27. SILICOFLAGELLATES AND EBRIDIANS FROM THE NEW JERSEY TRANSECT, DEEP SEA DRILLING PROJECT LEG 93, SITES 604 AND 605[1]

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ABSTRACT

Well-preserved and diverse silicoflagellate and ebridian populations are found in the lower and middle Eocene sediments of DSDP Site 605 and the upper Miocene sediments of DSDP Site 604. The ebridians outnumber the silicoflagellates in the siliceous interval of Site 605, but are less numerous at Site 604. The abundances of the various taxa are tabulated.

INTRODUCTION

Deep Sea Drilling Project Leg 93 drilled Sites 604 and 605 on the upper continental rise some 161 km (100 mi.) southeast of Atlantic City, New Jersey (Fig. 1). These holes are an integral part of the "New Jersey Transect," a series of holes providing the first dipwise traverse of a passive continental margin from the coastal plain to the abyssal plain. Well-preserved silicoflagellates were recovered at both sites. The oldest assemblages, early middle Eocene in age, were present in a silica-rich nannofossil chalk, 152 m thick, at Site 605. Site 604, 5 km seaward of Site 605, yielded upper Miocene assemblages from a glauconitic, silica-rich silty claystone deposited along with conglomeratic debris flows. Silicoflagellates elsewhere in these sections were poorly preserved or largely reworked and are not treated further here.

Exploration of the North Atlantic basin over the last two decades, including a dozen DSDP legs, has provided many localities in which Cenozoic silicoflagellates were sufficiently numerous or well preserved to be described in some detail. These studies have been summarized by Bukry (1978c, 1981b) and are tabulated in Table 1. Of these, DSDP Legs 43, 44, and 78 were drilled within the North American Basin.

Along the Atlantic margin of North America, silicoflagellates were described (as radiolarians) from the Miocene of Maryland as early as 1904 (Martin, 1904) and later, in more detail, by Tynan (1957). Silicoflagellates have since been described in stratigraphic studies of the Miocene of Georgia, South and North Carolina (Ernissee et al., 1977; Abbott and Ernissee, 1983), and in Abbott's analyses (Abbott, 1978, 1980) of siliceous microfossil assemblages recovered in AMCOR, JOIDES, and Atlantic Slope Project (ASP) wells cored offshore from Florida to Massachusetts. Most of these latter sites yielded Miocene or younger assemblages, but one, ASP 22, recovered Oligocene silicoflagellates (Abbott, 1980).

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

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SAMPLE PREPARATION AND METHODS OF STUDY

Raw samples were placed in 100 ml beakers and a small amount of 30% hydrogen peroxide added; more was added if it strongly effervesced. After 2–4 hr. (or longer if effervescence continued when more hydrogen peroxide was added), the beaker was placed in an ultrasonic cleaner and distilled water was added to about the 25 ml level. HCl was added and the beaker heated for 30 min. Samples were then centrifuged and decanted twice and washed once before strewn slides were made. For similar methods of slide preparation, see Bukry (1983) and Busen and Wise (1977).

Although a general practice is to count 300 specimens per sample, the silicoflagellate abundance in this study area was not sufficient to allow such counts without a prohibitive investment of time. Laws (1983) has shown that the microfossils on a smear slide may become segregated by size, so all of the specimens on each slide (with a 22 × 40 mm cover slip) were counted. Fragments representing more than half of the original skeleton were included in the counts.

SITE SUMMARIES

Site 604 (Table 2)

Hole 604 (38°42.79′N; 72°32.95′W; water depth, 2364 m) was drilled on the uppermost continental rise, 100 n.mi. (161 km) southeast of Atlantic City, as the seaward end-member of the New Jersey transect. The section consists of 239 m of Quaternary to upper Miocene dark clays and silts with variable amounts of biogenic silica and glauconitic shelf sand turbidites (lithostratigraphic Units I and II; see Site 604–605 chapter, this volume) that overlie 56 m of upper Miocene glauconitic, biosiliceous, silty claystone, sand, and conglomerate (lithologic Unit III). The last two components were emplaced largely as turbidites or debris flows. Workable numbers of silicoflagellates were present in 13 samples of biosiliceous claystone spanning an interval from the bottom of Core 22 through the bottom of Core 26.

Diversity and preservation are moderate at this site, and the relative abundance of broken specimens increases toward the top of the studied section. *Distephanus crux* is dominant in the lowermost two samples and is consistently present up through Sample 604-25-4, 20 cm, but is absent above that level. Similarly, *Mesocena circulus* and *M. diodon* are consistently present up through Sample 604-25-1, 20 cm; their joint disappearance above Section 604-25-1 may indicate a disconformity or sharp environmental change. No sample was available from Core

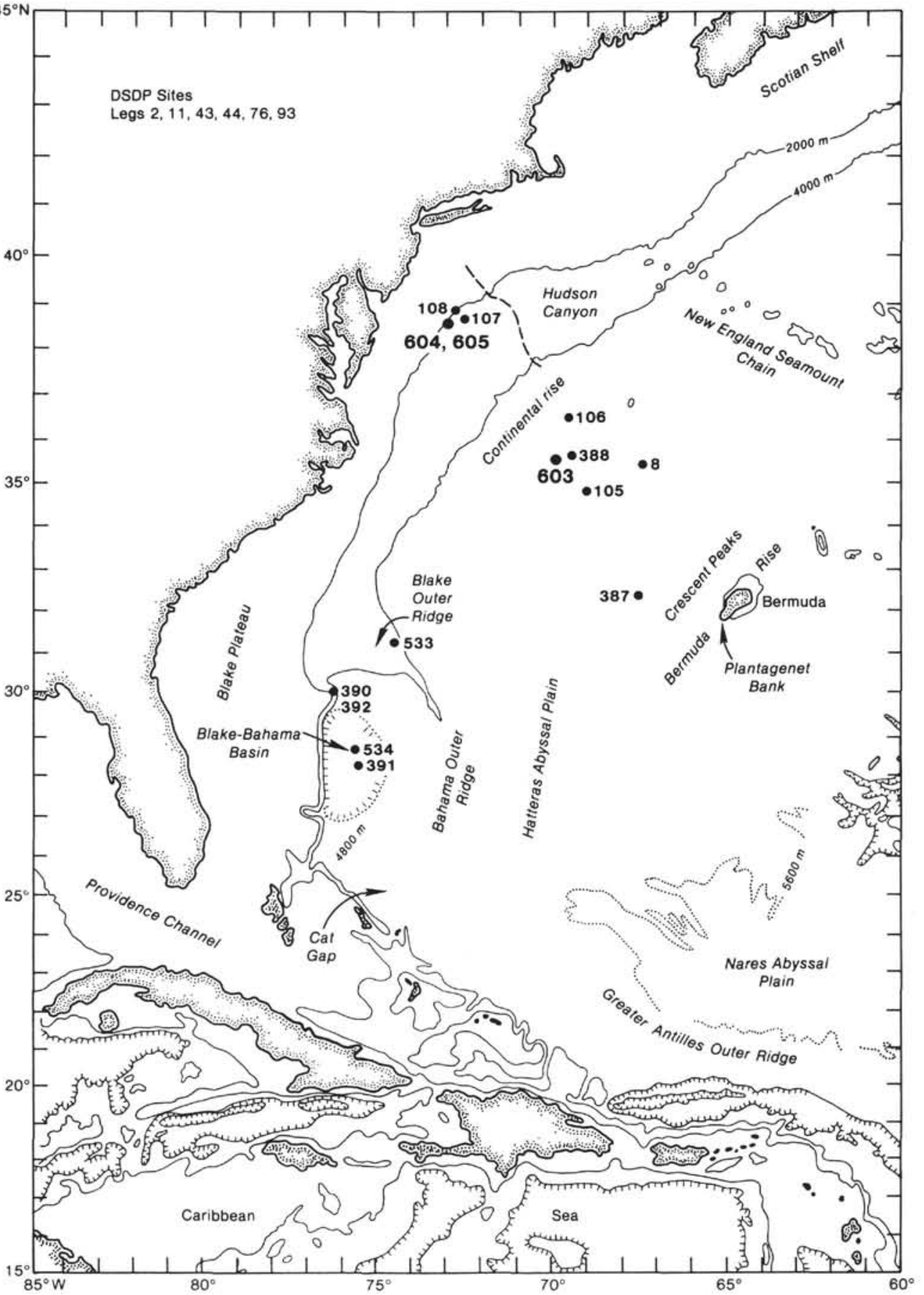

Figure 1. Location of sites drilled on Deep Sea Drilling Project Leg 93.

24, which recovered little sediment. The cool-water distephanids outnumber the warm-water dictyochids up through Core 25, but give way in Core 23 to the latter group, which is dominated by *Dictyocha brevispina*. Throughout the sequence, the asperoid forms of *Dictyocha* maintain dominance over the fibuloid forms.

Scattered throughout this section are rare *Naviculopsis* species and other taxa (e.g., *Corbisema hastata*) that are reworked from Eocene siliceous carbonates. Also noted are rare specimens of *N. ponticula*, reworked from the lower Miocene.

To summarize these observations, the notable local silicoflagellate events in this section seem to be the disappearance of *Distephanus crux* within Core 604-25, the disappearance of *M. circulus* and *M. diodon* above Core 604-25, and the absence of an obvious asperoid/fibuloid dominance reversal in *Dictyocha* (unless it occurs near the top of the sample suite, where the numbers of silicoflagellates are too small to provide meaningful data).

According to the zonation proposed by Bukry (1981b) for tropical and subtropical areas, the sample suite would

Table 1. Silicoflagellate and ebridian studies for the North Atlantic.

Leg (sites)	Pleistocene	Pliocene	Miocene	Oligocene	Eocene	Paleocene	Reference
VEMA					U, L	U	Perch-Nielsen, 1976
Leg 37 (332–335)	X	U	U				Bukry, 1977
Leg 38 (336–352)	X	X	X*	X*	U*, M		Bukry, 1976b
							Martini and Müller, 1976
							Perch-Nielsen, 1978
Leg 39 (354)				M*			Perch-Nielsen, 1977
Leg 41 (366–370)			L	U, L			Bukry, 1978a
Leg 43 (382–387)				L	X	U	Bukry, 1978c
Leg 44 (388–394)			M, L				Bukry, 1978b
Leg 47 (397)	X	U					Bukry, 1979b
Leg 48 (399–406)			L	U	U		Bukry, 1985
Leg 49 (407–414)	X	X	X	U, M			Martini, 1979
							Bukry, 1979a
Leg 50 (415–416)			M, L				Bukry, 1980
Leg 78 (541–543)			L				Bukry, 1984
Leg 81 (552–555)		L	U, L		M		Bukry, 1985

Note: All publications listed here have charts showing relative abundances. X = present throughout the series; U, M, or L = subseries; * = includes ebridian work.

fall within his *D. brevispina* Zone, which extends from the LAD of *C. triacantha* to the asperoid/fibuloid dominance reversal in *Dictyocha*. Bukry (1981b) tentatively correlates the top of this zone with the lower part of the nannofossil *Discoaster quinqueramus* Zone, but notes that the reversal of asperoid/fibuloid dominance may be diachronous. At DSDP Site 310 in the northwest Pacific, he found that the asperoid-dominated assemblages ranged from the Pliocene *Discoaster tamalis* coccolith Subzone to the upper Miocene *D. berggrenii* Subzone, because a cooler environment reduced the anticipated range of *Dictyocha fibula*. At Site 604, upwelling or the incursion of the Labrador Current, either of which would be accompanied by cooler surface waters, may account for the biosiliceous sediments near the bottom of the section. If this was the case, then the cooler waters may have affected the timing of the dominance reversal among the dictyochids.

In Hole 604, the Miocene/Pliocene boundary is placed at the top of Core 604-25, based on the LAD of the nannofossil *Discoaster quinqueramus* (Lang and Wise, this volume). This boundary is tentatively placed according to planktonic foraminifers between Sections 3 and 4 of Core 604-23 (Moullade, this volume). It would appear that the dominance reversal among the dictyochids in this region must have occurred after the Miocene, possibly because of cooler water conditions discussed earlier.

Other provincial zonations have been used at higher latitudes. Busen and Wise (1977) have described an upper Miocene *Mesocena circulus/M. diodon* Zone in the Southern Ocean based on the co-occurrence of those two taxa. The silicoflagellate assemblage they found is very similar to the assemblage at Site 604, but lacks the abundant *Dictyocha brevispina*. Their zonation is not applicable for the North American Basin, however, since *Mesocena diodon* occurs earlier (middle Miocene) in these middle latitudes (Bukry, 1978c) than it does at the Southern Ocean Sites 328 and 329. For this reason, in sediments of similar age and even 18° latitude farther north, Bukry (1985) has found it necessary to use the low-latitude zonation in this area.

Site 605 (Table 3)

Hole 605 (38°44.53′N; 72°36.55′W; water depth, 2197 m), drilled 5 km landward of Hole 604, recovered about 150 m of siliceous nannofossil chalk (lithostratigraphic Unit III; see Site 604–605 chapter, this volume) with good preservation of silicoflagellates and ebridians and high diversity. The section is early middle Eocene in age.

The distribution of silicoflagellates and ebridians is plotted in Table 3 for 23 samples from this thick middle Eocene section. The most striking aspect of the populations is the fact that the total ebridians outnumber the total silicoflagellates in all but two samples. In Sample 605-17-3, 20 cm, they exceed the silicoflagellates by an order of magnitude. This is in strong contrast to the Miocene of Site 604, where the ebridians comprise a minor part of the total siliceous population. We can offer no explanation for the preponderance of ebridians in the Eocene section.

The silicoflagellate assemblage is dominated by *Corbisema triacantha* and *Naviculopsis foliacea*. It can be assigned to the *N. foliacea* Zone, which Bukry (1981b) correlates with a long interval from the coccolith lower Eocene *Tribrachiatus orthostylus* Zone to within the *Coccolithus staurion* Subzone of the middle Eocene *Nannotetrina quadrata* Zone.

There is little stratigraphic variation within the silicoflagellate assemblage at Site 605. Two isolated specimens of *Dictyocha spinosa* in Cores 605-14 and 605-16 suggest that the assemblage can be assigned to the subzone of the same name defined by Bukry (1978b). The rarity of the species in this section does not make it a viable marker in this locality.

Lithostratigraphic Unit III is assigned to the coccolith *Chiasmolithus gigas* and *Discoaster strictus* subzones of the *Nannotetrina quadrata* Zone (Applegate and Wise, this volume). According to Bukry (1981b), that interval is well within the limits of the silicoflagellate *Dictyocha spinosa* Subzone.

COMMENT ON SILICOFLAGELLATE TAXONOMY

A major limitation upon the usefulness of silicoflagellates has been the great confusion concerning the biological validity of the various taxa. Silicoflagellates are marked by a wide diversity of skeletal shapes. Paleontologists, in particular, have described a great many species on the basis of the number of skeletal sides, types and dimensions of the apical structures, or the prominence of the basal spines, accessory spines, or surface ornamentation. Whereas the paleontologic literature has lengthy floral listings, investigators working with recent forms (Hovasse, 1946; Frenguelli, 1935; Poelchau, 1974, 1976) have emphasized the variation within populations. Van Valkenburg and Norris (1970) have found within a single clonal culture silicoflagellate skeletal shapes representing, if judged by the traditional taxonomy, three different genera. Furthermore, several investigators (Gemeinhardt, 1930; Bukry and Foster, 1973) have described

Table 2. Late Miocene silicoflagellates and ebridians from DSDP Site 604, Cores 22–26.

Age	Litho-logic unit	Nanno-fossil zonation	Silico-flagellate zonation	Sub-bottom depth (m)	Core/Section (interval in cm)	*Cannopilus depressus*	*Corbisema hastata*	*Dictyocha aspera*	*D. brevispina*	*D. fibula*	*Distephanus boliviensis*	*D. crux*
Pliocene	IIC	CN10	*Dictyocha brevispina* Zone	203.2	604-22-4, 20–22		2			1		
				208.3	604-23-1, 20–22				2	1	2	
				209.8	604-23-2, 20–22	1?			24		1	
				210.3	604-23-3, 20–22				63	9		
				212.8	604-23-4, 20–22				7			
late Miocene	IID	CN9		227.5	604-25-1, 20–22				4			
				229.0	604-25-2, 20–22			2				
				230.5	604-25-3, 20–22							
				232.0	604-25-4, 20–22				109	15	1	14
				237.1	604-26-1, 20–22			3	5	1	1?	2
	III			238.6	604-26-2, 20–22							
		CN8		240.1	604-26-3, 20–22	1		4				53
				241.6	604-26-4, 20–22	1		23		3		55

Note: Specimens are recorded as total no. found for no. of 22 × 40 mm slides examined.

double skeleton sets from a single cell in which each of the two silicoflagellate skeletons represents a different genus. Van Valkenburg (1970, 1980) states that many biologists believe that the current diversity of silicoflagellate skeletal shapes represent only two living species, *Dictyocha fibula* and *D. octonaria*.

Paleontologists, however, frequently see relatively minor differences in silicoflagellate shape as representing different species, and a complex taxonomy has resulted. The senior author questions the biologic validity of much of this taxonomy, but until there is a better understanding of the factors that control silicoflagellate shape and the relationship of the various shapes to each other, the current taxonomy must be maintained. The current taxonomy, with taxonomic names for all of the variations of silicoflagellate shape, may provide clues toward solving problems relating to silicoflagellate skeletal morphology. Efforts should be made to make distinctions between minor variations in morphology. Descriptive terms such as "cruxoid" or "medusoid" are important in that they draw attention to distinct skeletal shapes. To simply "lump" these distinct shapes in with the taxa to which they are closely related, without drawing attention to their relative abundance, causes a loss of information that may later be valuable.

SYSTEMATIC PALEONTOLOGY

To save time and space the synonomies include only the first description and, if needed, a recent reference that has a more complete taxonomy.

Silicoflagellates

Genus *CANNOPILUS* Haeckel, 1887

***Cannopilus depressus* (Ehrenberg)**

Halicalyptra depressa Ehrenberg, 1854, pl. 18, fig. 111.

Remarks. The rare specimens found in this study may have been reworked from strata lower in the Miocene.

Genus *CORBISEMA* Hanna, 1928

***Corbisema apiculata* (Lemmermann)**
(Plate 1, Fig. 10)

Dictyocha triacantha var. *apiculata* Lemmermann, 1901, p. 259, pl. 10, figs. 19, 20.

Corbisema apiculata (Lemmermann) Ling, 1972, p. 153, pl. 24, fig. 1.

Remarks. This species was found to vary in size, outline, and the position and size of the sustaining spines. The most common form has basal spines of moderate length and large sustaining spines that are directed obliquely. Specimens were usually twice the size of associated *Corbisema triacantha.*

Bukry (1978c) found *C. apiculata* in the middle Eocene of Site 386.

***Corbisema bimucronata* Deflandre**
(Plate 1, Fig. 9)

Corbisema bimucronata Deflandre, 1950, p. 191, figs. 174–177.

Remarks. This species is sporadic in the middle Eocene samples of Site 605.

***Corbisema hastata* (Lemmermann)**

Corbisema triacantha var. *hastata* Lemmermann, 1901, p. 259, pl. 10, fig. 16, 17.

Corbisema hastata (Lemmermann), Ling, 1972, p. 155, pl. 24, fig. 5.

Remarks. Specimens of *C. hastata*, belonging to several subspecies, were found sporadically in the middle Eocene of Site 605 and in a single sample of Site 604.

***Corbisema inermis inermis* (Lemmermann)**
(Plate 1, Figs. 13–16)

Dictyocha triacantha var. *inermis* Lemmermann, 1901, p. 259, pl. 10, fig. 21.

Corbisema inermis inermis (Lemmermann), Bukry, 1976a, p. 892.

Remarks. *C. inermis inermis* is characterized by a generally large size, narrow apical struts, and a lack of spines. Some of the specimens in this study were somewhat pointed at the corners of the basal ring. This species was uncommon, but present, throughout the middle Eocene interval of Site 605.

***Corbisema recta* (Schulz)**
(Plate 1, Figs. 11, 12)

Dictyocha triacantha var. *recta* Schulz, 1928, p. 250, fig. 32a, b.

Corbisema recta (Schulz), Ling, 1972, p. 155, pl. 24, figs. 6, 7.

Table 2 (continued).

D. speculum binoculus	*D. speculum hemisphaericus*	*D. speculum minutus*	*D. speculum speculum*	*Mesocena apiculata*	*M. circulus*	*M. diodon*	*M. elliptica*	*M. triodon*	*Naviculopsis ponticula*	*N. constricta/foliacea*	Total silicoflagellates	*Ammodochium rectangulare*	*Ebriopsis antiqua antiqua*	*E. antiqua cornuta*	*E. crenulata*	*Parathranium intermedium*	Total ebridians	No. slides examined
			4								7			1			1	3
1	3	1	2				4				16		6				6	2
	2	1	13				1		1		44						0	2
		3	5				1				81		2		1		3	2
	1		3								11		1				1	3
			7		1	6	1				19		1				1	2
			8		3	22	1	3		1	40		3				3	2
		1	4		1	3					9						0	2
		6	169		4	14					332	8	2	1			11	1
		1	19		2	21				2	57	2	2		1	3	8	2
											0						0	1
	1		1	2		25		1		4	92			1		2	3	2
2	1		29		1	8					123	1	1				2	2

Table 3. Eocene silicoflagellates and ebridians from DSDP Site 605, Cores 7 to 21.

Age	Litho-logic unit	Nanno-fossil zonation	Silico-flagellate zonation	Sub-bottom depth (m)	Core/Section (interval in cm)	*Corbisema apiculata*	*C. bimucronata*	*C. hastata* (s. ampl.)	*C. inermis inermis*	*C. triacantha* (s. ampl.)	*C. triacantha* (cruxoid)	*Dictyocha brevispina*	*D. byronalis* (asperoid)	*D. byronalis* (medusoid)	*D. byronalis* (fibuloid)	*D. spinosa*	*Distephanus crux*	*D. speculum pentagonus*	*Mesocena occidentalis*	*Naviculopsis constricta*	*N. eobiapiculata*	*N. foliacae*	Total silicoflagellates	*Ebriopsis antiqua antiqua*	*E. antiqua* (with lorica)	*E. antiqua cornuta*	*E. crenulata*	Total ebridians	No. slides examined
				205.5	7-3, 20–22															1		2	3	4				4	2
				210.0	7-6, 20–22															1		1	2	5			1	6	2
				224.7	9-3, 20–22			1	1	8									1	6		5	22	33				33	2
				234.3	10-3, 20–22	2			3	46	4	4	8							4		14	85	103	2	2	6	113	2
				243.9	11-3, 20–22	5			4	14	1	12								3		6	45	110			1	111	2
				248.8	11-6, 20–22	5	3		2	27		15	6		1				3	3		10	75	178	1	1	13	193	2
				253.5	12-3, 20–22	8	1		4	11		3	5				1	1		8		18	60	29		1	4	34	2
				258.0	12-6, 20–22	1		1	2	15		13	1						1	4	1	4	43	53		1	11	65	2
		CP13b		263.1	13-3, 20–22	2	1	1	3	12	1	4	6					2		3	2	24	61	94	1		5	100	2
				267.6	13-6, 20–22	6			2	23			10	2				1		3	5	20	72	41		1	13	55	2
early middle Eocene	II		*Naviculopsis foliacea* Zone	272.7	14-3, 20–22	2		1	1	11			5			1		2			1	14	38	47			3	50	2
				277.2	14-6, 20–22				2	4			3					1		4	1	10	25	41			4	45	2
				282.3	15-3, 20–22		1		1	6			3							4	8	11	34	98			3	101	2
				286.8	15-6, 20–22	2			1	3			1							2	4	11	24	104	1	1	4	110	2
				291.9	16-3, 20–22	1				6			2								2	10	21	74			2	76	2
				296.4	16-6, 20–22	9	2			20			2			1				12	10	19	75	65			4	69	2
				301.5	17-3, 20–22					8										2		12	22	214	2		9	225	2
				306.0	17-6, 20–22	1				2										1		8	12	92			4	96	2
				311.1	18-3, 20–22	1	2			7										2		9	21	150	1		6	157	1
		CP13a		320.7	19-3, 20–22		1	1		1											1	2	6	79			7	86	1
				325.2	19-6, 20–22			1		1			2	1						3	7	21	36	75			8	83	1
				330.3	20-3, 20–22					6											3	6	35	65			8	73	1
				339.9	21-3, 20–22	2			1	2				1						2		12	20	50	1		6	57	1

Note: Specimens are recorded as total no. found for no. of 22 × 40 mm slides examined.

Corbisema triacantha (Ehrenberg)
(Plate 1, Figs. 1–5, 7, 8)

Dictyocha triacantha Ehrenberg, 1844, p. 80.
Corbisema triacantha (Ehrenberg), Busen and Wise, 1977, p. 713.

Remarks. Although the size of all specimens is very consistent, about 40 μm across the side of the basal ring, there is considerable variation in the shape of the basal ring, the length of the spines, and the nature of the apical strut intersection. Bukry (1977, 1978b) and Ling (1972) have described several subspecies, but the specimens of this study did not fall into distinct taxa. Both *C. triacantha concava* and *C. triacantha triacantha* were well represented, but intermediates between those extremes were also common. Both types were occasionally found to have offset apical struts, as in *C. triacantha mediana*. Some specimens have the characteristics of two or all three of these subspecies. Rare specimens were found to have cruxoid openings in the apical strut intersection (Plate 1, Figs. 3, 8). Since division into subspecies was often difficult, and in the studied intervals had no apparent stratigraphic importance, all forms were simply counted as *C. triacantha*.

Genus *DICTYOCHA* Ehrenberg, 1837

Dictyocha aspera aspera (Lemmermann)
(Plate 3, Fig. 1)

Dictyocha fibula var. *aspera* Lemmermann, 1901, p. 260, pl. 10, figs. 27, 28.
Dictyocha aspera aspera (Lemmermann), Bukry, 1983, p. 329.

Remarks. *D. aspera aspera* is characterized by a bar that is parallel to the minor axis but has a shorter apical bar and a more rhomboid-shaped basal ring than *D. brevispina*. The bar is not inclined with respect to the minor axis. This species occurs sporadically below Core 24 of Site 604.

Dictyocha brevispina (Lemmermann)
(Plate 3, Figs. 2, 3, 8–10)

Dictyocha fibula var. *brevispina* Lemmermann, 1901, p. 260.
Dictyocha brevispina (Lemmermann), Bukry, 1976c, p. 723.

Remarks. *D. brevispina* has a longer apical bar and strut positions closer to the minor axis than *D. aspera*. This causes smaller minor-axis portals. The strut position closer to the minor axis causes less constraint on the rest of the basal ring, which bulges outward toward the major axis, causing an overall elliptical shape instead of the rhomboid shape usually found when the struts are more centered, as in *D. aspera* and *D. fibula*. The length of the apical bar varied a great deal, from 40 to nearly 100% of the internal diameter of the minor axis.

As one moves up the section in the silicoflagellate-bearing interval of Site 604, the bar length progressively increases, changing from forms similar to *D. aspera* (Pl. 3, Fig. 1, Section 604-26-4), to forms approaching *D. transversa* (Pl. 3, Figs. 9 and 10, Section 604-23-1). The change appears to be gradual, making identification of some forms difficult.

Dictyocha byronalis Bukry
(Plate 3, Figs. 4–7, 11)

Dictyocha byronalis Bukry *in* Barron et al., 1984, p. 151, pl. 3, figs. 1–4.

Remarks. *D. byronalis* is a robust form with relatively long major spines and an inclined, generally asperoid, bar. The bar is highly arched above the plane of the basal ring. Rare medusoid (Pl. 3, Fig. 7) and fibuloid (Pl. 3, Fig. 11) forms were found which, because of similarities in the shape, size, thickness of the struts, and the amount of arch of the apical bar, were counted as members of this taxon. *D. byronalis* was found throughout most of the silicoflagellate-bearing interval of Site 605.

Dictyocha fibula Ehrenberg

Dictyocha fibula Ehrenberg, 1839, *fide* Loeblich et al., 1968, p. 90, pl. 9, figs. 9–12.

Dictyocha fibula Ehrenberg, Bukry and Foster, 1973, pp. 826–827.

Remarks. The authors use a broad interpretation of this taxa. All dictyochids with vertically oriented apical bars were counted as *D. fibula*. *D. fibula* occurs sporadically throughout the silicoflagellate-bearing interval of Site 604.

Dictyocha spinosa (Deflandre)
(Plate 1, Fig. 6)

Corbisema spinosa Deflandre, 1950, p. 193, figs. 178-182.

Dictyocha spinosa (Deflandre) Glezer, 1966, p. 238, pl. 10, figs. 6–8.

Remarks. *Dictyocha spinosa* differs from *Corbisema hexacantha* in having only three of the six spines in the plane of the basal ring. The two taxa exist concurrently, though *D. spinosa* appears earlier and disappears later than *C. hexacantha*, and are frequently found together (Bukry, 1976a, c; Bukry and Foster, 1974; Barron et al., 1984). Their morphologic, stratigraphic, and geographic similarities may indicate an evolutionary relationship.

Genus *DISTEPHANUS* Stohr, 1880

Distephanus boliviensis (Frenguelli)
(Plate 2, Figs. 1, 4)

Dictyocha boliviensis Frenguelli, 1940 (in part), p. 44, fig. 4.

Remarks. *D. boliviensis* differs from *D. speculum* in being larger and having equant distal spines. In this study, *D. boliviensis* was about twice the size of specimens of *D. speculum speculum* in the same samples. Few specimens were found, but fragments, particularly in the top of the Site 604 interval, were more common. Specimens with both six and seven distal spines were found.

Distephanus crux (Ehrenberg)
(Plate 2, Fig. 9, 11)

Distephanus crux Ehrenberg, 1840, p. 207; Ehrenberg, 1854, pl. 18, fig. 56, pl. 33(XV), fig. 9.

Remarks. *D. crux* occurred only in the bottom section of Core 25 and throughout Core 26 of Site 604. The size of the specimens (about 65 μm) was similar to associated *D. speculum speculum*.

Distephanus speculum binoculus (Ehrenberg)
(Plate 2, Fig. 6)

Dictyocha binoculus Ehrenberg, 1844, p. 63, 79.

Distephanus speculum binoculus (Ehrenberg), Bukry, 1975, p. 854.

Distephanus speculum hemisphaericus (Ehrenberg)
(Plate 2, Figs. 3, 5)

Dictyocha hemisphaerica Ehrenberg, 1844, pl. 17, fig. 5.

Distephanus speculum hemisphaericus (Ehrenberg), Bukry, 1975, p. 854.

Remarks. *D. speculum hemisphaericus* is here considered to be any *Distephanus* with three or more apical openings and the basal ring and distal spines characteristic of *Distephanus speculum*—that is, with two opposing spines larger than the other spines. Bukry (1975) differentiated *D. speculum hemisphaericus* from *D. boliviensis major* by the presence of rounded rather than angular apical openings. Although the specimens in this study generally had angular apical openings, the nature of the basal ring and distal spines showed an affinity much closer to *Distephanus speculum* than to *D. boliviensis*.

Distephanus speculum minutus (Bachmann)
(Plate 2, Fig. 7)

Dictyocha speculum f. *minuta* Bachmann *in* Ichikawa et al., 1967, p. 161, pl. 7, figs. 12–15.

Remarks. Bukry (1981a) distinguished this subspecies from *D. speculum speculum* by a larger apical ring whose inner diameter is at least 50% of the inner diameter of the basal ring. This taxon is most common in the higher latitudes (Bukry, 1973). Specimens were present, but not common, through most of the silicoflagellate-bearing interval of Site 604. Specimens of *D. speculum minutus* were consistently smaller than most *D. speculum speculum* associated in the same samples. The distance between major spine tips was usually about 40 μm.

Distephanus speculum pentagonus Lemmermann
(Plate 2, Fig. 8)

Distephanus speculum var. *pentagonus* Lemmermann, 1901, p. 264, pl. 11, fig. 19.

Distephanus speculum pentagonus Lemmermann, Bukry, 1976a, p. 895.

Remarks. Specimens were found in a three-core interval in the middle Eocene of Site 605. This extends the known range of this subspecies, which had first been observed in upper Oligocene sediments (Bukry, 1975, 1976a). Their abundance, though they are by no means common, and the absence of *D. speculum speculum* and other younger fossils indicates that this occurrence might not be the result of downhole contamination.

Distephanus speculum speculum (Ehrenberg)
(Plate 2, Fig. 2)

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* in this study varied greatly in size but very little in morphology. The two major spines had lengths that together approximately equaled the length of the basal ring. The other spines were about half the length of the major spines. There was very little variation on this pattern. The apical apparatus was usually highly arched above the plane of the basal ring. Lengths, measured as the distance between major spine tips, ranged from 40 to 100 μm.

Genus *MESOCENA* Ehrenberg, 1839

Remarks. For this report all silicoflagellates not having an apical apparatus are assigned to Genus *Mesocena*.

Mesocena apiculata Schulz
(Plate 4, Fig. 8)

Mesocena oamaruensis apiculata Schulz, 1928, p. 240, fig. 11.

Mesocena apiculata (Schulz), Ling, 1972, p. 173, pl. 28, figs. 2–4.

Remarks. Two specimens were found in Section 604-26-3. Since the known range of *Mesocena apiculata* extends only to the early Miocene, these are probably reworked.

Mesocena circulus (Ehrenberg)
(Plate 4, Fig. 7)

Mesocena circulus (Ehrenberg) Ehrenberg, 1844, p. 65.

Mesocena diodon Ehrenberg
(Plate 4, Figs. 5, 6)

Mesocena diodon Ehrenberg, 1844, p. 71, 84.

Remarks. Both smooth and nodose forms of *Mesocena diodon* were found, with the smooth forms predominating. Aberrant forms were more common in this species than in any other in this chapter, making up almost 10% of all specimens seen (this value includes three-spined forms counted as *M. triodon*). Size was usually about 75 μm.

Mesocena elliptica (Ehrenberg)
(Plate 4, Fig. 9)

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

Mesocena occidentalis Hanna ex Bukry

Mesocena occidentalis Hanna, 1931, p. 200, pl. E, fig. 1.
Mesocena occidentalis Hanna ex Bukry, 1977, p. 834.

Remarks. *Mesocena occidentalis* has a quadrangular basal ring with relatively long spines at each corner. It differs from *M. elliptica* in being diamond-shaped in outline rather than elliptical, and in having longer spines. *M. occidentalis* was only rarely found in the middle Eocene of Site 605.

Mesocena triodon Bukry
(Plate 4, Figs. 1–4)

Mesocena triodon Bukry, 1978b, pp. 819–820.

Remarks. Three-spined mesocenids were occasionally found. These had somewhat elliptic basal rings with two major spines at opposing ends of the major axis. The third spine was smaller and its position varied. These were associated with specimens of *M. diodon* of similar size and appearance, indicating that the type may be an aberrant variety of *M. diodon* rather than a separate species.

Genus _NAVICULOPSIS_ Frenguelli, 1940

Naviculopsis constricta (Schulz)
(Plate 5, Figs. 3, 4)

Dictyocha navicula biapiculata constricta Schulz, 1928, p. 246, fig. 21.
Naviculopsis constricta (Schulz), Bukry, 1975, p. 856.

Remarks. *N. constricta* has larger portals and a narrower band than *N. foliacea*. The width of the band was usually equal to half the width of the basal ring, though specimens with wider bands, sometimes approaching *N. foliacea*, were seen.

Naviculopsis eobiapiculata Bukry
(Plate 5, Figs. 5–8)

Naviculopsis eobiapiculata Bukry, 1978c, p. 878.

Remarks. *N. eobiapiculata* is distinguished by its highly arched band, which is of constant width until the band is in close proximity to the ring (see Fig. 2). Although this species is easy to identify when the specimen is tilted (as shown in Plate 5, Fig. 4), it can be difficult to distinguish from *N. constricta* when it is lying flat on its basal ring. *Naviculopsis eobiapiculata*, however, usually is slightly smaller and wider than *N. constricta* and the margins of the band are straight and parallel until very close to the basal ring.

Naviculopsis foliacea Deflandre
(Plate 5, Figs. 1–2)

Naviculopsis foliacea Deflandre, 1950, p. 204, figs. 235–240.

Remarks. This species has moderately sized elliptical portals and a wide band with concave margins. In this study there was much variation in band width, which was between 25 and 50% of the internal length of the basal ring.

Naviculopsis ponticula Ehrenberg
(Plate 5, Fig. 9)

Dictyocha ponticulus Ehrenberg, 1844, p. 258, 267; Bailey, 1845, pl. 4, fig. 21.
Naviculopsis ponticula (Ehrenberg), Bukry, 1978b, p. 821.

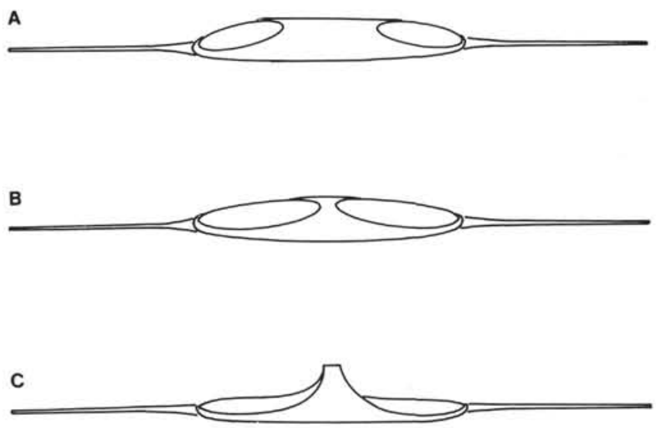

Figure 2. Drawings of three *Naviculopsis* species. View is slightly tilted with respect to both the major and the minor axes. A. *Naviculopsis foliacea*. B. *Naviculopsis constricta*. C. *Naviculopsis eobiapiculata*.

Remarks. One specimen was found in Section 604-23-2. This is above the known extinction of *Naviculopsis* and therefore the specimen is probably reworked from lower Miocene strata.

Ebridian Taxonomy

Genus _AMMODOCHIUM_ Hovasse, 1932

Ammodochium rectangulare (Schulz)
(Plate 5, Fig. 15)

Ebria antiqua var. *rectangularis* Schulz, 1928, p. 274, fig. 72 a–d.
Ammodochium rectangulare (Schulz), Ling, 1971, p. 694.

Remarks. *Ammodochium rectangulare* was found in Section 604-25-4 and through Core 604-26.

Genus _EBRIOPSIS_ Hovasse, 1932

Ebriopsis antiqua antiqua (Schulz)
(Plate 5, Fig. 10)

Ebria antiqua Schulz, 1928 (in part), pp. 273, 274, fig. 696.
Ebriopsis antiqua antiqua (Schulz), Ling, 1977, p. 215, pl. 17, 18.

Remarks. This species was very abundant throughout the siliceous interval of Site 605 (it was, in fact, generally more common than the sum of all silicoflagellate taxa), and was generally present throughout the siliceous interval of Site 604. Specimens of *Ebriopsis antiqua antiqua* and *E. crenulata* were of similar size and some specimens were found that appeared to be intermediates between the two. Specimens of *E. antiqua* with lorica are tabulated separately.

Ebriopsis antiqua cornuta Ling
(Plate 5, Fig. 17)

Ebriopsis cornuta Dumitrică and Perch-Nielsen, *in* Perch-Nielsen, 1975, p. 880, fig. 2, pl. 7.
Ebriopsis antiqua cornuta Ling, 1977, p. 215, pl. 3, figs. 19–22.

Ebriopsis crenulata Hovasse
(Plate 5, Fig. 11)

Ebriopsis crenulata Hovasse, 1932b, p.281, fig. 4 I, II.

Remarks. *Ebriopsis crenulata* was distinguished from *E. antiqua antiqua* by its coarsely crenulated surface ornamentation.

Genus _PARATHRANIUM_ Hovasse, 1932

Parathranium tenuipes (Hovasse)
(Plate 5, Figs. 14, 16)

Thranium tenuipes Hovasse, 1932a, p. 123, fig. 5.
Parathranium tenuipes (Hovasse), Ling, 1972, pp. 198–199.

Remarks. Five specimens of *Parathranium tenuipes* were found in Core 26 of Site 604. This species differs from *P. intermedium* in having relatively thinner skeletal elements (Ling and McPherson, 1974).

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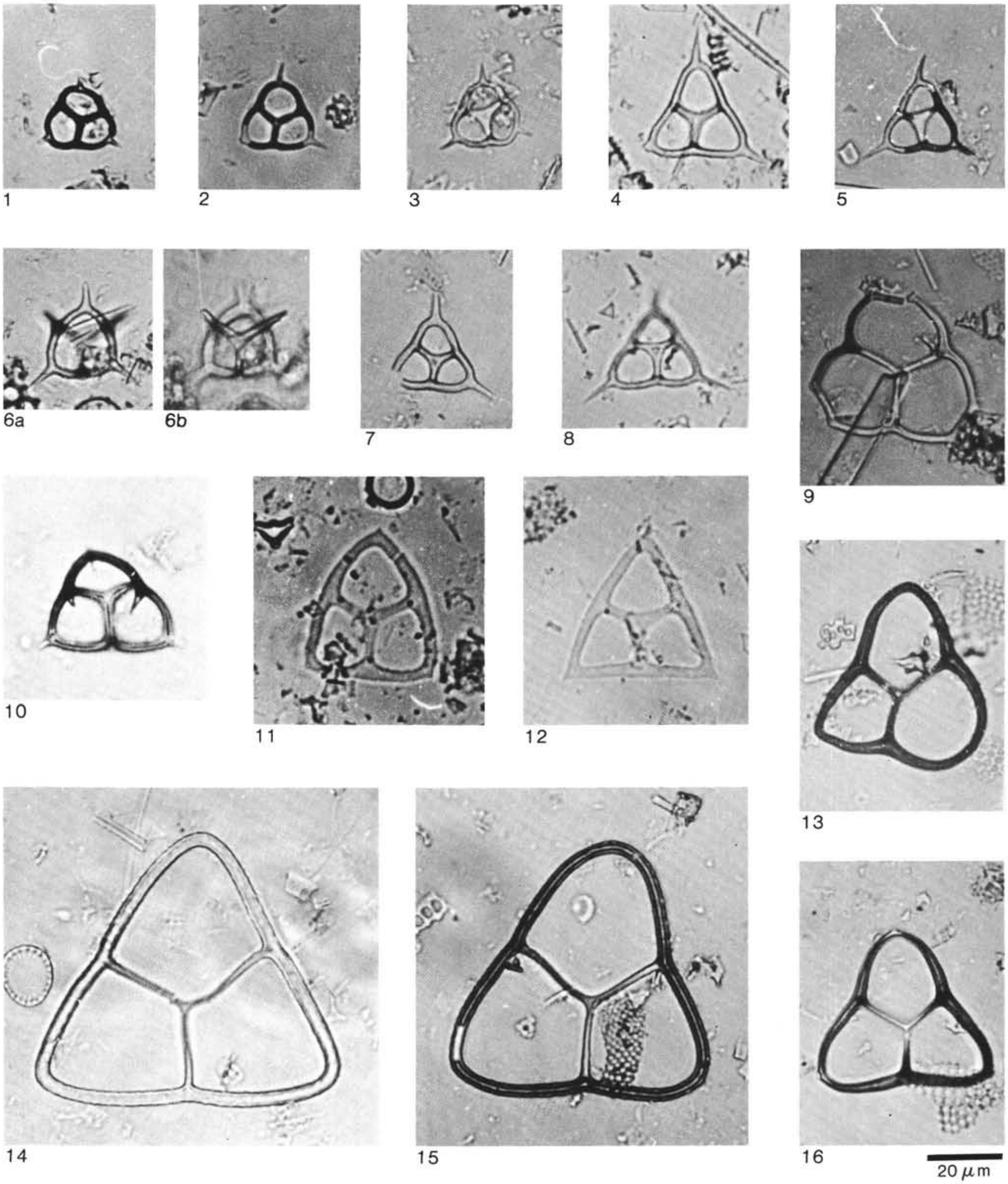

Plate 1. Silicoflagellates from Leg 93. (Magnification 640×; scale bar 20 μm.) **1-5.** *Corbisema triacantha* (Ehrenberg), (1-3) Sample 605-10-3, 20-22 cm (3, cruxoid), (4) Sample 605-16-6, 20-22 cm, (5) 605-13-6, 20-22 cm. **6.** *Dictyocha spinosa* (Deflandre), Sample 605-16-6, 20-22 cm, (a) focusing on basal ring and (b) focusing on apical spines. **7, 8.** *Corbisema triacantha* (Ehrenberg), cruxoid, Sample 605-10-3, 20-22 cm. **9.** *Corbisema bimucronata* Deflandre, Sample 605-15-6, 20-22 cm. **11, 12.** *Corbisema recta* (Schulz), (11) Sample 605-14-3, 20-22 cm, (12) Sample 605-13-6, 20-22 cm. **13.** *Corbisema* cf. *inermis inermis* (Lemmermann), Sample 605-13-6, 20-22 cm. **14-16.** *Corbisema inermis inermis* (Lemmermann), (14) Sample 605-11-3, 20-22 cm, (15) Sample 605-11-6, 20-22 cm, (16) Sample 605-17-6, 20-22 cm.

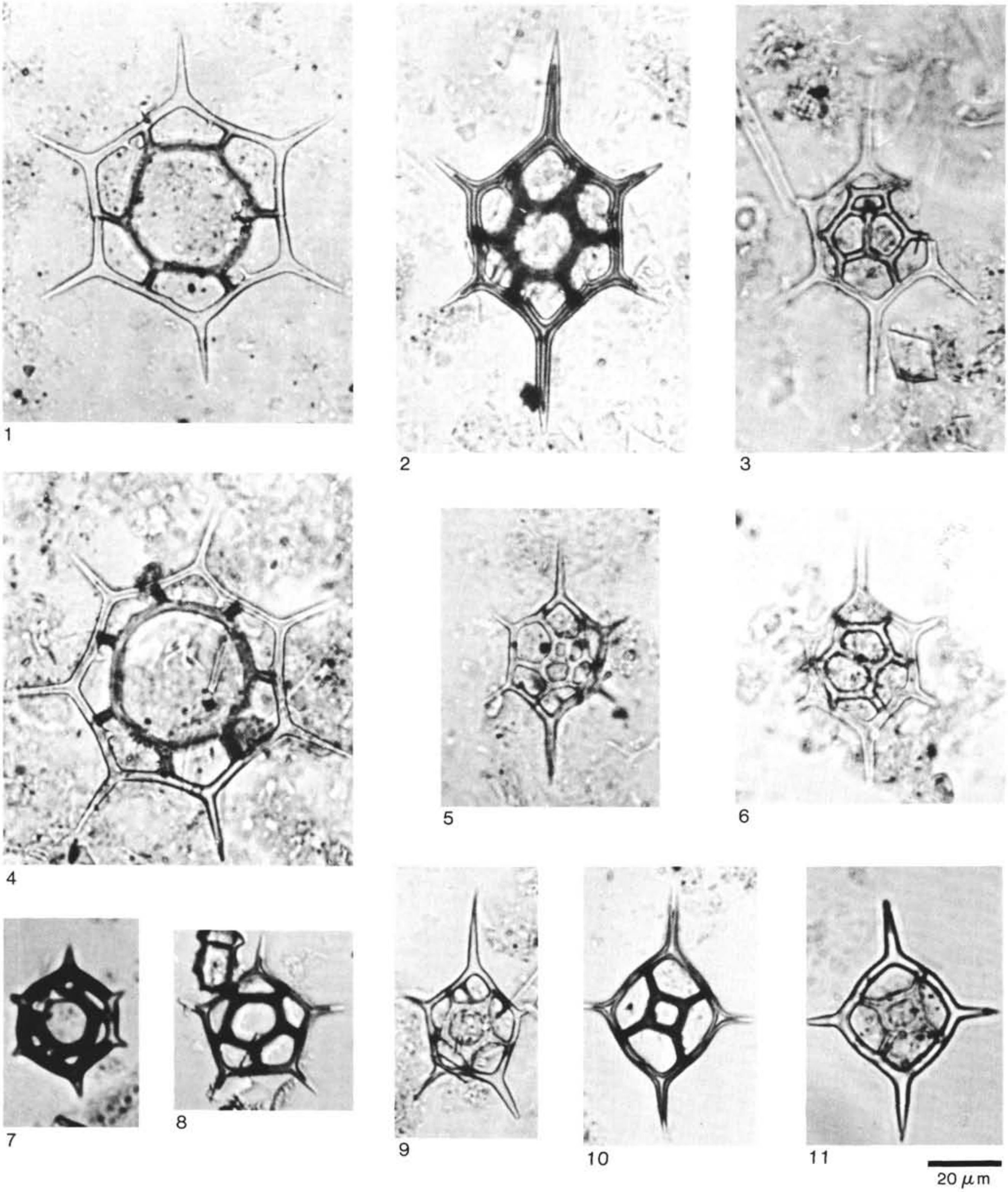

Plate 2. Silicoflagellates from Leg 93. (Magnification 640×; scale bar 20 μm.) **1.** *Distephanus boliviensis* (Frenguelli), Sample 604-23-1, 20–22 cm. **2.** *Distephanus speculum speculum* (Ehrenberg), Sample 604-25-3, 20–22 cm. **3.** *Distephanus speculum hemisphaericus* (Ehrenberg), Sample 604-23-2, 20–22 cm. **4.** *Distephanus boliviensis* (Frenguelli), Sample 604-23-1, 20–22 cm. **5.** *Distephanus speculum hemisphaericus* (Ehrenberg), Sample 604-23-2, 20–22 cm. **6.** *Distephanus speculum binoculus* (Ehrenberg), Sample 604-23-1, 20–22 cm. **7.** *Distephanus speculum minutus* (Bachmann), Sample 604-23-4, 20–22 cm. **8.** *Distephanus speculum pentagonus* Lemmermann, Sample 605-13-6, 20–22 cm. **9.** *Distephanus speculum/crux*, Sample 604-26-3, 20–22 cm. **10, 11.** *Distephanus crux* (Ehrenberg), (10) Sample 604-26-3, 20–22 cm, (11) Sample 604-26-4, 20–22 cm.

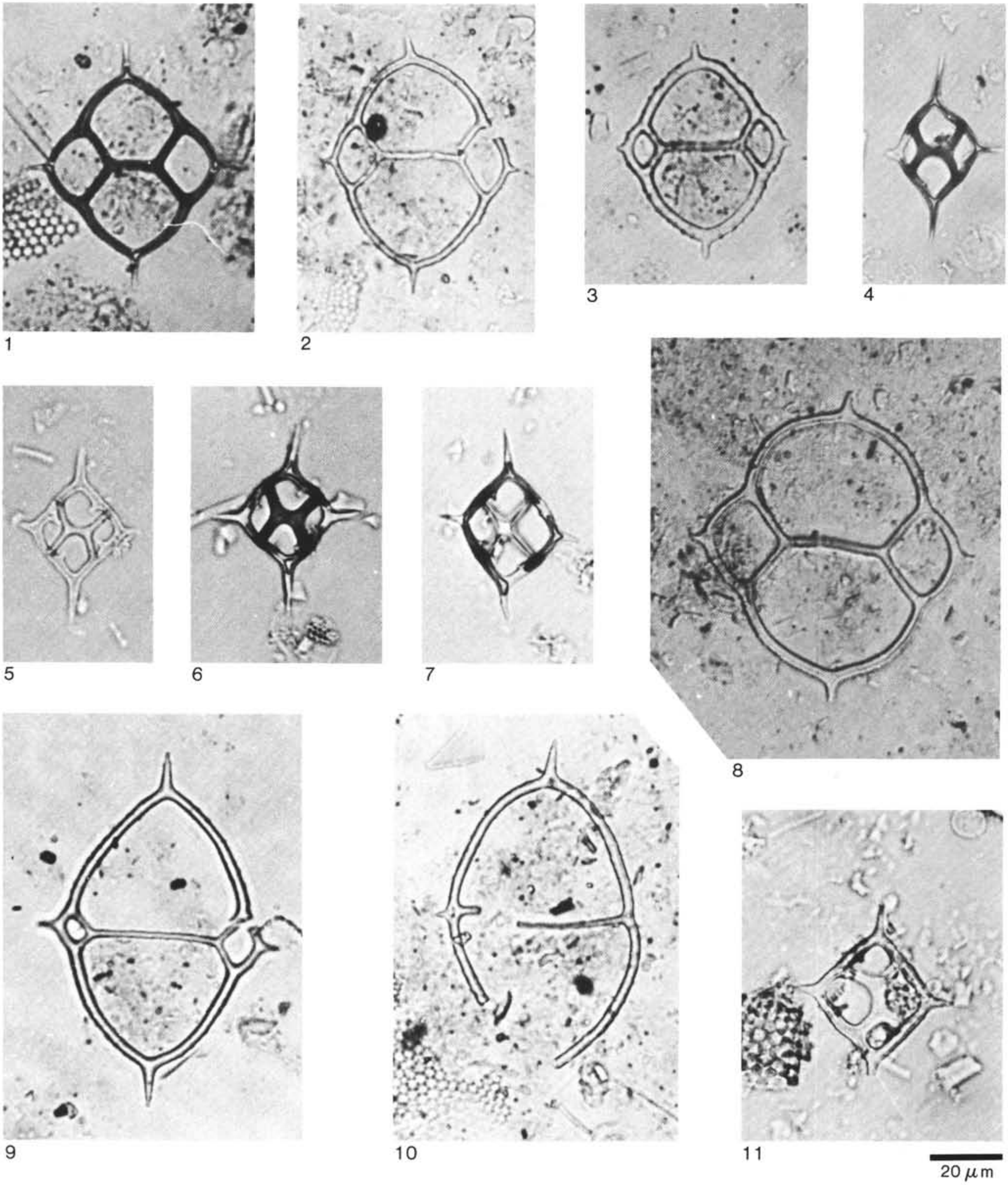

Plate 3. Silicoflagellates from Leg 93. (Magnification 640×; scale bar 20 μm.) **1.** *Dictyocha aspera aspera* (Lemmermann), Sample 604-26-4, 20–22 cm. **2, 3.** *Dictyocha brevispina* (Lemmermann), Sample 604-23-2, 20–22 cm. **4–7.** *Dictyocha byronalis* Bukry, (4) Sample 605-13-6, 20–22 cm, (5) Sample 605-15-6, 20–22 cm, (6) Sample 605-10-3, 20–22 cm, (7) medusoid, Sample 605-13-6, 20–22 cm. **8, 9.** *Dictyocha brevispina* (Lemmermann), (8) Sample 604-23-3, 20–22 cm, (9) Sample 604-23-1, 20–22 cm. **10.** *Dictyocha brevispina/transversa*, Sample 604-23-1, 20–22 cm. **11.** *Dictyocha byronalis* Bukry, fibuloid, Sample 605-18-3, 20–22 cm.

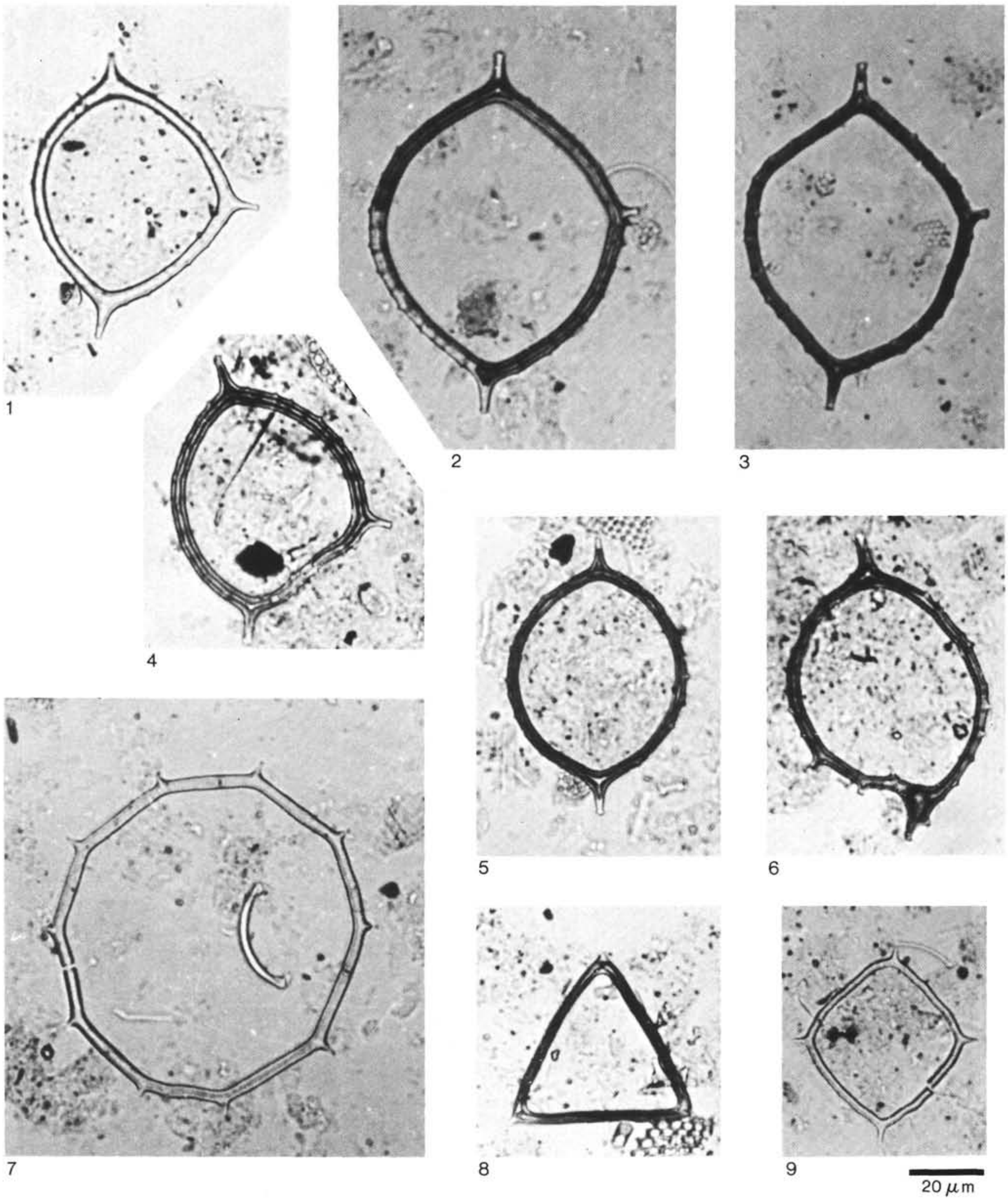

Plate 4. Silicoflagellates from Leg 93. (Magnification 640×; scale bar 20 μm.) **1-4.** *Mesocena triodon* Bukry, (1) Sample 604-26-4, 20-22 cm, (2-4) Sample 604-25-2, 20-22 cm. **5, 6.** *Mesocena diodon* Ehrenberg, (5) Sample 604-26-3, 20-22 cm, (6) aberrant, Sample 604-23-3, 20-22 cm. **7.** *Mesocena circulus* (Ehrenberg), Sample 604-25-2, 20-22 cm. **8.** *Mesocena apiculata* Schulz, Sample 604-26-3, 20-22 cm. **9.** *Mesocena elliptica* (Ehrenberg), Sample 604-23-1, 20-22 cm.

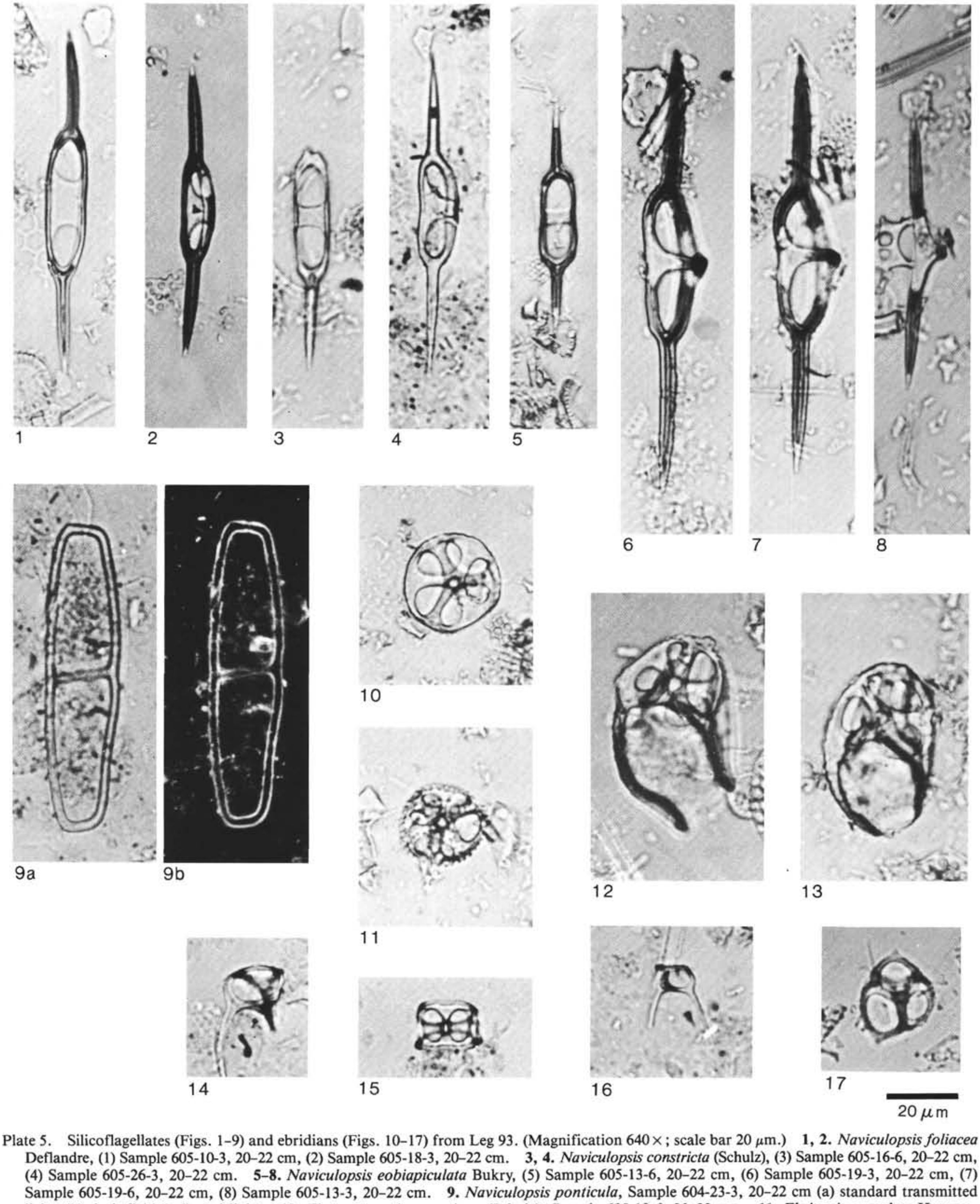

Plate 5. Silicoflagellates (Figs. 1–9) and ebridians (Figs. 10–17) from Leg 93. (Magnification 640×; scale bar 20 μm.) **1, 2.** *Naviculopsis foliacea* Deflandre, (1) Sample 605-10-3, 20–22 cm, (2) Sample 605-18-3, 20–22 cm. **3, 4.** *Naviculopsis constricta* (Schulz), (3) Sample 605-16-6, 20–22 cm, (4) Sample 605-26-3, 20–22 cm. **5–8.** *Naviculopsis eobiapiculata* Bukry, (5) Sample 605-13-6, 20–22 cm, (6) Sample 605-19-3, 20–22 cm, (7) Sample 605-19-6, 20–22 cm, (8) Sample 605-13-3, 20–22 cm. **9.** *Naviculopsis ponticula*, Sample 604-23-3, 20–22 cm (a) standard transmitted light, (b) dark field (reflected light) **10.** *Ebriopsis antiqua antiqua* (Schulz), Sample 605-19-6, 20–22 cm. **11.** *Ebriopsis crenulata* Hovasse, Sample 605-19-6, 20–22 cm. **12, 13.** *Ebriopsis antiqua antiqua* with lorica, (12) Sample 605-10-3, 20–22 cm, (13) Sample 605-21-3, 20–22 cm. **14.** *Parathranium tenuipes* Hovasse, Sample 604-26-1, 20–22 cm. **15.** *Ammodochium rectangulare* (Schulz), Sample 604-26-4, 20–22 cm. **16.** *Parathranium tenuipes* Hovasse, Sample 604-26-1, 20–22 cm. **17.** *Ebriopsis antiqua cornuta* Ling, Sample 605-10-3, 20–22 cm.