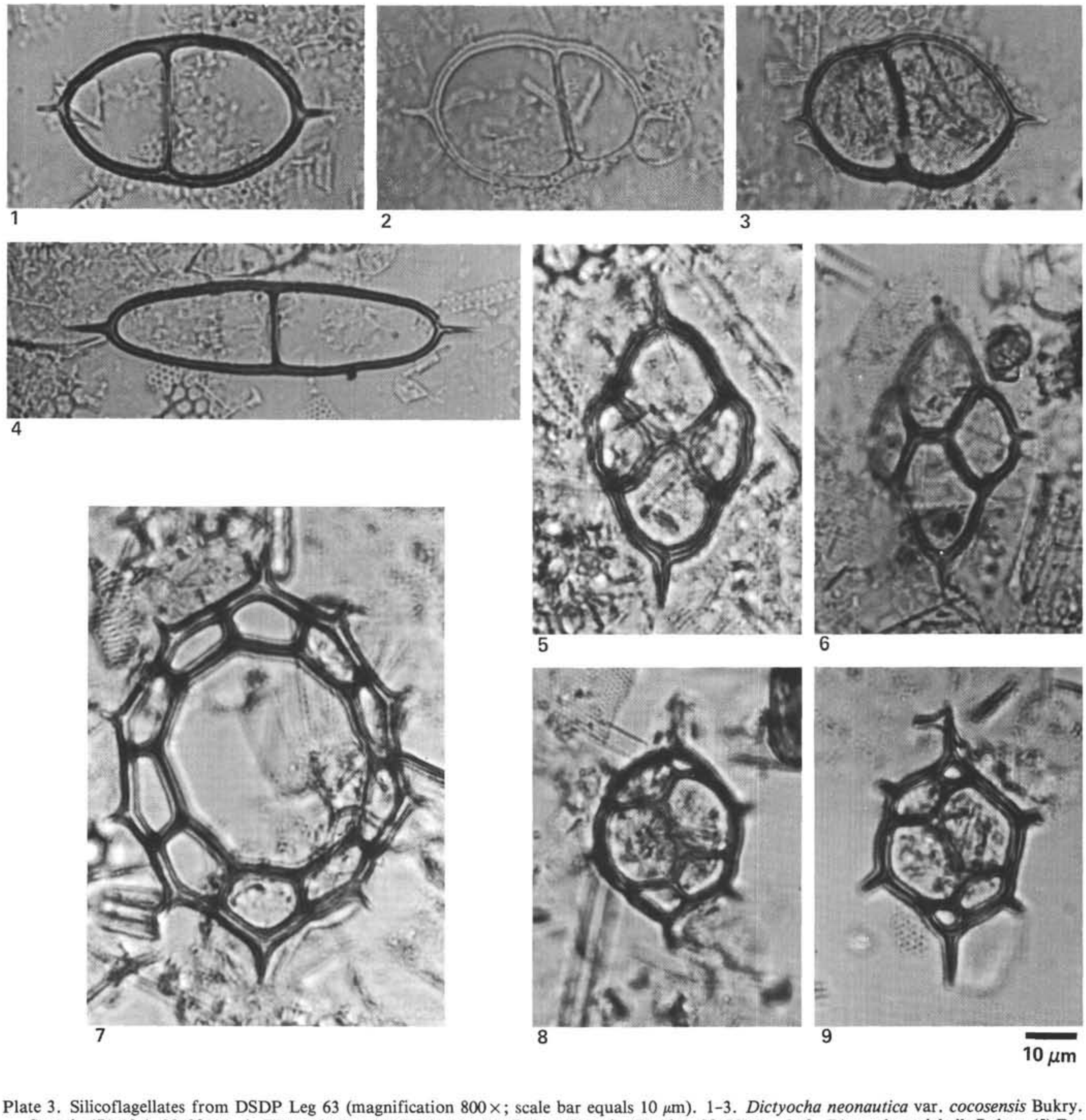

Plate 3. Silicoflagellates from DSDP Leg 63 (magnification 800×; scale bar equals 10 μm). 1–3. *Dictyocha neonautica* var. *cocosensis* Bukry. Sample 471-10-1, 20–22 cm. 4. *Dictyocha neonautica neonautica* Bukry. Sample 471-10-1, 20–22 cm. 5, 6. *Dictyocha pulchella* Bukry. (5) Deformed specimen, reminiscent of *Dictyocha aegea* Stradner and Bachmann. Sample 469-14,CC. (6) Elongate specimen from the same sample where elongate *Mesocena diodon borderlandensis* occurs. Sample 469-15,CC. 7. *Distephanus polyactis* (Ehrenberg). Elongate form; compare to circular form (Bukry, 1979). Sample 470-15-2, 100–102 cm. 8, 9. *Distephanus pseudofibula* (Schulz). Sample 470-9-1, 100–102 cm.

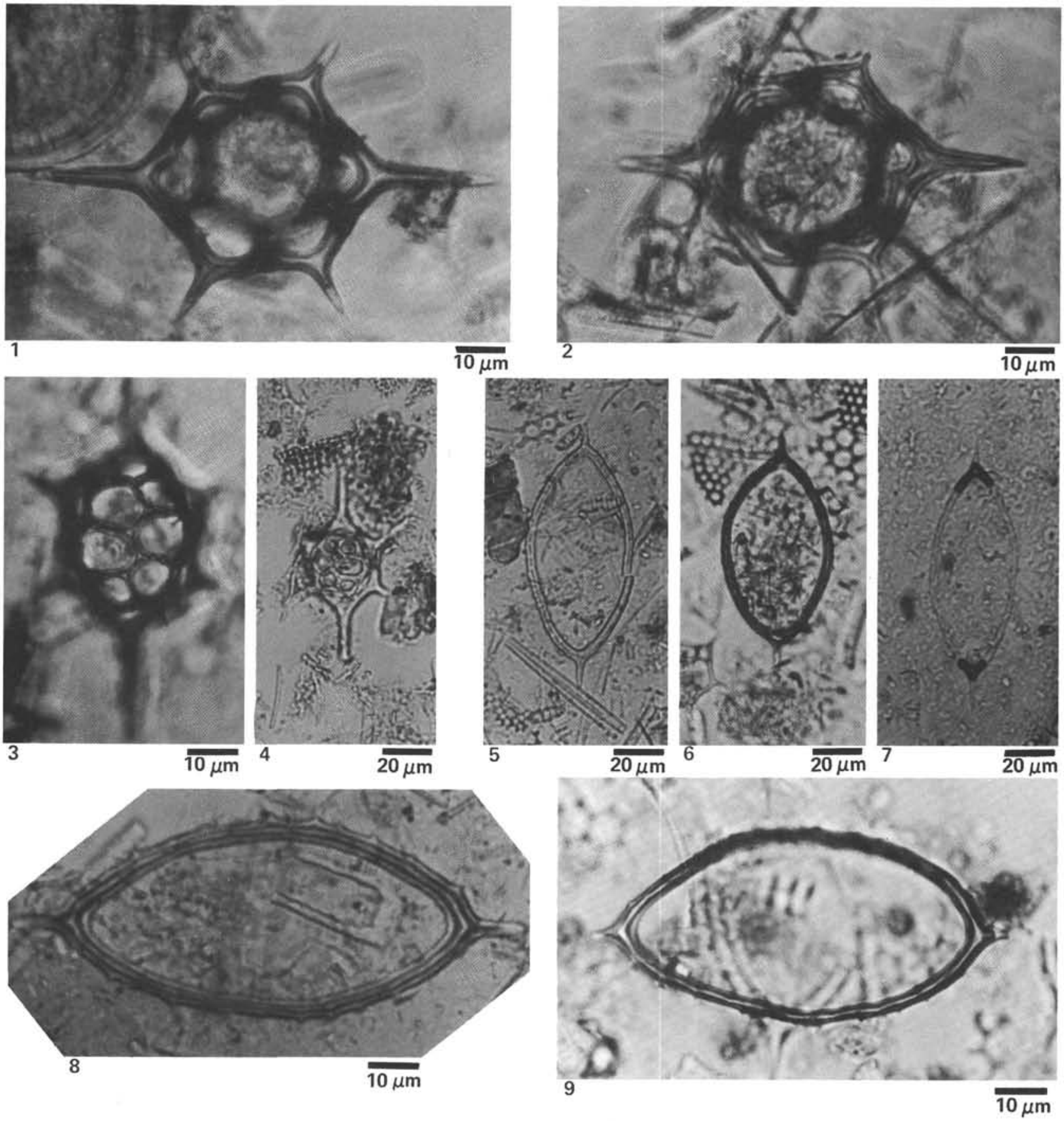

Plate 4. Silicoflagellates from DSDP Leg 63 and USGS-LEE-2-76-SC (Figs. 1–3, 8, 9 magnified 800×; scale bar equals 10 μm; Figs. 4–7 magnified 400×; scale bar equals 20 μm). 1, 2. *Distephanus speculum giganteus* Bukry. (1) Sample 470-11-6, 100–102 cm. (2) Sample 470-11-1, 100–102 cm. 3, 4. *Distephanus speculum hemisphaericus* (Ehrenberg). Tortoise-back variants with unusual, noncentric, portal pattern. (3) Sample 470-16,CC. (4) Sample 470-17-2, 100–102 cm. 5–9. *Mesocena diodon borderlandensis* Bukry, n. subsp. (5) USNM 304812, Sample 469-15,CC. (6) USNM 304813, Sample 469-14,CC. (7) USNM 304814, Sample 469-15,CC. (8) Holotype, USNM 304811, Sample 469-14,CC. (9) USNM 304815, Sample LEE-2-76-SC-161.

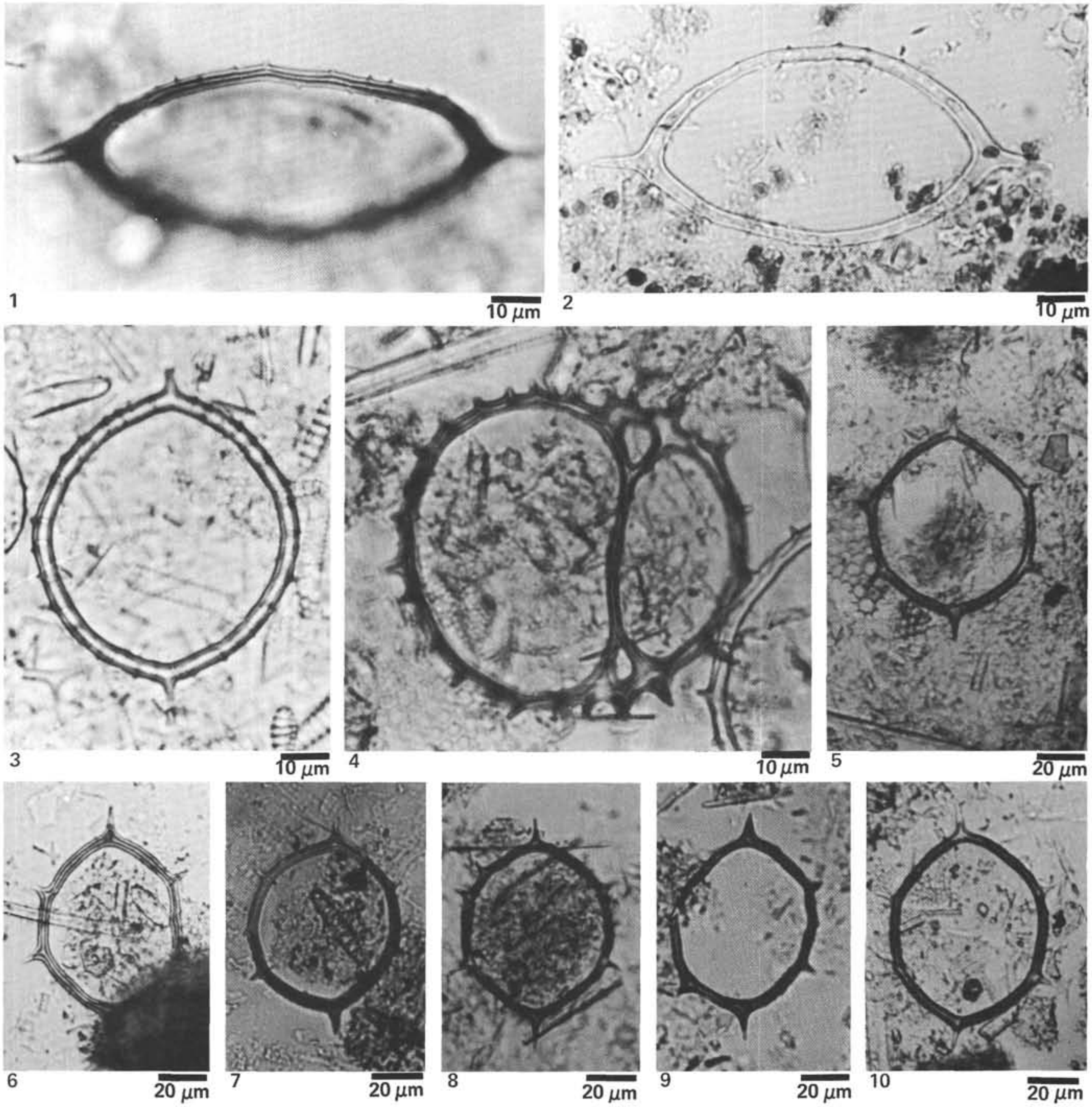

Plate 5. Silicoflagellates from DSDP Legs 19 and 63, and USGS-LEE-2-76-SC (Figs. 1–4 magnified 800×; scale bar equals 10 μm; Figs. 5–10 magnified 400×; scale bar equals 20 μm). 1, 2. *Mesocena diodon borderlandensis* Bukry, n. subsp. (1) USNM 304816, Sample LEE-2-76-SC-161. (2) USNM 304817, Sample LEE-2-76-SC-161. 3. *Mesocena diodon nodosa* Bukry. Sample 192-13-2, 69–70 cm. 4. *Mesocena* sp. Dictyochoid variant. Sample 470-12-1, 10–11 cm. 5–10. *Mesocena hexalitha* Bukry, n. sp. (5) Holotype, USNM 304818, Sample 470-12-1, 10–11 cm. (6) USNM 304819, Sample 470-12-2, 100–102 cm. (7) USNM 304820, Sample 470-12-5, 40–42 cm. (8) USNM 304821, Sample 470-12-2, 100–102 cm. (9) USNM 304822, Sample 470-12-1, 10–11 cm. (10) USNM 304823, Sample 470-12-2, 100–102 cm.