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36. OLIGOCENE TO EARLY MIOCENE SILICOFLAGELLATES FROM THE IVORIAN BASIN, EASTERN EQUATORIAL ATLANTIC, SITE 959[1]

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ABSTRACT

Silicoflagellate biostratigraphy and relative abundance were determined for Site 959 in the eastern equatorial Atlantic. Five silicoflagellate zones, *Corbisema apiculata, Naviculopsis biapiculata, Naviculopsis lata, Naviculopsis ponticula, and Corbisema triacantha* Zones, were used with the *Distephanus speculum hemisphaericus* Subzone occurring in the *N. biapiculata* Zone. The *Naviculopsis quadrata* Zone is missing between the *N. ponticula* and *N. lata* Zones, indicating a hiatus in the lower Miocene cores that corresponds to hiatus NH1. Silicoflagellate relative abundance was graphed as a measure of paleoproductivity for Hole 959A. One large pulse of productivity occurred in the latest early Miocene, right before silica deposition came to an abrupt halt in the earliest middle Miocene.

INTRODUCTION

Leg 159 has been one of the few legs of the Ocean Drilling Program to drill the eastern equatorial Atlantic. The objectives of the cruise were to study the evolutionary stages of continental transform margins and investigate deep and intermediate water influences in the eastern equatorial Atlantic throughout the development of the basin. From the Oligocene to the present, Site 959 has been at or near the equator, and therefore, the cores recovered offer an excellent opportunity to study the paleoceanographic history of the eastern equatorial Atlantic and to determine the characteristics of the water masses that were present. In this study, silicoflagellate relative abundance data were collected to define the biostratigraphy for the upper Oligocene to the lower Miocene and investigate the paleoproductivity of the site.

Site 959 is located at 3°37.7′N, 2°44.1′W on the Ivory Coast-Ghana Marginal Ridge south of the Ivorian Basin (Fig. 1). Cores from Site 959 provide a sediment record from the mid-Cretaceous to the present, with silicoflagellates occurring in the Oligocene to lower Miocene. Silicoflagellate preservation and abundance are excellent in the upper Oligocene to uppermost lower Miocene sediment, but downcore in the lower Oligocene, silicoflagellate preservation diminishes. Hole 959A consists of calcareous ooze in the upper 205 m (Sections 159-959A-1H-CC through 22X-CC) underlain by 237 m (Sample 159-959A-23X-1, 39–41 cm, to Sample 159-959A-46X-CC) of interbedded nannofossil ooze and biosiliceous ooze. Twelve samples from the upper portion of Hole 959D (Samples 159-959D-1R-CC through 7R-CC) contain poorly preserved, biogenic siliceous components with sparse nannofossils. Core recovery for this interval of Hole 959D was 16%, which made age designations and identification difficult. Samples downcore from 159-959D-7R-CC consist of diagenetically altered porcellanite and chert and were not examined for silicoflagellates.

METHODS AND SAMPLE PREPARATION

Samples were prepared as smear slides on 22 mm × 40 mm cover slips. The number of silicoflagellates was tabulated in 10 transects across the slide, which is equal to an area of 4.92 cm^2, more than half of the slide area (Tables 1–4). The specimens were counted at 200× magnification, and a magnification of 400× was used for more precise identification. Only specimens with over half of the skeleton were counted. On a few slides, over 300 specimens were counted, but for most of the slides, 50–100 specimens were found in the 10 transects. Because aberrant specimens may be an indication of environmental stress, they were counted on a separate tally.

Silicoflagellates from Holes 959A and 959D were examined for biostratigraphic purposes. The slides from Hole 959A, ranging from lower Miocene to upper Oligocene, exhibit good silicoflagellate skeletal preservation. In sediments of the lower Oligocene, incomplete diatom and silicoflagellate skeletons show evidence of dissolution and diagenesis.

BIOSTRATIGRAPHY

The biostratigraphy used here is derived from the previously published zonations of Bukry (1981), Perch-Nielsen (1985), and Locker and Martini (1986). Silicoflagellate counts in the oldest cores of Hole 959A and all of Hole 959D are so low that it is difficult to obtain a good biostratigraphic record for the ?lower Oligocene to lowermost upper Oligocene.

Corbisema triacantha Zone

Definition: This zone is bracketed by the last occurrence of *Naviculopsis* to the last occurrence of *Corbisema triacantha triacantha*.

Author: Martini, 1971.

Common species: The common species in this zone include *Dictyocha pulchella, Dictyocha fibula ausonia, Corbisema triacantha triacantha, Bachmannocena elliptica*, and *D. fibula ausonia* (naviculopsoid). *Distephanus speculum hemisphaericus* also is present in the lower part of the zone, but is not as common as the other listed species.

Remarks: The upper part of the *C. triacantha* Zone is not recognized in the sediments of Site 959, because there was a halt in siliceous preservation by the middle Miocene, before the last occurrence of *C. triacantha.* The last occurrence of *Naviculopsis* lies in Sample 159-959A-25X-CC. The minimum thickness of the zone is 27.2 m.

Naviculopsis ponticula Zone

Definition: This zone is the interval defined by the first occurrence of *Naviculopsis ponticula* to the last occurrence of *Naviculopsis*.

Author: Bukry, 1981.

Common species: The common species include *C. triacantha, N. ponticula, Distephanus crux,* and *B. elliptica*. Other species include *Distephanus speculum patulus, Distephanus speculum hemisphaericus,* and *Distephanus speculum pentagonus.*

Remarks: This zone was found in Hole 959A with the first occurrence of *N. ponticula* in Sample 159-959A-29X-3, 38–40 cm, and the last occurrence

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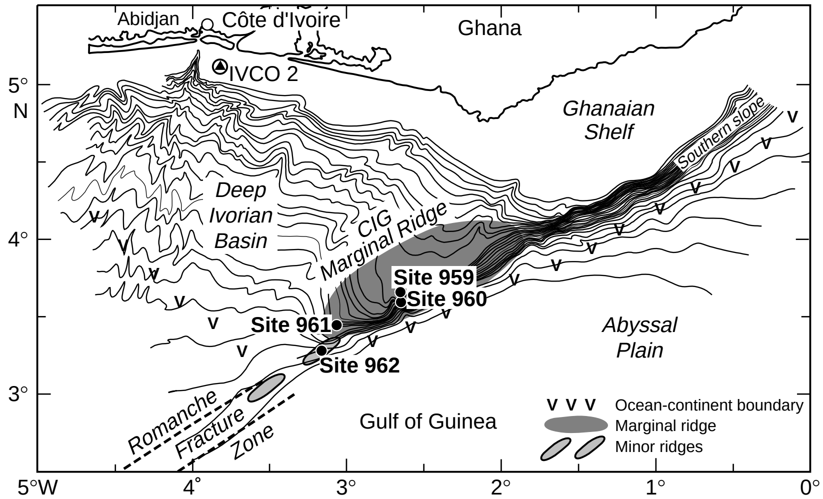

Figure 1. Diagram showing the drilling sites (solid circles) of Leg 159. Site 959 is located on the CIG Marginal Ridge (Mascle, Lohmann, Clift, et al., 1996). Triangle is the location of Hole IVCO 2.

of *Naviculopsis* in Sample 159-959A-25X-CC. The *Naviculopsis quadrata* Zone is completely absent in this sequence. According to most silicoflagellate biostratigraphic zonations for low latitudes, the *Naviculopsis quadrata* Zone should be present between the *Naviculopsis lata* and *Naviculopsis ponticula* Zones of the early Miocene, but no specimens of *N. quadrata* were identified between these particular zones. One specimen of *N. quadrata* was found in Sample 159-959A-34X-CC, near the Oligocene/Miocene boundary, but this occurs lower in the core in the *Naviculopsis lata* Zone. The lowermost portion of the *Naviculopsis ponticula* Zone is missing because of a possible hiatus. The thickness of this zone is 32.3 m.

***Naviculopsis lata* Zone**

Definition: This zone is the interval between the first occurrence of *Naviculopsis lata* to the first occurrence of *N. quadrata*.

Author: Martini, 1972; emended Bukry, 1978d.

Common species: The common silicoflagellate species in this interval include *Ds. crux, N. lata, Naviculopsis biapiculata* (in the lowermost portion of the zone), *D. fibula ausonia, Ds. speculum speculum,* and *Ds. speculum hemisphaericus.*

Remarks: The first occurrence of *N. lata* is in Sample 159-959A-31X-5, 86–88 cm. As stated above in the zonation for the *Naviculopsis ponticula* Zone, the *Naviculopsis quadrata* Zone is not represented in these cores; therefore, the first occurrence of *N. quadrata* is probably not the true evolutionary first occurrence. It is likely that there is a hiatus between the *Naviculopsis lata* and *Naviculopsis ponticula* Zones. It is also possible that the uppermost part of the *Naviculopsis lata* Zone was missing at the disconformity, so the entire zone may not be present. The thickness of the zone is 22.6 m.

***Naviculopsis biapiculata* Zone**

Definition: The bottom of the zone is marked by the last occurrence of *Corbisema hastata hastata*, and the top of the zone is marked by the first occurrence of *N. lata*.

Author: Bukry, 1974; modified Bukry, 1978d.

Common species: The common species in this zone include *C. triacantha triacantha, Dictyocha deflandrei, N. biapiculata, Bachmannocena apiculata apiculata, Bachmannocena apiculata glabra, Naviculopsis biapiculata* var. 1, *Ds. speculum speculum, Ds. crux, Naviculopsis constricta, Naviculopsis lata* var. 1, *Distephanus hannai, Distephanus longispinus,* and *Distephanus stradneri* var. *grandis.*

Remarks: The first occurrence of *N. lata* was found in Sample 159-959A-31X-5, 86–88 cm. No specimens of *C. hastata hastata* were identified in Hole 959A, so *Corbisema hastata globulata*, which has its last occurrence at the top marker of the *Corbisema apiculata* Zone, was used as the marker species. The thickness of the zone is 106.0 m.

***Distephanus speculum haliomma* Subzone**

Definition: This subzone spans the interval from the first occurrence of *Ds. speculum hemisphaericus* to the first occurrence of *N. lata*.

Author: Bukry, 1981.

Common species: Common species of this subzone include *Ds. speculum speculum, Ds. crux, B. apiculata apiculata, Dictyocha fibula fibula, Distephanus stradneri* var. *grandis, Ds. hannai, Ds. longispinus, Naviculopsis* var. 2, *Naviculopsis lata* var. 1, and *N. constricta*.

Remarks: Bukry (1981) originally described this interval as ranging from the first occurrence of *Distephanus speculum haliomma* and the first occurrence of *Ds. speculum hemisphaericus* to the first occurrence of *N. lata*. However, in this work only the first occurrence of *Ds. speculum hemisphaericus* was used as the lower boundary because *Ds. speculum haliomma* was not distinguished from *Ds. speculum hemisphaericus*. The first occurrences of *Ds. speculum hemisphaericus* and *Ds. speculum speculum* are in Sample 159-959A-39X-5, 123–124 cm. The first occurrence of *N. lata* is in Sample 159-959A-31X-5, 86–88 cm. Preservation was good throughout the subzone, which spanned a thickness of 75.8 m.

***Corbisema apiculata* Zone**

Definition: This zone is defined by the last occurrence of *Dictyocha hexacantha* to the last occurrence of *Corbisema hastata hastata.*

Author: Perch-Nielsen, 1975; emended, Bukry, 1978a.

Common species: In this zone the common species were *C. hastata globulata, C. triacantha triacantha, N. biapiculata, N. constricta, B. apiculata apiculata, D. deflandrei, Naviculopsis biapiculata* var. 2, and *Ds. crux.*

Remarks: The boundaries of this zone were difficult to accurately determine because silicoflagellates were sparse. *Corbisema hastata hastata* was not identified in any of the samples, so it can not be used as the zonal marker. *Corbisema hastata globulata* was identified in the cores and was used as the zonal marker in place of *C. hastata hastata*. The last occurrence of *C. hastata globulata* marks the top of the *C. apiculata* Zone in Sample 159-959A-42X-CC. Because lower sediments in this zone consisted of porcellanite and chert, the bottom zonal marker of this zone was not determined. The minimum thickness of this zone is 75.8 m.

DISCUSSION

The missing *N. quadrata* Zone marks a disconformity in the lower Miocene sequence. As discussed earlier, the *N. quadrata* Zone should be present between the *N. lata* and *N. ponticula* Zones. Its absence in the cores of Site 959 suggests a hiatus in the lower Miocene sediment. Nannofossil biostratigraphy indicates that nannofossils for the same samples in Hole 959A were reworked, therefore, supporting the presence of a hiatus between the *N. lata* and *N. ponticula* silicoflagellate Zones. Poorly preserved nannofossils of Subzone CN1c co-occur with the *N. Ponticula* silicoflagellate zone, which should not be found in Subzone CN1c; therefore, rare nannofossils from Subzone CN1c are reworked across the hiatus. Nannofossil biostratigraphy also shows that Subzone CN1c is significantly thinner than one would expect given the sedimentation rates of the nannofossil zones above and below Subzone CN1c. The sedimentation rates for Subzones CN1a and CN1b are 72 m/m.y. and for Zone CN2 the sedimentation rate is 40 m/m.y., but the sedimentation rate for

Subzone CN1c is less than 10 m/m.y. The relatively low sedimentation rate in Subzone CN1c suggests that a disconformity occurs in the lower Miocene sequence in Subzone CN1c. Works by other authors support this conclusion (Keller and Barron, 1983; Locker and Martini, 1986).

Sites 575 and 591 (31°S, in the southwest Pacific) also indicate a missing zone in the lower Miocene rock. At Site 575 in the tropical Pacific, Bukry documents the absence of the *N. quadrata* Zone and attributes it to a poor silicoflagellate assemblage, not a hiatus, in the cores and also suggests that *N. quadrata* must have a latitudinal preference for the cooler, high-latitude regions (Bukry, 1985). Paleotemperature analyses by Bukry (1985) correlates periods of cool water with hiatus NH1 found by Keller and Barron (1983). Locker and Martini (1986) reviewed cores from Site 206 and recognized a hiatus in the uppermost lower Miocene sequence from nannofossil Zone NN2 through NN4. In the same work they also identified a hiatus in Zones NN2 through NN4 for Site 591. The missing sediments in Sites 591, and the tropical cores of Sites 959 and 575, are likely due to an ocean hiatus (NH1) that occurs in the lower Miocene sediment, from 20 to 18 Ma, (Keller and Barron, 1983).

Silicoflagellate relative abundance for the ?lower Oligocene to lower Miocene sediment of Hole 959A (Fig. 2) indicates there were two major pulses of silicoflagellate abundance. The first occurred just before the Oligocene/Miocene boundary in the late Oligocene, and the second pulse of silicoflagellates occurred in the latest early Miocene, just before siliceous sedimentation nearly ceased in the middle Miocene.

The first pulse of abundance is very distinct with a total silicoflagellate count of 1715 specimens. This is good evidence that productivity at this time (latest early Miocene) was high even though the counts were done on smear slides, which may cause a slight distortion of the magnitude of the pulses. The second pulse, near the Oligocene/Miocene boundary is also distinct with a count of 522 total specimens, but this pulse is more difficult to assign as a time of high productivity because the samples downcore were poorly preserved, showing evidence of dissolution.

At Site 366, in the eastern equatorial Atlantic, productivity was determined using $\delta^{18}O$, $\delta^{13}C$, percent carbonate, and percent biogenic opal (Stein, 1985). Stein's graph of percent biogenic opal at Site 366 shows similar trends for the early Miocene with two periods of biosiliceous preservation. The first period occurred near the Oligocene/Miocene boundary, and the second occurred in the late early Miocene, which correlates with the data in Figure 2.

By the middle Miocene in the Atlantic Ocean, most biosiliceous sedimentation had abruptly declined. Selected Atlantic Ocean sites in the eastern, western, and southern basins show that a major reorganization in the silica budget had occurred (Mikkelsen and Barron, 1996), causing little or no biosiliceous microfossils to be preserved. This idea of reorganization of the silica budget is not a new one, and previously published works have recognized the change of silica deposition, with silica being deposited mainly in the Atlantic up until the middle Miocene to silica being deposited mainly in the North Pacific after the middle Miocene (Keller and Barron, 1983; Woodruff and Savin, 1989).

CONCLUSIONS

A silicoflagellate biostratigraphy was constructed for the Oligocene and lower Miocene for Site 959 with five silicoflagellate zones. The zones are the *C. apiculata* Zone, the *N. biapiculata* Zone, the *N. lata* Zone, the *N. ponticula* Zone, and the *C. triacantha* Zone, with Subzone *Ds. speculum hemisphaericus* occurring in the *N. biapiculata* Zone. The absence of the *N. quadrata* Zone is indication that a hiatus occurs in the lower Miocene cores of Site 959. The reworked nannofossils in Subzone CN1c and the relatively low sedimentation rates in Subzone CN1c support the presence of a hiatus in Subzone CN1c of the lower Miocene cores.

Two siliceous paleoproductivity events punctuated the upper Oligocene and lower Miocene sediments with the first high-productivity event occurring right before the Oligocene/Miocene boundary, and the second high productivity event occurring in the latest early Miocene. Right after the second high-productivity event, siliceous sedimentation comes to an abrupt halt in the Ivorian Basin, supporting a middle Miocene change in distribution of global biogenic silica.

SYSTEMATIC PALEONTOLOGY

In the systematic paleontology section of this paper the following species were identified using Geological Society of America Memoir 106 (Loeblich et al., 1968): *Cannopilus iidaensis*, *Cannopilus schulzii*, and *Cannopilus schulzii* forma *longispinus*.

Genus *BACHMANNOCENA* Locker, 1974, emend. Bukry, 1987

Bachmannocena apiculata apiculata (Schulz) Bukry
(Pl. 1, Figs. 2, 6)

Mesocena oamaruensis var. *apiculata* Schulz, 1928, p. 240, fig. 11.
Mesocena apiculata apiculata (Schulz) Bukry, 1975, p. 856, pl. 5, figs. 6, 9.
Bachmannocena apiculata apiculata (Schulz) Bukry, 1987, p. 403.

Description: *Bachmannocena apiculata apiculata* includes all taxa with a three-sided basal ring where the sides of the basal ring were straight to slightly convex. Each of the vertices of the basal ring have a short radial spine.

Bachmannocena apiculata glabra (Schulz) Bukry
(Pl. 1, Fig. 3)

Mesocena polymorpha var. *triangula* Lemmermann fa. *glabra* Schulz, 1928, p. 237, fig. ?3b, 3c.
Mesocena apiculata glabra (Schulz) Bukry, 1978a, p. 705, pl. 2, figs. 14, 15.
Bachmannocena apiculata glabra (Schulz) Bukry, 1987, p. 404.

Description: This species has a three-sided basal ring like *B. apiculata apiculata*, but the shape of the basal ring is different with two of the sides concave and the third side convex. Three short spines radiate from each vertex.

Bachmannocena apiculata inflata (Bukry) Bukry

Mesocena apiculata inflata Bukry, 1978c, p. 797, pl. 3, figs. 1–3.
Bachmannocena apiculata inflata (Bukry) Bukry, 1987, p. 404.

Description: This taxon has a three-sided basal ring with three short spines at each vertex. It is distinguished from *B. apiculata apiculata* by having all sides convex so that the basal ring is nearly circular.

Bachmannocena diodon (Ehrenberg) Bukry

Mesocena diodon Ehrenberg, 1844, p. 84; Martini and Müller, 1976, p. 881, pl. 4, fig. 4.
Bachmannocena diodon (Ehrenberg) Bukry, 1987, p. 404.

Description: *Bachmannocena diodon* has an elliptical basal ring with only two spines radiating along the major axis. The skeletal surface may be noded or smooth.

Bachmannocena elliptica (Ehrenberg) Bukry
(Pl. 1, Fig. 1)

Dictyocha elliptica Ehrenberg, 1840, p. 208.
Mesocena elliptica (Ehrenberg) Ehrenberg, 1844, pp. 71, 84.
Bachmannocena elliptica (Ehrenberg) Bukry, 1987, p. 404.

Description: *Bachmannocena elliptica* has a four-sided basal ring that is elliptical, rhomboid, and sometimes circular, with four spines radiating from the vertices. The major axis spines are usually longer than the minor axis spines. This species has a highly variable morphology and it is almost impossible to separate the species into separate groups based on the shape of the bas-

Table 1. Silicoflagellate abundance data of Hole 959A from the *Corbisema triacantha* Zone to the *Naviculopsis lata* Zone.

Silicoflagellate zonation	Sample	*B. apiculata apiculata*	*B. diodon diodon*	*B. elliptica*	*B. elliptica* (aberrant)	*B. tridon*	*Ca. iidaensis*	*Ca. schulzii*	*Ca. schulzii* forma *longispinus*	*C. triacantha triacantha*	*Dictyocha* species 1	*D. challengeri*	*D. extensa extensa*	*D. fibula fibula*	*D. fibula ausonia*	*D. fibula ausonia* (naviculopsoid)	*D. hexacantha*	*D. spinosa*	*D. varia*	*Ds. crux*	*Ds. crux* (aberrant)	*Ds. hannai*	*Ds. speculum binoculus*	*Ds. speculum hemisphaericus*	*Ds. speculum hemisphaericus* (7-sided)	*Ds. speculum hemisphaericus* (5-sided)
	159- 959A-																									
	23X-1, 39-41			30						4									9							
	23X-4, 66-68			12																						
	23X-6, 89-91			1503	24	2			1	57			3		1	3			91					25		
	23X-CC			108															3							
	24X-2, 59-60	10		60			1	2		44		1		1	496	217			30				1	3		
C. triacantha	24X-4, 48-51			10						6		1			62	176			8					10		
	24X-6, 25-27														23	84			20					1		
	24X-CC														3	2			1							
	25X-4, 5-6									36	1				27				16	24	1					
	25X-4, 145-147									2	2			4	160	2			8	33	3					
	25X-7, 39-41	14								11	5									183	1	241	1	1		
	25X-CC									10	2						1			24		110				
	26X-3, 116-117									15									1	12		10	1	2		
	26X-5, 37-38																			21		3				
	26X-CC										2									5		5				
	27X-3, 37-38	1		22						14										14	2	10	7	36		
	27X-5, 23-25			16																18	3	25				
N. ponticula	27X-CC	1	1	27						4										48		17		4		
	28X-3, 9-11			30						2	1						1			56				6		
	28X-4, 59-61			8						1										4						
	28X-6, 106-108			29		1				5										78		6	1	3		
	28X-CC			1														1		3						
	29X-1, 13-15			8							1									81						
	29X-3, 38-40			2																44						
	29X-5, 30-33			3						2					2	1				34				1		
	29X-CC														6					11						
	30X-1, 30-32													2	12					3						
	30X-3, 86-88																			9						
N. lata	30X-5, 86-88														4					8				3		
	30X-7, 36-38													4	13					13				11	1	1
	30X-CC																			3	9					
	31X-1, 24-25														8					4				3		
	31X-2, 128-130																			12						
	31X-5, 67-68														2					11				1		

al ring. Thus rhomboid, elliptical, and circular skeletons were grouped together as *B. elliptica*.

Remarks: *Bachmannocena elliptica* occurs in Samples 159-959A-29X-5, 30–33 cm, through 159-959A-27X-3, 37–38 cm, and Samples 159-959A-24X-4, 48–51 cm, through 159-959A-23X-1, 39–41 cm, intervals from the lower Miocene sequence. Several authors (Bukry, 1980; Bukry, 1978b; McCartney et al., 1995) make the distinction between *B. elliptica* and *B. quadrata* with the Quaternary *B. quadrata* having a more noded surface and a more quadrate form than the lower Miocene *B. elliptica*. In these cores, this taxon has a varied morphology ranging from small, elliptical, and noded to large, quadrate, and delicate. Because of the variation in morphology of this species, all of the forms were grouped into one species, *B. elliptica*. In Sample 159-959A-23X-6, 89–91 cm, 1503 specimens of *B. elliptica* were counted. With such a large count of *B. elliptica* it is possible that nutrient supply to the surface water at this time was very high and caused a wide range of skeletal morphologies in *B. elliptica* species, often times very robust and ornate.

Bachmannocena triodon (Bukry) Bukry
(Pl. 1, Fig. 11)

Mesocena triodon Bukry, 1973, p. 860, pl. 2, fig. 11; Bukry, 1978b, p. 839, pl. 7, figs. 9, 10; McCartney and Wise, 1987, p. 813, pl. 4, figs. 1–4.
Bachmannocena triodon (Bukry) Bukry, 1987, p. 405.

Description: *Bachmannocena* triodon has an elliptical basal ring and three spines. Two of the spines radiate from the major axis and the third spine occurs on one side of the minor axis. Only three specimens were counted from Site 959, two specimens occurred in Sample 159-959A-23X-6, 89–91 cm, and one specimen occurred in Sample 159-959A-28X-6, 106–108 cm.

Genus *CANNOPILUS* Haeckel, 1887

Cannopilus iidaensis Bachmann

Cannopilus iidaensis Bachmann *in* Ichikawa and others 1967, pl. 52, figs. 1–7; Locker and Martini, 1986, p. 912, pl. 1, figs. 5, 6.

Description: The basal ring of this taxon has many basal spines radiating at about the same length with the number of spines varying. In the description given by Locker and Martini, the basal ring has nine spines, but the preservation of these specimens in Hole 959A was so poor that the number of basal spines was not evident. The cannopolid silicoflagellates were commonly fragmented and broken whereas other silicoflagellates were well preserved; this may be due to their larger size. The apical structure is cannopolid (elevated and spherical) and has many irregularly shaped apical windows.

Cannopilus schulzii (Deflandre) Schulz

Cannopilus schulzii Deflandre *in* Bachmann and Ichikawa 1962; *Cannopilus schulzii* (Deflandre), Perch-Nielsen, 1985, p. 824, pl. 9. fig. 4.

Description: This taxon has a hemispherical apical structure with a varying number of apical windows. The basal ring is eight sided with eight radiating spines.

Table 1 (continued).

Silicoflagellate zonation	Sample	*Ds. speculum patulus*	*Ds. speculum pentagonus*	*Ds. speculum pentagonus* (multi-window)	*Ds. speculum speculum*	*Ds. speculum speclum* (aberrant)	*Ds. stradneri*	*N. biapiculata*	*N. biapiculata nodulifera*	*N. constricta*	*N. contraria*	*N. lata*	*N. lata* var. 2	*N. lata* (off-centered apical bar)	*N. lata* (windowed form)	*N. lata* (*danica* type)	*N. obtusarca*	*N. ponticula ponticula*	*N. ponticula spinosa*	Other aberrant forms	Total count
	159- 959A-																				
	23X-1, 39-41				1																44
	23X-4, 66-68									1											13
	23X-6, 89-91				1															4	1715
	23X-CC																				111
	24X-2, 59-60					1															867
C. triacantha	24X-4, 48-51																				273
	24X-6, 25-27																				128
	24X-CC																				6
	25X-4, 5-6																			3	108
	25X-4, 145-147	1																			215
	25X-7, 39-41	2	10																		469
	25X-CC		2		4												2				155
	26X-3, 116-117	5	1				1											1			49
	26X-5, 37-38	2	1				1											1			29
	26X-CC						3											2			17
	27X-3, 37-38	2	12									11								1	132
	27X-5, 23-25	3					6												6		77
N. ponticula	27X-CC						14										1		1		118
	28X-3, 9-11					1	2					8							1		108
	28X-4, 59-61	1								3	4	3									24
	28X-6, 106-108	1					2			6							28	3			163
	28X-CC																	1			6
	29X-1, 13-15																2	14			106
	29X-3, 38-40																	2			48
	29X-5, 30-33											16									59
	29X-CC									1		40									58
	30X-1, 30-32											29									46
	30X-3, 86-88											23									32
N. lata	30X-5, 86-88				3					1		147			1						167
	30X-7, 36-38		1		2			4				197	60	14	13	2				1	337
	30X-CC							1				37	71	4	2						127
	31X-1, 24-25		3		2					1		19	15		5						60
	31X-2, 128-130							122	2			2	1	2							141
	31X-5, 67-68		1	1	2			31		3		46	24	3							125

Cannopilus schulzii forma *longispinus* Bachmann and Ichikawa

Cannopilus schulzii forma *longispinus* Bachmann and Ichikawa, 1962; Loeblich et al., 1968, p. 205, pl. 2, figs. 6–24.

Genus *CORBISEMA* Hanna, 1928

Corbisema apiculata (Lemmermann) Hanna
(Pl. 1, Fig. 7)

Dictyocha triacantha var. *apiculata* Lemmermann, 1901, p. 259, pl. 10, figs. 19, 20.
Corbisema apiculata (Lemmermann) Hanna, 1931, p. 187–201; Perch-Nielsen, 1975, p. 685, pl. 2, figs. 15, 16, 19.

Corbisema apiculata var. 1

Description: This taxon is similar to *C. apiculata* in its size, but the basal spines are longer than those of *C. apiculata* and the skeleton is more robust and noded.

Corbisema hastata globulata Bukry

Corbisema hastata globulata Bukry, 1976a, p. 907, pl. 4, figs. 1–8.

Corbisema triacantha mediana Bukry
(Pl. 1, Fig. 12)

Corbisema triacantha mediana Bukry, 1978a, p. 703, pl. 1, figs. 8–12.

Corbisema triacantha triacantha (Ehrenberg) Bukry
(Pl. 1, Fig. 5)

Dictyocha triacantha Ehrenberg, 1844, p. 80.
Corbisema triacantha triacantha (Ehrenberg) Bukry, 1978a, p. 703, pl. 1, figs. 13–15.

Description: This is a three-sided species with three spines radiating from the vertices and three apical bars that meet at the center of the skeleton. This species has a variable morphology; the corners of the basal ring may be rounded to slightly angular, and the length of the spines is variable from short to medium.

Corbisema triacantha var. 1
(Pl. 1, Fig. 8)

Description: These specimens include those that had a basal ring smaller and more convex than that of *C. triacantha triacantha*. The basal ring of *C. triacantha triacantha* is commonly indented where the apical struts meet the basal ring; whereas, specimens designated *Corbisema triacantha* variety 1 do not have that indention. *Corbisema triacantha* variety 1 also has a basal ring comparable to *D. spinosa* in its shape, but larger.

Table 2. Silicoflagellate abundance data of Hole 959A in the *Naviculopsis biapiculata* Zone.

Silicoflagellate zonation	Sample	*B. apiculata apiculata*	*B. apiculata curvata*	*B. apiculata glabra*	*B. apiculata inflata*	*C. triacantha triacantha*	*C. triacantha mediana*	*Dictyocha* species 1	*D. fibula fibula*	*D. fibula ausonia*	*D. spinosa*	*Ds. crux*	*Ds. crux* (aberrant)	*Ds. hannai*	*Ds. stradneri* var. *grandis*	*Ds. longispinus*	*Ds. speculum binoculus*	*Ds. speculum hemisphaericus*	*Ds. speculum patulus*
	159-959A-																		
	31X-7, 2-3									9		4							
	31X-CC								1	25		53					1		
	32X-1, 49-51	6			1				2	13		32						3	3
	32X-3, 98-100	18								44		25							
	32X-5, 40-41	16		1				15	1	1		77				1			1
	32X-CC	10		6				1		26	1	13	1						
	33X-2, 149-150	20	2	2				1	5	3		104	2			8	2	9	1
	33X-4, 58-59	16		2	1			3				23	3	131		20		2	
	33X-6, 62-64	1						1				9		70					
	33X-CC	2										31		76	3	1			
	34X-2, 64-65	7		1				1				6	1	16		17			
	34X-4, 72-74					1	1					28		4	13	15			1
	34X-6, 44-45	10						1				43		4	5	29			
	34X-CC	45		1				1				106		1	35	87			
	35X-1, 93-94	5										16							
	35X-3, 59-61	2										1		1					
	35X-5, 8-10	2												3					
	35X-CC																		
Ds. speculum hemisphaericus	36X-1, 109-110				1										1				
	36X-3, 88-89	9		4								3							
	36X-5, 46-48	16														1			
	36X-CC	7		1								1							
	37X -1, 1-3	48										3		2					
	37X-3, 51-52	18		1								2							
	37X-6, 0-1	11																	
	37X-CC	25									1							1	
	38X-1, 31-33	2																	
	38X-3, 100-102																		
	38X-5, 71-73	8		1		4												1	
	38X-CC																	1	
	39X-1, 13-14	24				3											2	1	
	39X-3, 58-59	27				18												1	
	39X-5, 123-124	31		1		19												4	
	39X-CC					1													
	40X-1, 63-65																		
N. biapiculata	40X-4, 93-95	6				6													
	40X-5, 50-52	1				2													
	40X-CC																		
	41X-1, 22-23																		

Genus *DICTYOCHA* Ehrenberg

Dictyocha species 1
(Pl. 2, Fig. 4)

Description: Specimens of *Dictyocha* sp. cf. *Ds. crux* include forms that have basal rings similar to the basal ring of *Ds. crux*, and the same variance of spine length of *Ds. crux*. The only difference is that *Dictyocha* sp. cf. *Ds. crux* has an apical bar structure instead of an apical window that may be oriented parallel to the major or minor axis.

Dictyocha challengeri Martini and Müller

Dictyocha challengeri Martini and Müller, 1976, p. 878, pl. 2, fig. 8; pl. 8, fig. 3; Shaw and Ciesielski, 1983, p. 722, pl. 5, figs. 5, 10.

Dictyocha deflandrei Frenguelli ex Glezer
(Pl. 1, Fig. 13)

Dictyocha deflandrei Frenguelli, 1940 (in part), p. 65, fig. 14a, c, d, ?e, and f; Bukry (in part), 1975, p. 863, pl. 2, figs. 11, 12; Perch-Nielsen, 1985, p. 828, pl. 15, figs. 5–7.

Dictyocha extensa extensa (Locker) Locker and Martini
(Pl. 1, Figs. 10, 15)

Dictyocha varia f. extensa Locker, 1975, pp. 99–101, figs. 1/2, 3/3.
Dictyocha extensa (Locker) Locker and Martini, 1986, pp. 903–904, pl. 2, figs. 10–12; pl. 11, fig. 3.
Dictyocha extensa extensa (Locker) Locker and Martini, McCartney et al., 1995, pl. 3, figs. 2–5; pl. 8, fig. 8.

Description: *Dictyocha extensa extensa* includes all specimens with a basal ring identical or similar to *D. varia*, with the apical bar oriented along the major axis, unlike *D. varia*, which has an apical bar oriented along the minor axis. In these samples *D. extensa extensa* is very rare, occurring only three times, all in Sample 159-959A-23X-6, 89–91 cm.

Dictyocha fibula ausonia (Deflandre) McCartney et al.
(Pl. 1, Fig. 14)

Dictyocha ausonia Deflandre, 1950, p. 195, figs. 194–196, 199–202; Ling (in part), 1972, p. 216, pl. 25, figs. 1–5, 9, 10 (not 6–8).
Dictyocha brevispina ausonia (Deflandre) Bukry, 1978a, p. 703, pl. 1, figs. 17–19.
Dictyocha fibula ausonia (Deflandre) McCartney et al., 1995, pl. 2, fig. 2; pl. 8, fig. 6.

Description: This taxon has an apical bar along the minor axis with four spines from each of the vertices. There are two portals where the apical struts meet the basal ring.

Remarks: McCartney et al., 1995, changed the name of this taxon and several others that have been previously attributed as aspera or fibula, depend-

Table 2 (continued).

Silicoflagellate zonation	Sample	*Ds. speculum speculum*	*Ds. speculum speculum* (aberrant)	*Ds. stradneri*	*N. biapiculata*	*N. biapiculata* var. 1	*N. biapiculata* var. 2	*N. constricta*	*N. constricta* var. 1	*N. constricta* var. 2	*N. lata* var. 1	*N. lata* var. 2	*N. lata* (windowed form)	*N. quadrata*	Other aberrant forms	Total count
	159-959A-															
Ds. speculum hemisphaericus	31X-7, 2-3					25	2			38						78
	31X-CC	2			17	6	5	16		18		1			1	146
	32X-1, 49-51	1			3		9	13		1						87
	32X-3, 98-100	1					8									96
	32X-5, 40-41						1				3		1		4	122
	32X-CC	10					3	1							2	74
	33X-2, 149-150	34	4	1		3	11	5								217
	33X-4, 58-59	42					17		11						6	277
	33X-6, 62-64						27								1	109
	33X-CC	8					3								1	125
	34X-2, 64-65						1								1	51
	34X-4, 72-74						64			2	2				2	133
	34X-6, 44-45	1					3			1	36				1	134
	34X-CC	28					159				48			1	10	522
	35X-1, 93-94															21
	35X-3, 59-61															4
	35X-5, 8-10															5
	35X-CC	1														1
	36X-1, 109-110	2						1								5
	36X-3, 88-89	7					1	2	7						2	35
	36X-5, 46-48	1					1	2	1							22
	36X-CC	26	1				1	4								41
	37X -1, 1-3	22	1												2	78
	37X-3, 51-52	2					4	1							1	29
	37X-6, 0-1	12					12				1				1	37
	37X-CC	15													1	43
	38X-1, 31-33	4													1	7
	38X-3, 100-102	1					1									2
	38X-5, 71-73	2					7	13								36
	38X-CC						1									2
	39X-1, 13-14	1					2								1	34
	39X-3, 58-59	2					1									49
	39X-5, 123-124	2													1	58
N. biapiculata	39X-CC						1									2
	40X-1, 63-65															0
	40X-4, 93-95						1	1			4					18
	40X-5, 50-52															3
	40X-CC															0
	41X-1, 22-23															0

ing on the orientation of the apical bar. The author accepts McCartney's more recent name designations.

Dictyocha fibula ausonia (Deflandre) (naviculopsid) McCartney et al.
(Pl. 2, Fig. 1)

Dictyocha sp. cf. *Dictyocha brevispina ausonia* (Deflandre) Bukry, 1980, p. 513, pl. 1, figs. 7–14.
Dictyocha fibula ausonia (Deflandre) (naviculopsid) McCartney et al., 1995, pl. 2, fig. 4.

Description: This taxon has an elliptical basal ring with four spines radiating from the major and minor axes. It also has an off-centered apical bar parallel to the minor axis. It differs from *D. brevispina ausonia* in that the apical bar is displaced from the center of the skeleton and that there are no portals and struts in the apical structure.

Dictyocha fibula fibula Ehrenberg
(Pl. 1, Fig. 9)

Dictyocha fibula Ehrenberg, Locker, 1974, p. 636, pl. 1, fig. 6 (=lectotype).
Dictyocha fibula fibula Ehrenberg, Locker and Martini, 1986, p. 904, pl. 5, figs. 1, 2; pl. 11, figs. 8, 9.
Dictyocha fibula fibula Ehrenberg, McCartney et al., 1995, pl. 2, fig. 1; pl. 5, fig. 5.

Dictyocha hexacantha Schulz

Dictyocha hexacantha Schulz, 1928, p. 255, fig. 43; Martini and Müller, 1976, p. 878, pl. 2., fig. 7; p. 886, pl. 7, fig. 10.

Remarks: Eocene *Dictyocha hexacantha* was found in two cores of the early Miocene, which is younger than its known biostratigraphic range. Lithologic data indicate that the samples in which this taxon are present are moderately to heavily bioturbated, suggesting possible reworking.

Dictyocha spinosa (Deflandre) Glezer
(Pl. 1, Fig. 4)

Corbisema spinosa Deflandre, 1950, p. 193, figs. 178–182.
Dictyocha spinosa (Deflandre) Glezer, 1966, p. 238, pl. 10, figs. 6–8; McCartney and Wise, 1987, p. 806, pl. 1, fig. 6.

Remarks: Eocene *Dictyocha spinosa* was found in four samples from Hole 959A, the first three specimens were found in core catchers of the upper Oligocene and lower Miocene cores, and the fourth specimen was found in

Table 3. Silicoflagellate abundance data of Hole 959A from the *Naviculopsis biapiculata* Zone to the *Corbisema apiculata* Zone.

Silicoflagellate zonation	Sample	*B. apiculata apiculata*	*B. apiculata glabra*	*C. hastata globulata*	*C. triacantha triacantha*	*C. triacantha* var. 1	*D. deflandrei*	*D. spinosa*	*Ds. crux*	*Ds. crux* (aberrant)	*Ds. stradneri* var. *grandis*	*N. biapiculata*	*N. biapiculata* var. 2	*N. biapiculata* var. 3	*N. biapiculata nodulifera*	*N. constricta*	*N. lata* var. 1	*N. trispinosa*	Other aberrant forms	Total count
	159-959A-																			
	41X-4, 48-50				2							1	1							4
	41X-6, 11-13	2			1						1									4
	41X-CC	1			4						1									6
N. biapiculata	42X-2, 60-62	3			4									1			1			9
	42X-4, 50-53	1																		1
	42X-7, 17-19	2			7				2							2				13
	42X-CC	1		2	5															8
	43X-2, 91-92	6			7							30		3	4	3				53
	43X-4, 45-47	7	3		15				2			29	1	2		2	16			77
	43X-6, 54-56	1							2		1	17		2			3	2		28
	43X-CC	1										18								19
	44X-1, 44-45											7	1	4				2	1	15
	44X-3, 5-6	2						1		1		47		14				10	1	76
	44X-5, 35-37	5				15	5					5	2	3		2	1		1	39
C. apiculata	44X-CC	11			1	8	1		1			6		7		1				36
	45X-1, 110-111	1			7		1		2			3		6						20
	45X-3, 101-102	15			9	2	11					25	2	3						67
	45X-5, 120-121	2			11															13
	45X-CC				14	1						1	1							17
	46X-1,21-23				13	1	5													19
	46X-4, 7-9				4															4
	46X-7, 25-27																			0
	46X-CC			1	2		1							3						7

Table 4. Silicoflagellate abundance data of Hole 959D in the *Corbisema apiculata* Zone.

Silicoflagellate zonation	Sample	*B. apiculata apiculata*	*B. apiculata glabra*	*C. apiculata*	*C. apiculata* variety 1	*C. hastata globulata*	*C. triacantha mediana*	*C. triacantha triacantha*	*D. deflandrei*	*Ds. crux*	*Ds. stradneri* var. *grandis*	*N. biapiculata*	*N. eobiapiculata*	*Naviculopsis* sp. cf. *N. biapiculata*	*N. constricta*	*Naviculopsis* sp. cf. *N. constricta*	*N. foliacea tumida*	*Naviculopsis lata* variety 1	Total count
	159-959D-																		
	1R-CC			1	1	6	2	4		3			2						19
	2R-1, 14-15					1		5	1	1		1							9
	2R-CC	1				1		4	1										7
	3R-CC, 9-10				1	2		1					1						5
	3R-CC	1			1			2				1							5
	4R-1, 8-9																		0
C. apiculata	4R-CC																		0
	5R-CC, 1-2	1	1			4		4				1		4	12	2			29
	5R-CC	5				2		6			1		1	4	35			2	54
	6R-CC, 1-2																		0
	6R-CC																		0
	7R-CC	1				1		2				13	12				1	3	30

Sample 159-959A-44X-3, 5–6 cm, in the *C. apiculata* Zone (?lower Oligocene, ?upper Eocene). The sediments in which *D. spinosa* are present are moderately to heavily bioturbated, suggesting possible reworking.

Dictyocha varia Locker
(Pl. 2, Figs. 2, 3)

Dictyocha varia Locker, 1975, pp. 99–101, figs. 3–7.
Dictyocha pulchella Bukry, 1975, pp. 677–701.
Dictyocha varia Locker, McCartney et al., 1995, pl. 5, fig. 2 (not pl. 8, fig. 6).

Genus *DISTEPHANUS* Stohr
Distephanus crux Ehrenberg
(Pl. 2, Figs. 5, 6)

Distephanus crux Ehrenberg, 1840, p. 207; McCartney and Wise, 1987, p. 811, pl. 2, figs. 10–11.
Distephanus crux crux (Ehrenberg) Bukry, 1979b, p. 999, pl. 5, fig. 2; McCartney et al., 1995, p. 159, pl. 7, fig. 9.
Distephanus crux carolae (Ehrenberg) Bukry (in part), 1982, p. 322, pl. 5. figs. 5–10 (not 4, 11).
Distephanus crux scutulatus (Ehrenberg) Bukry, 1985, p. 494, pl. 3, figs. 7, 8.

Description: This is a four-sided *Distephanus* with a square to round apical opening. The shape of the basal ring can be round or square, with no indention where the apical struts meet the basal ring. The spine lengths are short with the longer spines on the major axis. The apical opening for *Ds. crux* is larger than the apical opening of *Ds. hannai*, also the basal ring for Ds. hannai is indented where the struts meet the basal ring, and more diamond shaped. This taxon is commonly smaller than *Ds. hannai*.

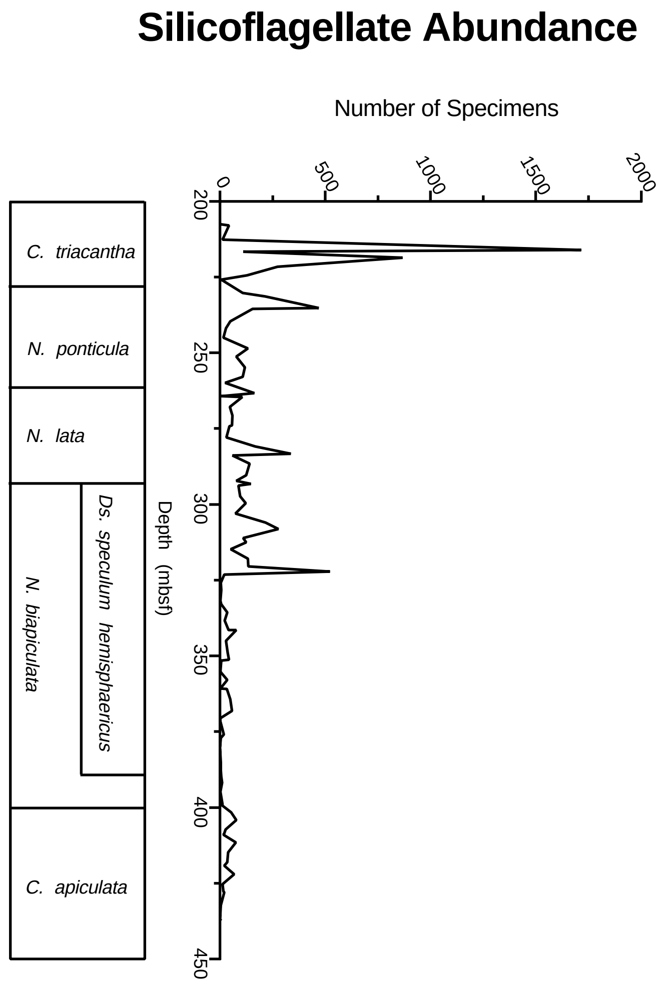

Figure 2. Graph of silicoflagellate abundance vs. age for Hole 959A, with a hiatus occurring between the *Naviculopsis lata* and *Naviculopsis ponticula* Zones of the lower Miocene cores.

Remarks: This is a broad designation for *Distephanus* species with a four-sided apical window, four spines, and a four-sided basal ring, and includes all species and subspecies listed above.

Distephanus hannai (Bukry) Bukry

Distephanus crux hannai Bukry, 1975, p. 867, pl. 4., figs. 4–6.
Distephanus hannai (Bukry) Bukry, 1979a, p. 561.

Description: This taxon is a four-sided *Distephanus* with four spines radiating from the vertices of the basal ring. The spines along the major axis are longer than the spines along the minor axis. The apical opening is round to square and is smaller than the apical opening for *Ds. crux*. *Distephanus hannai* also has a basal ring that is distinguished from *Ds. crux* by having more indention where the basal ring and struts meet.

Distephanus longispina (Schulz) Bukry & Foster
(Pl. 2, Fig. 8)

Distephanus crux f. *longispina* Schulz, 1928, p. 256, fig. 44; Ling, 1972, pl. 26, figs. 17–19.
Distephanus longispina (Schulz) Bukry and Foster, 1973, p. 844, pl. 4, figs. 7, 8.

Description: This four-sided *Distephanus* has a round or square basal ring with extra long spines along the major axis. It closely resembles *Ds. crux*, and is different only in that the major axis spines are greater than three-fourths the length of the basal ring, whereas the spine length of *Ds. crux* is less than one-half the length of the basal ring.

Distephanus speculum binoculus (Ehrenberg) Bukry
(Pl. 3, Fig. 6)

Dictyocha binoculus Ehrenberg, 1844, pp. 63, 79.
Distephanus speculum binoculus (Ehrenberg) Bukry, 1975, p. 855; McCartney and Wise, 1987, p. 811, pl. 6, fig. 6.

Description: This taxon has a basal ring that is similar to that of *Ds. speculum speculum* with six sides and six spines radiating from each vertex. The apical structure has two apical windows with six struts connecting the apical ring to the basal ring. Basal spikes on the basal ring are common.

Distephanus speculum hemisphaericus (Ehrenberg) Bukry
(Pl. 3, Figs. 3, 4)

Dictyocha hemisphaerica Ehrenberg, 1844, pl. 17, fig. 5.
Distephanus speculum hemisphaericus (Ehrenberg) Bukry, 1975, p. 855, pl. 4, fig. 8.

Description: This species includes specimens that have a six-sided basal ring with six radiating spines, two of the spines are longer along the major axis. The apical structure consists of three to seven windows that are connected to the basal ring by six struts. The designation *Ds. speculum hemisphaericus* include specimens of *Ds. speculum haliomma* as in Bukry, 1978a.

Distephanus speculum patulus Bukry
(Pl. 3, Fig. 7)

Distephanus speculum patulus (Ehrenberg) Bukry, 1982, p. 441, figs. 7–10.

Description: This taxon has a six-sided basal ring like that of *Ds. speculum speculum*, but has shorter spines, a larger apical ring, and no basal spikes.

Distephanus speculum pentagonus Lemmermann
(Pl. 3, Fig. 5)

Distephamus speculum var. *pentagonus* Lemmermann, 1901, p. 264, pl. 11, fig. 19; Bukry, 1976a, p. 895; McCartney and Wise, 1987, p. 811, pl. 8, fig. 8.

Description: This five-sided *Distephanus* has five equant radiating spines and a five-sided apical ring that is connected to the basal ring by five struts, and the basal ring has no spikes. These specimens are common in the lower Miocene and uppermost Oligocene.

Distephanus speculum speculum (Ehrenberg) Glezer
(Pl. 2, Figs. 11, 12; Pl. 3, Figs. 1, 2)

Dictyocha speculum Ehrenberg, 1839, p. 150.
Distephanus speculum speculum (Ehrenberg) Glezer, 1966, p. 282, pl. 19, figs. 7–9.

Description: This taxon has a six-sided basal ring with six spines radiating from each corner of the basal ring. Two opposing spines are commonly longer than the other four spines, and the basal ring commonly has basal spikes. The apical ring has six sides and is attached to the basal ring by six struts that bisect each side of the basal ring.

Distephanus stradneri (Jerkovic) Bukry
(Pl. 2, Fig. 7)

Dictyocha schauinslandii stradneri Jerkovic, 1965, pp. 56, 76; Ehrenberg, 1854, pl. 33, fig. 11.
Distephanus stradneri (Jerkovic) Bukry, 1978a, p. 698.

Description: Four-sided *Distephanus* with four spines, two longer spines along the major axis and two short spines along the minor axis. The apical window is less than one-half the size of the basal ring and is square. It is generally larger than *Ds. crux* and has basal spikes. This skeleton of this taxon is very symmetrical with a robust skeleton.

Distephanus stradneri var. *grandis* Bukry
(Pl. 2, Figs. 9, 10)

Distephanus stradneri var. *grandis* Bukry, 1985, p. 495, pl. 4, figs. 1–7.

Description: *Distephanus stradneri* var. *grandis* is a four-sided silicoflagellate with four radial spines at each of the vertices and a small apical window. The vertices are angular and where the struts meet the basal ring it is indented. This taxon is similar to *Ds. hannai*, but differs in its larger size, and its angular vertices.

Genus *NAVICULOPSIS* Frenguelli, 1940

Naviculopsis biapiculata (Lemmermann) Frenguellii
(Pl. 4, Fig. 12)

?*Dictyocha navicula biapiculata* Lemmermann, 1901, p. 258, pl. 10, figs. 14, 15.
Naviculopsis biapiculata (Lemmermann) Frenguellii, 1940, p. 60, fig. 11c, d; Bukry, 1976a, pp. 896–897.

Description: This species has a small apical ring that is rounded where the basal ring and apical bar meet. The spines occur parallel to the major axis and vary in length, and the apical bar is narrow and greatly elevated compared to the apical bars of *N. biapiculata* variety 2 and *N. constricta*.

Naviculopsis biapiculata variety 1
(Pl. 4, Fig. 13)

Description: This taxon is very small with long spines, usually more than half the length of the basal ring. The area where the apical bar and the basal ring meet is not constricted, but is straight, unlike *N. biapiculata* that is rounded where the apical bar and basal ring meet. This species looks very much like *Naviculopsis constricta* variety 2, but differs only by the fact than *Naviculopsis constricta* variety 2 has constriction where the basal ring meets the apical bar.

Naviculopsis biapiculata variety 2
(Pl. 4, Figs. 1, 2, 11)

Naviculsopsis eobiapiculata Bukry, 1978c, p. 799, pl. 4, figs. 9, 10, 15, 16 (not 11–14).
Naviculopsis biapiculata (Lemmermann) Frenguellii, Weaver and Spaw, 1978.
Naviculopsis biapiculata s.l. (Lemmermann) Frenguellii, Perch-Nielsen, 1975, p. 714, pl. 12, figs. 18, 20, 21 (not fig. 19).

Description: The designation *N. biapiculata* variety 2 includes a variety of *Naviculopsis* specimens that have an oval basal ring and can be either straight or bowed out where the apical bar meets the basal ring, as listed in the above references. It has two spines radiating along the major axis which vary in length from over one-half the major axis length to longer than the basal ring. It has a narrow apical bar with only slight, if any, constriction where the apical bar meets the basal ring.

Naviculopsis biapiculata variety 3
(Pl. 4, Figs. 4, 10)

Description: This designation includes all specimens that have a small, oblong basal ring and two spines along the major axis. The spines are almost the same length as the basal ring. *Naviculopsis biapiculata* variety 3 is similar to *N. biapiculata* variety 2, but differs in that the apical bar is wider and the size of the specimen is generally smaller.

Naviculopsis biapiculata nodulifera Ciesielski
(Pl. 4, Figs. 8, 9)

Naviculopsis biapiculata nodulifera Ciesielski, 1991, p. 82, pl. 10, figs. 6, 7.

Description: This taxon has the same morphology as *N. biapiculata* and differs only by a small, almost unnoticeable nodule that protrudes from the center of the apical bar.

Naviculopsis constricta (Schulz) Frenguellii
(Pl. 4, Fig. 3)

Dictyocha navicula biapiculata constricta Schulz, 1928, p. 246, fig. 21.
Naviculopsis constricta (Schulz) Frenguellii, 1940, figs. 11a, b; Bukry, 1975, p. 872, pl. 7, figs. 1–3.

Description: *Naviculopsis* species with a very long basal ring and very long spines, commonly equal to or longer than the length of the basal ring. The apical bar is commonly wider than, or, at times, the same width as the basal ring bars, and there is constriction where the apical bar meets the basal ring.

Naviculopsis constricta variety 1
(Pl. 4, Fig. 7)

Description: *Naviculopsis constricta* variety 1 has a very long basal ring with two short spines along the major axis. The apical bar can be narrow or wide, but is commonly wide with constriction where the basal ring meets the apical bar.

Naviculopsis constricta variety 2
(Pl. 4, Fig. 6)

Description: Specimens of *Naviculopsis constricta* variety 2 have a narrow and elongate basal ring with very pronounced constriction where the apical bar meets the basal ring. It commonly has a wider apical bar than *N. biapiculata* variety 2, although the width of the apical bar may vary. The specimens have a shorter basal ring than *N. constricta* and also shorter spines.

Naviculopsis contraria Bukry

Naviculopsis contraria Bukry, 1982, p. 442, pl. 6, figs. 5–13; Bukry, 1985, p. 497, pl. 6, fig. 1.

Remarks: Only four specimens of this taxon were found in Sample 159-959A-28X-4, 59–61 cm, in the *N. ponticula* Zone of the lower Miocene cores.

Naviculopsis foliacea tumida Bukry
(Pl. 4, Fig. 5)

Naviculopsis foliacea tumida Bukry, 1978b, p. 841, pl. 8, figs. 1–8.

Naviculopsis lata (Deflandre) Frenguellii
(Pl. 3, Fig. 11)

Dictyocha biapiculata var. *lata* Deflandre, 1932, Soc. Bot. France, Bull., v. 79, p. 500, figs. 30, 31.
Naviculopsis lata (Deflandre) Frenguelli, 1940, p. 61, fig. 11h; Ling, 1972, pl. 30, figs.12–14; Bukry, 1982, p. 443, pl. 7, figs. 11–14.

Description: This *Naviculopsis* has a round and stout basal ring with two short spines radiating along the long axis. Where the apical bar meets the basal ring the sides are straight or only slightly indented. This taxon has a larger basal ring than other *Naviculopsis* forms discussed.

Naviculopsis lata variety 1

Description: Specimens designated *Naviculopsis lata* variety 1 include all those with a large basal ring, a narrow apical bar, and basal spines that are from one-fourth to one-half the length of the major axis.

Naviculopsis lata variety 2

Description: This species differs from *N. lata* in that the area where the apical bar meets the basal ring is bowed out; whereas *N. lata* has sides that are straight or slightly indented. This species differs from *N. biapiculata* in that its spines are shorter and the basal ring is larger, the size of *N. lata*.

Naviculopsis obtusarca Bukry
(Pl. 3, Figs. 10, 12)

Naviculopsis obtusarca Bukry, 1978b, p. 821.

Naviculopsis ponticula (Ehrenberg) Bukry
(Pl. 3, Fig. 9)

Dictyocha ponticulus Ehrenberg, 1844b, pp. 258, 267.
Naviculopsis ponticula (Ehrenberg) Bukry, 1978b, p. 821; McCartney and Wise, 1987, p. 814, pl. 5. figs. 9a, b.

Naviculopsis ponticula spinosa Bukry
(Pl. 3, Fig. 13)

Naviculopsis ponticula spinosa Bukry, 1982, p. 445, pl. 9, figs. 2–6.

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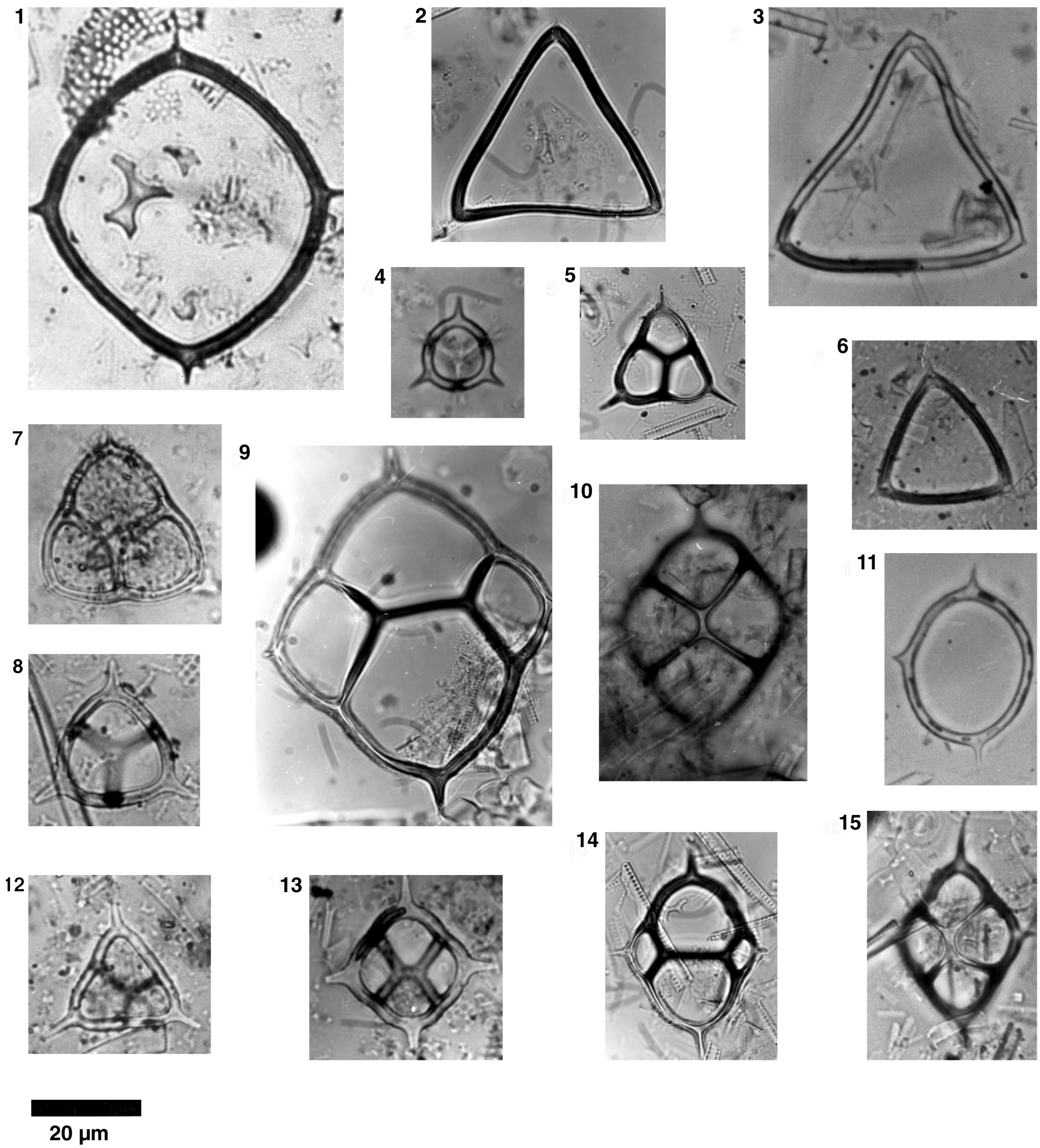

Plate 1. Silicoflagellates from Leg 159. **1.** *Bachmannocena elliptica* (Ehrenberg) Ehrenberg, Sample 159-959A-27X-5, 23–25 cm. **2, 6.** *Bachmannocena apiculata apiculata* (Schulz) Bukry, Samples 159-959A-35X-3, 59–61 cm, and 159-959A-33X-CC. **3.** *Bachmannocena apiculata glabra* (Schulz) Bukry, Sample 159-959A-33X-4, 58–59 cm. **4.** *Dictyocha spinosa* (Deflandre) Glezer, Sample 159-959A-28X-CC. **5.** *Corbisema triacantha triacantha* (Ehrenberg) Bukry, Sample 159-959A-38X-5, 71–73 cm. **7.** *Corbisema apiculata* (Lemmermann) Hanna, Sample 159-959D-1R-CC. **8.** *Corbisema triacantha* variety 1, Sample 159-959A-44X-5, 35–37 cm. **9.** *Dictyocha fibula fibula* Ehrenberg, Sample 159-959A-30X-7, 36–38 cm. **10, 15.** *Dictyocha extensa extensa* (Locker) Locker and Martini, Sample 159-959A-23X-6, 89–91 cm. **11.** *Bachmannocena triodon* Bukry, Sample 159-959A-23X-6, 89–91 cm. **12.** *Corbisema triacantha mediana* Bukry, Sample 159-959D-1R-CC. **13.** *Dictyocha deflandrei* Frenguellii (1940) ex Glezer, Sample 159-959A-45X-3, 101–102 cm. **14.** *Dictyocha fibula ausonia* (Deflandre) McCartney et al., Sample 159-959A-24X-2, 59–60 cm.

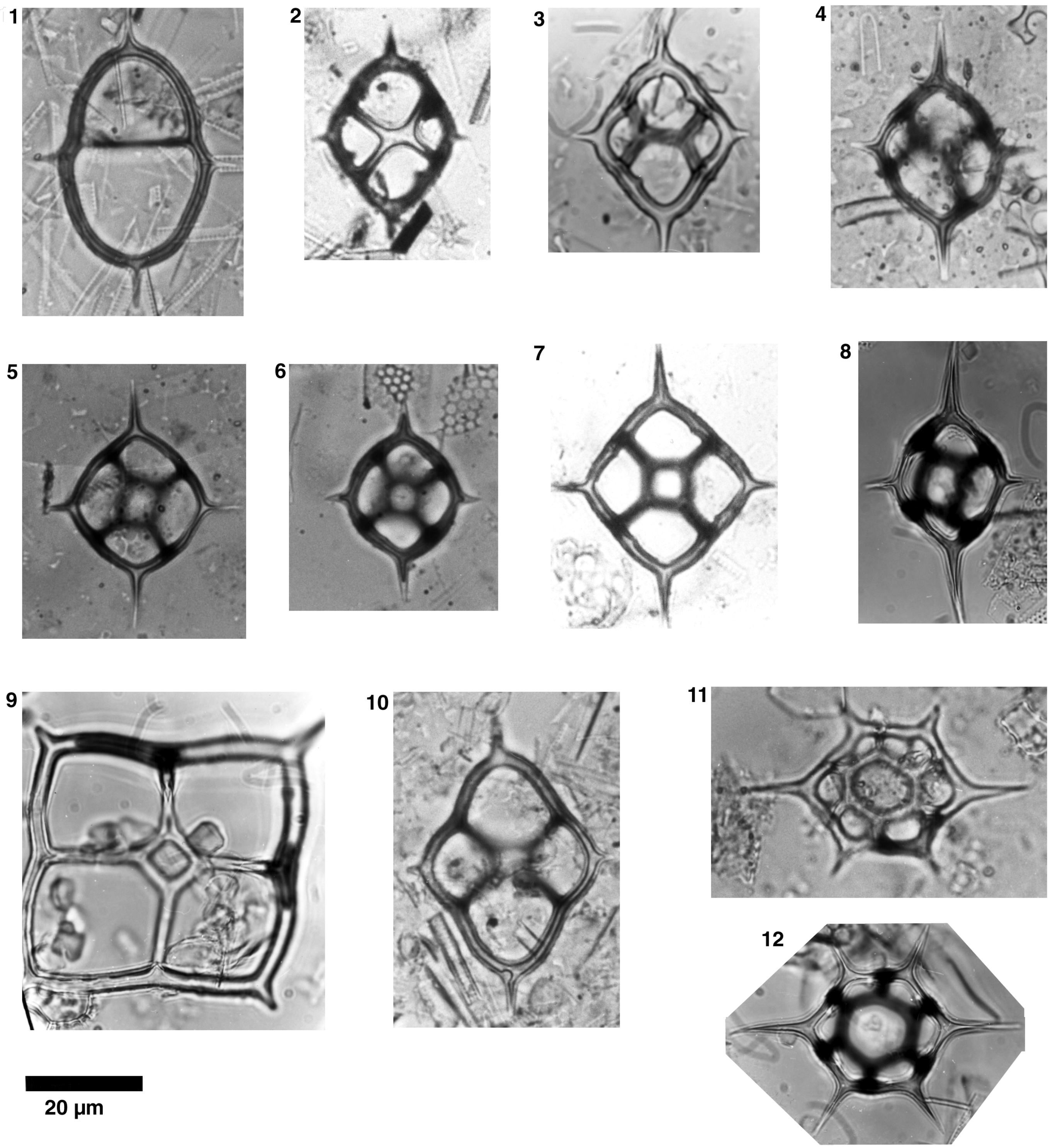

Plate 2. Silicoflagellates from Leg 159. **1.** *Dictyocha fibula ausonia* (Deflandre) (naviculopsoid) McCartney et al., Sample 159-959A-24X-2, 59–60 cm. **2, 3.** *Dictyocha varia* Locker, Sample 159-959A-23X-6, 89–91 cm. **4.** *Dictyocha* species 1, Sample 159-959A-31X-CC. **5, 6.** *Distephanus crux* Ehrenberg, Samples 159-959A-28X-3, 9–11 cm, and 159-959A-36X-3, 88–89 cm. **7.** *Distephanus stradneri* Jerkovic, Sample 159-959A-27X-5, 23–25 cm. **8.** *Distephanus longispinus* (Schulz) Bukry and Foster, Sample 159-959A-34X-CC. **9, 10.** *Distephanus stradneri* var. *grandis* Bukry, Sample 159-959A-34X-CC. **11, 12.** *Distephanus speculum speculum* (Ehrenberg) Glezer, Samples 159-959A-36X-3, 88–89 cm, and 159-959A-33X-4, 58–59 cm.

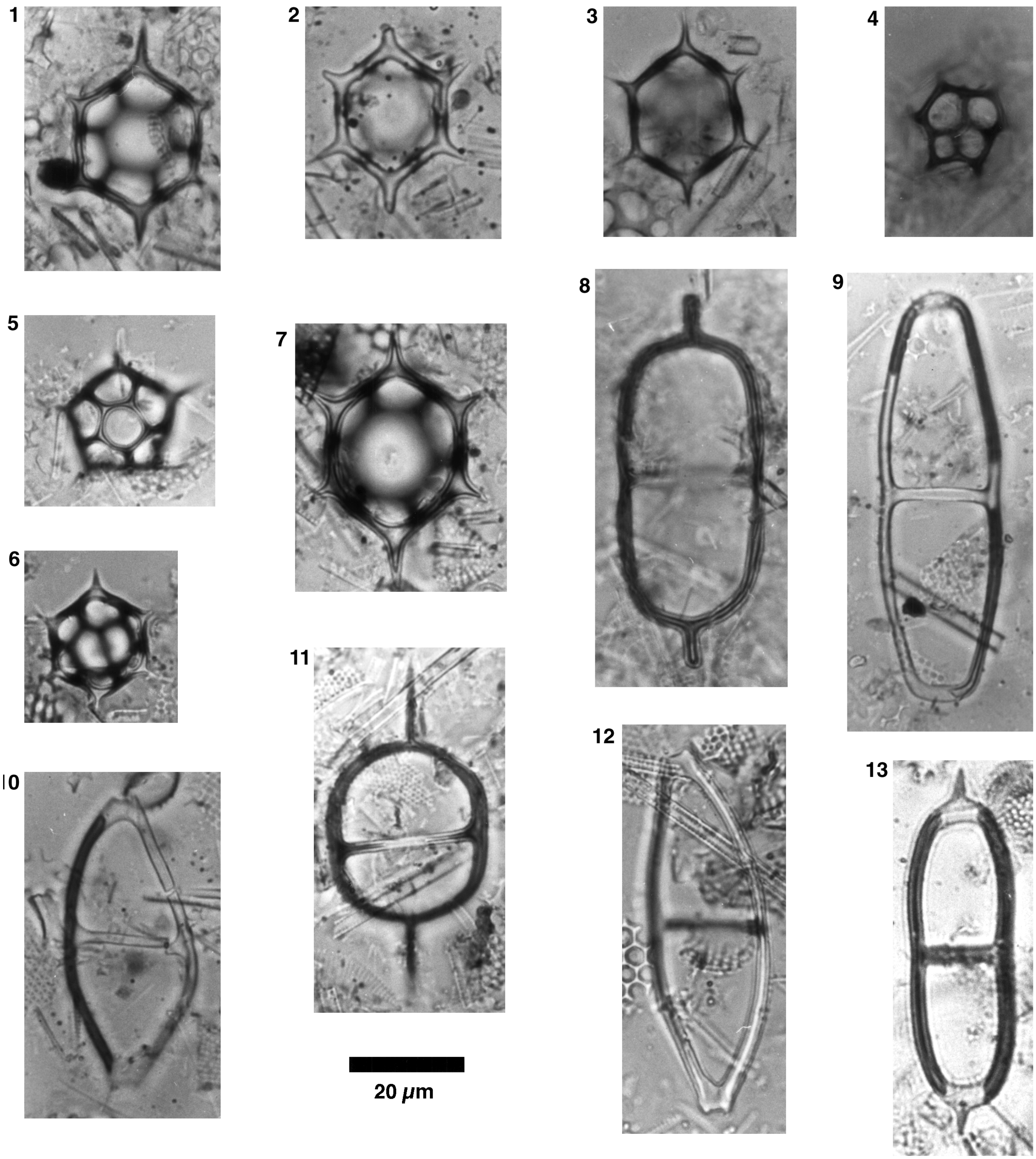

Plate 3. Silicoflagellates from Leg 159. **1, 2.** *Distephanus speculum speculum* (Ehrenberg) Glezer, Samples 159-959A-34X-CC and 159-959A-32X-1, 49–51 cm. **3, 4.** *Distephanus speculum hemisphaericus* (Ehrenberg) Bukry, Sample 159-959A-23X-6, 89–91 cm. **5.** *Distephanus speculum pentagonus* Lemmermann, Sample 159-959A-27X-3, 37–38 cm. **6.** *Distephanus speculum binoculus* (Ehrenberg) Bukry, Sample 159-959A-27X-3, 37–38 cm. **7.** *Distephanus speculum patulus* Bukry, Sample 159-959A-27X-3, 37–38 cm. **8.** *Naviculopsis quadrata* (Ehrenberg) Locker, Sample 159-959A-34X-CC. **9.** *Naviculopsis ponticula* (Ehrenberg) Bukry, Sample 159-959A-28X-6, 106–108 cm. **10, 12.** *Naviculopsis obtusarca* Bukry, Sample 159-959A-28X-6, 106–108 cm. **11.** *Naviculopsis lata* Deflandre, Sample 159-959A-30X-7, 36–38 cm. **13.** *Naviculopsis ponticula spinosa* Bukry, Sample 159-959A-27X-5, 23–25 cm.

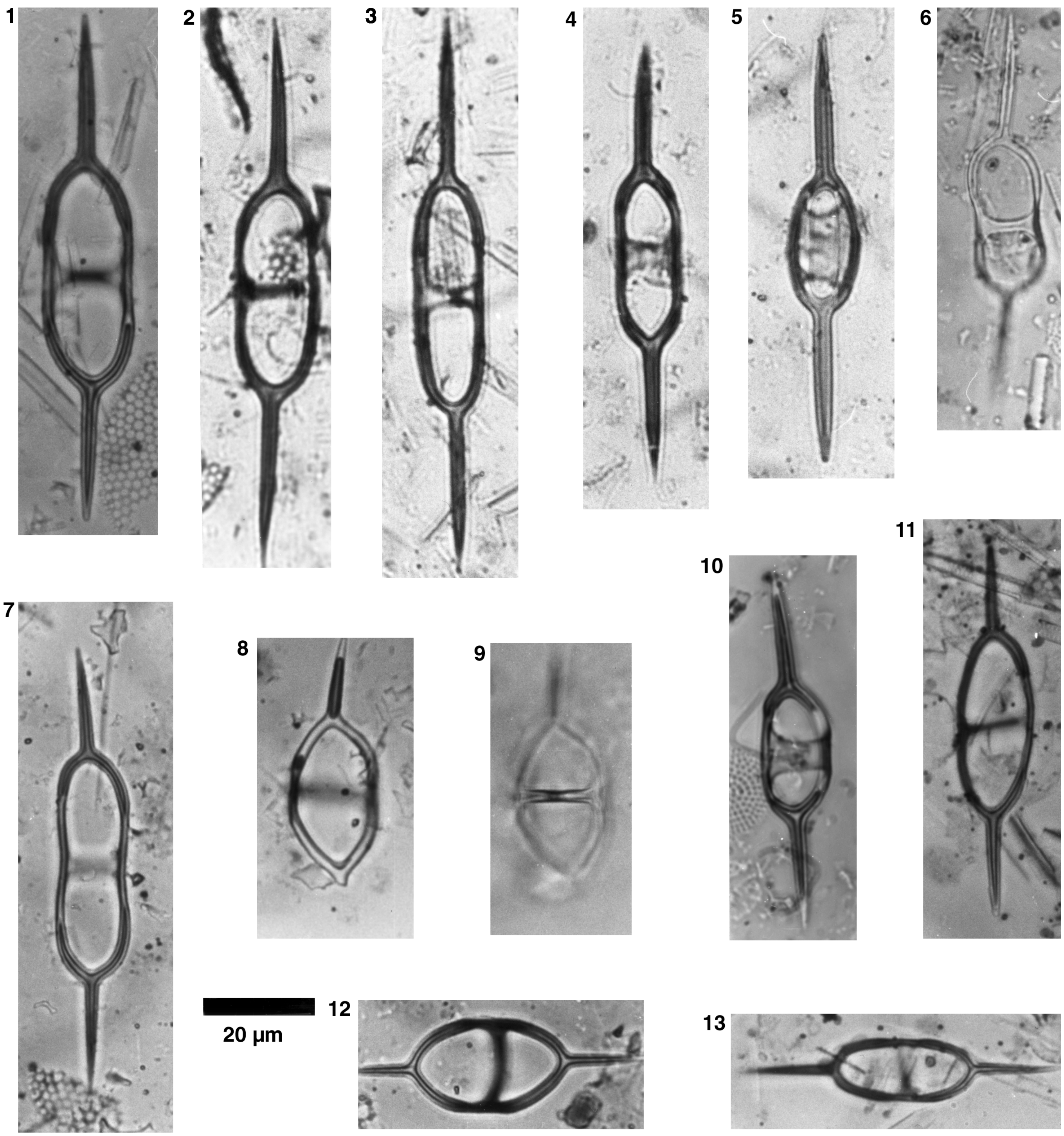

Plate 4. Silicoflagellates from Leg 159. **1, 2, 11.** *Naviculopsis biapiculata* variety 2, Samples 159-959A-33X-6, 62–64 cm, 159-959A-38X-5, 71–73 cm, and 159-959A-33X-4, 58–59 cm. **3.** *Naviculopsis constricta* (Schulz) Frenguellii, Sample 159-959A-33X-2, 149–150 cm. **4, 10.** *Naviculopsis biapiculata* variety 3, Sample 159-959A-44X-1, 44–45 cm, and 159-959D-5R-CC, 1–2 cm. **5.** *Naviculopsis foliacea tumida* Bukry, Sample 159-959D-7R-CC. **6.** *Naviculopsis constricta* variety 2, Sample 159-959A–31X-7, 2–3 cm. **7.** *Naviculopsis constricta* variety 1, Sample 159-959A-36X-3, 88–89 cm. **8, 9.** *Naviculopsis biapiculata nodulifera* Ciesielski, Sample 159-959A-43X-2, 91–92 cm. **12.** *Naviculopsis biapiculata* (Lemmermann) Frenguellii, Sample 159-959A-31X-2, 128–130 cm. **13.** *Naviculopsis biapiculata* var. 1, Sample 159-959A-31X-7, 2–3 cm.