Thiede, J., Myhre, A.M., Firth, J.V., Johnson, G.L., and Ruddiman, W.F. (Eds.), 1996
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 151

6. CENOZOIC SILICEOUS FLAGELLATES FROM THE FRAM STRAIT AND THE EAST GREENLAND MARGIN: BIOSTRATIGRAPHIC AND PALEOCEANOGRAPHIC RESULTS[1]

Sigurd Locker[2]

ABSTRACT

More than 110 taxa of siliceous flagellates including silicoflagellates, ebridians, actiniscidians, and synuraceans are tabulated from Cenozoic sediments of Holes 908A and 913B. The assemblages investigated from Hole 908A, Fram Strait, are assigned to the upper Oligocene *Cannopilus hemisphaericus* Zone of silicoflagellates. The assemblages studied from Hole 913B, East Greenland margin, yielded in the upper part the middle Miocene *Spongebria miocenica* Zone of ebridians and in the lower part the middle to upper Eocene *Corbisema hexacantha* Zone of silicoflagellates.

The assemblages of siliceous flagellates demonstrate that a permanent surface-water exchange may have existed between the Norwegian-Greenland Sea, the Arctic Ocean, and probably also the Barents Sea during Eocene and Oligocene times. Minor input of surface-water from the North Atlantic is indicated by certain silicoflagellates for late Oligocene time.

Several taxa of silicoflagellates and ebridians were recognized as new, but most of them are treated with open nomenclature. Only 3 ebridian species that characterize middle to upper Eocene and upper Oligocene assemblages are formally introduced as new: *Ebriopsis acuta, Hermesinella paraconata,* and *Hermesinum acus.*

INTRODUCTION

During Ocean Drilling Program Leg 151, seven sites were occupied in the Norwegian-Greenland Sea and the Arctic Ocean. The sites were located in four regions (Fig. 1) to investigate the paleoceanographic, paleoclimatic, and biotic evolution of the boreal, subarctic, and arctic realms (Myhre, Thiede, Firth, et al., 1995). The study of paleoceanography was especially addressed to the development of the northern and southern gateways that connect the Norwegian-Greenland Sea in the present with adjacent oceanic regions, (i.e. the Arctic Ocean in the north and the North Atlantic in the south). Investigations of siliceous plankton groups may help to understand when and in what manner the northern and southern gateways, the Fram Strait and the Greenland-Scotland Ridge, allowed continuous surface-water exchange.

The history of the Norwegian-Greenland Sea as a deep-water connection between the Arctic Ocean and the North Atlantic commenced in early Eocene time (Eldholm et al., 1989). Siliceous plankton species documenting this early phase of paleoceanographic evolution were recovered during previous DSDP/ODP legs only at a few sites (Talwani, Udintsev, et al., 1976; Eldholm, Thiede, Taylor, et al., 1989). Hence, the recovery of Paleogene sediments at Sites 908 and 913, enabling high-resolution studies of siliceous flagellates, is of great importance.

In this paper, silicoflagellates are used to establish a continuous biostratigraphy from the lower Eocene to the Quaternary (Table 1; Fig. 2) and to determine the stratigraphic position of Paleogene biosilica-bearing sediments in Holes 908A and 913B (Tables 2, 4). Since ebridian data are insufficient for the Paleogene, only informal assemblages are designated and are correlated to silicoflagellate zones (Tables 3, 5). The stratigraphy of Miocene sediments in Hole 913B is determined solely by ebridians (Table 4).

[1]Thiede, J., Myhre, A.M., Firth, J.V., Johnson, G.L., and Ruddiman, W.F. (Eds.), 1996. *Proc. ODP, Sci. Results,* 151: College Station, TX (Ocean Drilling Program).

[2]Christian-Albrechts-Universität, Sonderforschungsbereich 313, Heinrich-Hecht-Platz 10, D-24118 Kiel, Federal Republic of Germany. (Present address: GEOMAR, Research Center for the Marine Geosciences, Wischhofstraße 1-3, D-12418, Kiel, Federal Republic of Germany.) slocker@geomar.de

METHODS

Sediment samples totalling 235 were treated from Holes 908A and 913B to investigate Cenozoic silicoflagellates, ebridians, and other siliceous flagellates. Usually one sample per section was taken, but from the deeper part of Hole 913B only two samples per core were used. To concentrate the skeletons, samples were successively processed with hydrogen peroxide, hydrochloric acid, and sodium pyrophosphate. After the use of acid and lye, samples were washed three times. The decalcified residues were strewn on cover glasses 22 × 22 mm in size and embedded in Canada balsam on glass slides.

Generally, eight traverses across a cover glass (21%) were counted with a magnification of 390× and tabulated for species abundances. In many cases, more traverses were scanned to recognize rare but indicative species. The following abundance classes were used: B = barren; T = traces, specimens out of count; R = rare, 1–5 specimens; F = few, 6–15 specimens; C = common, 16–50 specimens; A = abundant, >50 specimens. Special assumptions were made for certain taxa. If complete skeletons of *Naviculopsis* species were missing, fragments were indicated as P = present. Because small specimens of *Hovassebria brevispinosa* can be easily confused with triodes, all skeletons were indicated only as P = present. Although noted during the counting process, isolated triodes and triaenes were neglected in tables.

Since siliceous flagellates are minor constituents of the plankton assemblages, diatom frequencies were estimated as an indicator for expected abundances of siliceous flagellates. Diatom abundances were referred to the decalcified residue and noted as percent coverage of the viewing field. The following abundance classes were adopted: B = barren; T = traces, single valves and/or remnants of corrosion, generally <1% of coverage; R = rare, 1%–5%; F = few, 6%–15%; C = common, 16%–50%; A = abundant, >50%.

The preservation of skeletons was indicated as follows: P = poor, specimens are fragmented or strongly corroded; M = moderate, specimens show minor signs of fragmentation or corrosion; G = good, specimens are not fragmented or corroded. Because an assemblage may exhibit all stages of preservation ranging from poor to good, the preservation is usually indicated by two letters. The first letter gives the most frequent category, the second one the next frequent category.

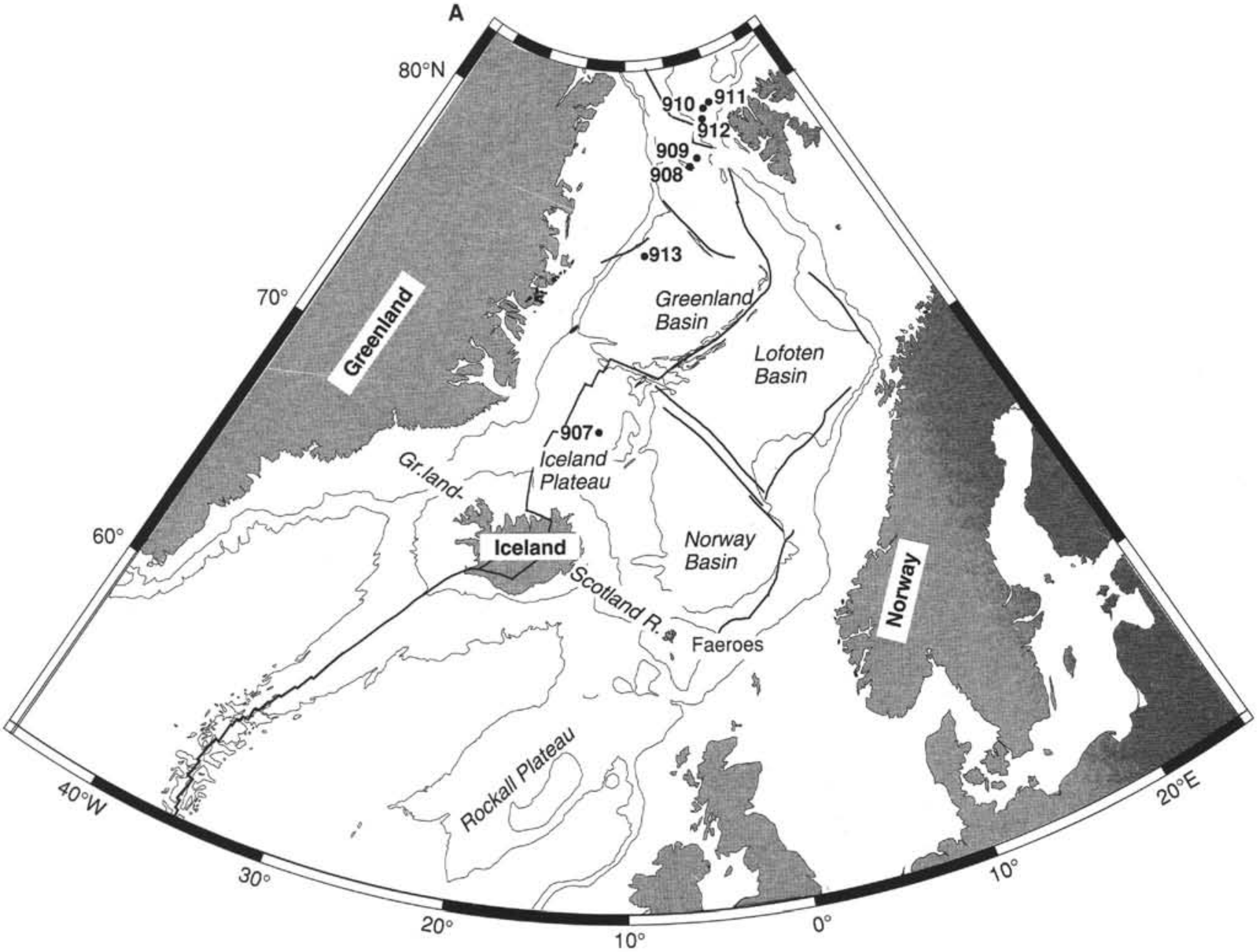

Figure 1. Location of Leg 151 sites in the Norwegian-Greenland Sea and in the Arctic Ocean.

The sediment sequences studied are placed into silicoflagellate zones which are delimited by certain bioevents (Table 1; Fig. 2). The silicoflagellate events, that is, the first and last occurrences (FO, LO) of particular species, are referred to the paleomagnetic time scale of Cande and Kent (1992) and to the recalculated nannoplankton ages of Wei and Peleo-Alampay (1993). The events are preferably related to the North Atlantic and Norwegian-Greenland Sea realms to avoid bioprovincially biased data. Since no ebridian zones are available for the Paleogene at present, the assemblages found are correlated to silicoflagellate zones. This enables indirect correlation to the calcareous nannoplankton zonation of Martini (1971).

SILICOFLAGELLATE EVENTS

The silicoflagellate zonation used for ODP Leg 151 is based on the set of events displayed in Table 1 and Figure 2. The Neogene zonation corresponds to that described by Locker and Martini (1989) and the Paleogene zonation mainly to that introduced by Bukry (1981b). The Neogene zonation is well established both in the Atlantic and Pacific Oceans. Only minor changes must be introduced to get a better fit with the nannoplankton zonations of Martini (1971) and Okada and Bukry (1980). The Paleogene zonation is rather loosely defined in certain parts, because biosilica-bearing sediments of that age are predominantly represented only in short sequences. The set of events that establishes the silicoflagellate zonation of ODP Leg 151 is described from base to top.

FO of *Naviculopsis robusta*

Although the *Naviculopsis robusta* Zone has a wide geographic range in former epicontinental seas of Russia (Glezer, 1970), this zone seems to represent more oceanic conditions in the North Atlantic realm (Bukry, 1978b). The first occurrence (FO) of *N. robusta* correlates in DSDP Hole 390A (Bukry, 1978b), Northwest Atlantic, with nannoplankton Zone CP10 of Okada and Bukry (1980) = Zone NP12 of Martini (1971). The overlying *Corbisema spinosa* Zone starts with Zone CP11 = Zone NP13. The base of Zone CP10 has an age of 52.5 Ma (Wei and Peleo-Alampay, 1993).

FO of *Corbisema spinosa*

The *Corbisema spinosa* Zone is known from many holes of the Atlantic and Pacific Oceans. The FO of *C. spinosa* ranges from Zone CP11 to CP13b = Zone NP13 to NP15. The lowest occurrence is in Hole 390A (Bukry, 1978b), Northwest Atlantic, and belongs to Zone CP11 = Zone NP13. The base of Zone CP11 has an age of 50.5 Ma (Wei and Peleo-Alampay, 1993).

FO of *Corbisema hexacantha*

The *Corbisema hexacantha* Zone is described from several holes in the Atlantic and Pacific Oceans. The FO of *C. hexacantha* displays a considerable range, which may be due to the short intervals usually recovered. The lowest occurrence is found in DSDP Hole 386

Table 1. Cenozoic silicoflagellate events, adopted occurrences in North Atlantic and Norwegian-Greenland Sea holes, and ages. Paleomagnetic data are from Bleil (1989), ages are from Wei and Peleo-Alampay (1993).

Epoch		Silicoflagellate event	Norwegian-Greenland Sea	Age (Ma)
Quaternary	LO	*Mesocena quadrangula*	644A: uppermost C1r.1r = upper NN19B	0.8
	FCO	*Mesocena quadrangula*	644A: C1r.1n = middle NN19B	1.0
	FO	*Distephanus speculum octonarius*	644A: uppermost C1r.2r = NN19B	
Pliocene	LO	*Distephanus aculeatus*	644A: uppermost C2An.1n = upper NN16	3.2
	LO	*Mesocena diodon*	642C: C3An.1n = lower NN12	5.8
	LO	*Paramesocena circulus apiculata*	642C: C3Ar = middle NN11B	6.4
	LO	*Cannopilus depressus*	408: top NN7	11.2
	LO	*Corbisema triacantha*	408: middle NN7	12.2
	LO	*Distephanus stauracanthus*	642C: top NN6	13.2
	FO	*Distephanus stauracanthus*	642C: middle NN6	13.8
Miocene	FO	*Paramesocena circulus apiculata*	642C: NN6	
	FO	*Mesocena diodon*	642C: C5ADr = upper NN5	14.7
	LO	*Naviculopsis*	642D: lower C5En = uppermost NN2	18.8
	FO	*Naviculopsis navicula*	642D: C6An.1n = middle NN2	20.7
	FO	*Naviculopsis iberica*	642D: C6An.1r = middle NN2	20.9
	FO	*Naviculopsis lata*	369A/407: base NN1	24.0
Oligocene	FO	*Cannopilus hemisphaericus*	338: middle NP24	27.8
	LO	*Corbisema apiculata*	369A: top CP16c = top NP22	32.4
	LO	*Corbisema hexacantha*	612: middle CP15b = middle NP19/20	34.7
Eocene	FO	*Corbisema hexacantha*	386: middle CP13c = upper NP15	44.2
	FO	*Corbisema spinosa*	390A: base CP11 = NP13	50.5
	FO	*Naviculopsis robusta*	390A: base CP10 = NP12	52.5

(Bukry, 1978c), Northwest Atlantic, and correlates to Zone CP13c = upper Zone NP15. This is in accordance with data from the Kellogg Shale, California, where the FO is also found in Zone CP13c = upper Zone NP15 (Bukry in Barron et al., 1984). Here an intermediate age of 44.2 Ma is adopted for the middle of Zone CP13c (Wei and Peleo-Alampay, 1993).

LO of *Corbisema hexacantha*

The last occurrence (LO) of *C. hexacantha* is detected in several holes of the Atlantic and Pacific Oceans, but is often poorly defined by nannoplankton correlations. In DSDP Hole 406 (Bukry, 1985a), North Atlantic, the LO of this species occurs within Zones NP19/20 (Müller, 1979). In DSDP Hole 612 (Bukry, 1987), Northwest Atlantic, the LO occurs in the middle of Zone CP15b = Zones NP19/20. Here an intermediate age of 34.7 Ma is adopted for the middle of Zone CP15b (Wei and Peleo-Alampay, 1993).

LO of *Corbisema apiculata*

The *Corbisema apiculata* Zone straddles the Eocene to Oligocene transition, which is characterized by a decline of species diversities and abundances in most regions. Since biosiliceous sediments of early Oligocene age are rarely recovered both in the Atlantic and Pacific Oceans, stratigraphical resolution is generally poorer for this interval. Reworking may also mask the LO of *C. apiculata* in many holes. The best correlation seems to be in DSDP Hole 369A, Northeast Atlantic (Bukry, 1978a), where the last common and consistent occurrence is in Zone CP16c = Zone NP22. Hence, the LO of *C. apiculata* is tentatively placed at the top of Zone CP16c, corresponding to an age of 32.4 Ma (Wei and Peleo-Alampay, 1993).

FO of *Cannopilus hemisphaericus*

The FO of *C. hemisphaericus* delimits the top of the *Naviculopsis biapiculata* Zone, which is a rather undifferentiated lower to upper Oligocene silicoflagellate zone. The FO simultaneously marks the base of the *Cannopilus hemisphaericus* Zone, which is sometimes noted as *Distephanus speculum haliomma* Zone (Bukry, 1981b; Perch-Nielsen, 1985). The FO of *C. hemisphaericus* occurs in Hole 369A (Bukry, 1978a), Northeast Atlantic, in Zone CP19b = Zone NP25. In DSDP Hole 338 (Martini and Müller, 1976), Norwegian Sea, the FO is found in Zones NP24/25 (new interpretation) and in Hole 406 (Bukry, 1985a), North Atlantic, in Zone NP24 (Müller, 1979). According to the joint occurrence of *C. hemisphaericus* and *Discolithina desueta* in Hole 338 (Müller, 1976), the FO of *C. hemisphaericus* may really be in Zone NP24 (see Müller, 1970). Acknowledging these results, the FO of *C. hemisphaericus* may be placed at the base of Zone NP25 or, tentatively, in the middle of Zone NP24. Here the latter datum is preferred, corresponding to an age of 27.8 Ma (Wei and Peleo-Alampay, 1993).

FO of *Naviculopsis lata*

The *Naviculopsis lata* Zone is well known from several sites in the Atlantic and Pacific Oceans. The FO of *N. lata* lies in Hole 369A (Bukry, 1978a), Northeast Atlantic, possibly in Zone CP19b = Zone NP25. In DSDP Hole 407 (Martini, 1979), North Atlantic, the FO is in the middle of Zone NN1. Assuming an intermediate level, the base of Zone NN1 can be adopted as the datum plane, corresponding to an age of 24.0 Ma (Wei and Peleo-Alampay, 1993).

FO of *Naviculopsis navicula*

The *Naviculopsis navicula* Zone ranges from the FO of *N. navicula* to the LO of *N. quadratum* and all *Naviculopsis* species, respectively. The FO of *N. navicula* is precisely indicated in Chron C6An.1n of DSDP Hole 642C, Norwegian Sea (Locker and Martini, 1989; Bleil, 1989). This correlates with the middle of Zone NN2 and an age of 20.7 Ma (recalculated from Locker and Martini, 1989).

LO of all *Naviculopsis* species

The LO of all *Naviculopsis* species lies in Hole 407 (Martini, 1979), North Atlantic, in upper Zones CN1b/2 = Zones NN1/3 (Bukry, 1979). In Hole 642C, Norwegian Sea, the LO is in lower Chron C5En (Locker and Martini, 1989; Bleil, 1989), which approximates the top of Zone NN2. The top of Zone NN2 has an age of 18.7 Ma (Wei and Peleo-Alampay, 1993).

FO of *Mesocena diodon*

In many holes, the very distinctive FO of *M. diodon* subdivides the *Corbisema triacantha* Zone into a lower and an upper part. The

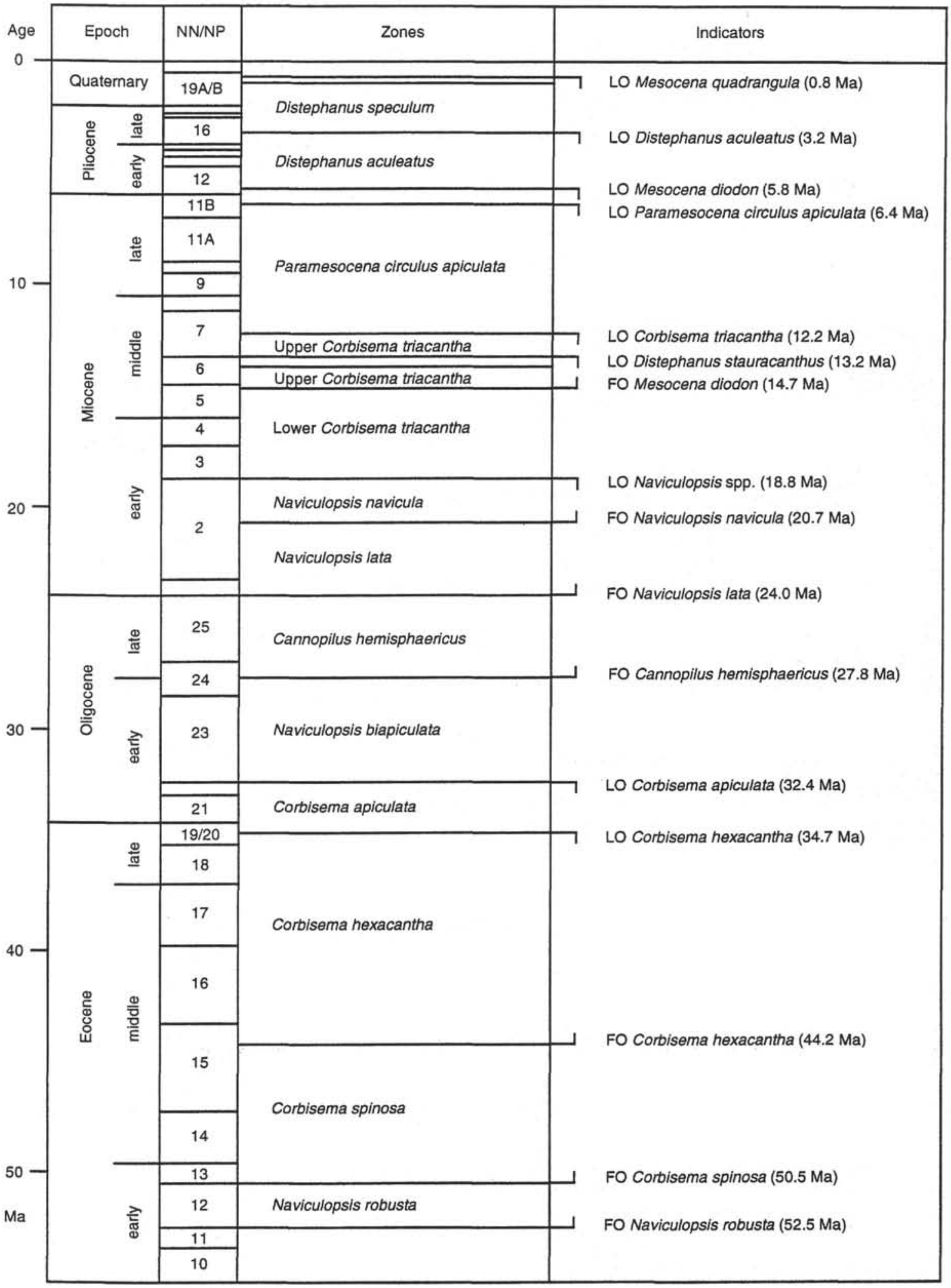

Figure 2. Silicoflagellate zonation of the Cenozoic used for ODP Leg 151, first and last occurrences (FO, LO) of diagnostic species, and correlation to the nannoplankton zonation of Martini (1971). Ages are from Wei and Peleo-Alampay (1993).

Table 2. Hole 908A, stratigraphic distribution of silicoflagellates in upper Oligocene and Miocene–Pliocene sediments.

Core, section, interval (cm)	Depth (mbsf)	Slide area (%)	Diatom abundance	Specimens counted	Preservation	*Cannopilus hemisphaericus*	*Cannopilus* cf. *hemisphaericus*	*Cannopilus jouseae*	*Corbisema angularis*	*Corbisema apiculata*	*Corbisema archangelskiana*	*Corbisema convexa*	*Corbisema elata*	*Corbisema globulata*	*Corbisema hastata*	*Corbisema lamell. constricta*	*Corbisema lamell. hastata*	*Corbisema lamell. lamellifera*	*Corbisema reducta*	*Corbisema spinosa*	*Corbisema triacantha* s.l.	*Corbisema* spp.	*Dictyocha bryonalis bryonalis*	*Dictyocha bryonalis* subsp. A	*Dictyocha bryonalis*, medusoid	*Dictyocha carentis carentis*	*Dictyocha carentis incerta*	*Dictyocha deflandrei*	*Dictyocha martinii*	*Dictyocha obliqua*	*Dictyocha precarentis*	*Dictyocha rotundata rotundata*	*Dictyocha rotundata secta*	*Dictyocha transitoria*	*Dictyocha* spp.	*Distephanus antiquus*	*Distephanus crux crux*	*Distephanus crux* subsp. A	*Distephanus norvegiensis*	*Distephanus paulii*	*Distephanus specul.* f. *pentagonus*	*Distephanus specul.* f. *schulzii*	*Distephanus specul.* f. *septenarius*	*Distephanus specul.* f. *speculum*	*Distephanus speculum*, diverse	*Lyramula furcula*	*Mesocena quadrangula*	*Naviculopsis aspera*	*Naviculopsis biapiculata*	*Naviculopsis* aff. *constricta*	*Naviculopsis eobiapiculata*	*Naviculopsis minor*	*Naviculopsis* spp.	*Naviculopsis* spp., fragments	*Septamesocena apiculata glabra*	Silicoflagellate zone
151-908A-																																																								
13X-1, 78–82, to	111.18	5	B	0														Barren																									Barren													Barren
16X-4, 48–53	144.18	5	T	0														Barren																									Barren													
17X-1, 52–54	149.22	24	R	17	PM			R				R				R	T	R								R	R	R				R														R				R						
17X-2, 52–54	150.72	21	R	21	PM												R	R	R				R				R	R				R			R											R				R						
17X-3, 52–54	152.22	21	T	0	P													Fragments																									Fragments													
17X-4, 52–54	153.72	21	T	2	P																							R																					R							
17X-5, 52–54, to	155.22	21	T	0	P													Fragments																									Fragments													
17X-7, 09–12	157.79	5	T	0	P													Fragments																									Fragments													
18X-1, 58–60	158.78	40	R	33	PM					T		R	R				T	R		R		T	R			R	R	R				R	R	R	R	T										R				R	R	R	R			Unzoned interval
18X-2, 58–60	160.28	21	T	13	PM					R		R				R		R									R	R			R	R	R																R	R						
18X-3, 58–60	161.78	21	T	10	PM							R																R				R		R	R											R			R							
18X-4, 58–60	163.28	5	T	0														Barren																									Barren													
18X-5, 58–60	164.78	21	T	7	PM							R															R	R				R																								
18X-6, 58–60	166.28	21	T	1	PM																						R																													
19X-1, 56–59, to	168.36	5	T	0														Barren																									Barren													
20X-4, 57–60	182.47	5	T	0														Barren																									Barren													
20X-5, 57–60	183.97	24	T	11	PM											T		R									F	T	R		R	R																R	T							
20X-6, 57–60	185.47	5	B	0														Barren																									Barren													
21X-1, 56–57	187.66	40	R	19	MP			R		T		R		T			T		R	R	T	T	T		T	R	R	R			T	R	R		T		T				T						R		T	R	T					
21X-2, 56–57	189.16	21	A	26	MP				R									R	R	R			R		R			R					R				F				R													P	R	
21X-3, 57–58	190.67	21	A	30	MP	R																R					R					R			R	R	F				F													P	R	
21X-4, 56–57	192.16	40	R	11	PM				R			R	T	R					R							R	R	R		R		T		T			R				T							T								
21X-5, 56–57	193.66	21	A	26	MP	R																				R		R									C				R													P	R	
21X-6, 57–58	195.17	21	A	19	MP																					R	R					R					F				R													P	R	
22X-1, 57–59	197.27	40	R	8	MP							R						T				R						R				R			R														R							
22X-2, 57–59	198.77	21	F	15	MP					R								R					R		R			R				R					F				R									R						
22X-3, 57–59	200.27	24	C	9	PM												R	T														R					R	T			R									R						
22X-4, 57–59	201.77	40	R	11	PM							R						R										R		R		R	T	R																				P		*Cannopilus hemisphaericus* Zone
22X-5, 56–58	203.26	40	R	12	P											T	R	T	R			R	R				R	R				R	R	R													T			R						
23X-1, 59–60	206.89	40	T	13	PM					T			R	T					R				R				R	R	T					R	R															R						
23X-2, 59–60	208.39	40	F	29	MP			R		R		T		R	T	R	T	R	R			R			R	R	R	R		R		R	R	T	R	T								R						R					T	
23X-3, 59–60	209.89	21	A	47	MP																		R				R	R				R			R		F				F			F	R									P	R	
23X-4, 59–60	211.39	21	A	137	MP	F					R	R	R						R		R		R		R	R	R		R			R				R	A	R			C			C						R	R				R	
23X-5, 59–60	212.89	21	A	55	MP	R							R						R			R			R	R							R				C				R			F												
23X-6, 59–60	214.39	21	C	23	MP											R			R							R	R								R		R	R			F			R								R				
24X-1, 58–59	216.58	40	R	16	MP		R			R		R			T		R	T			R					R	R	R			T	R		T	R														R			R	R			
24X-2, 58–59	218.08	21	C	56	MP	R						R						R	R				R		R	R	R	R				R									F			C						R			R		R	
24X-3, 58–59	219.58	21	F	28	MP	R			R			R	R	R					R	R			R				R	R				R	R		R	R	R				R			R						R		R				
24X-4, 58–59	221.08	21	C	108	MP	R				R		R	R	R				R			R		R				R	R				R	R		R		R	F		C	R		R	C					R	R	R	R			R	
24X-5, 58–59	222.58	40	R	15	P					R		R		T	T							T				R	R				R	R		R	R	R													R	R						
24X-6, 58–59	224.08	21	C	67	MP	R									R								R			R	R	R				R	R	R	R	R		R		F	R		R	F						R	R	R			R	
25X-1, 56–60	226.16	21	A	56	MP	R				R	R		R													R	R	R			R	R		T						F				C					R		R	R				
25X-2, 56–60	227.66	40	R	35	PM				R	R		T		R				R	T		R		R			R	R	R			R	F	R	R	R					T									R			R	T			*Distephanus paulii* Subzone
25X-3, 58–62	229.18	40	F	63	MP	R		T	R	R		R		R				R	T		R		R			F	F	R		R		F	R		R						T			R					R	R						
25X-4, 55–59	230.65	21	C	62	MG	F							R	R					R								R	R		R				R	R			R		F	R		R	C						R					R	
25X-5, 56–59	232.16	21	A	67	MP	R				R		R	R			R	R	R	R	R		R	R			R	R	R	R			R			R	R				F	R		R	F						R	R	R			R	
26X-1, 57–59	235.77	40	R	16	MP			R		R		R				R							R			R	R	R	R			R	T			R					R									T			T		R	
26X-2, 57–59	237.27	21	A	21	MG	R						R			R				R				R			R	R	R				R	R			R				R		R	R	R				R							T	
26X-3, 57–59	238.77	40	A	30	MG	R						R						R	R								R	R				R	R				R			R	R		R	R	R							R			R	

Table 2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Slide area (%)	Diatom abundance	Specimens counted	Preservation	*Cannopilus hemisphaericus*	*Cannopilus* cf. *hemisphaericus*	*Cannopilus jouseae*	*Corbisema angularis*	*Corbisema apiculata*	*Corbisema archangelskiana*	*Corbisema convexa*	*Corbisema elata*	*Corbisema globulata*	*Corbisema hastata*	*Corbisema lamell. constricta*	*Corbisema lamell. hastata*	*Corbisema lamell. lamellifera*	*Corbisema reducta*	*Corbisema spinosa*
26X-4, 57–59	240.27	40	R	13	MP							T	R			R			R	
26X-5, 57–59	241.77	40	T	2	P															
26X-6, 57–59	243.27	40	T	2	P							R	T						R	
27X-1, 57–60	245.47	40	T	16	PM					R		T		R	R			T		
27X-2, 57–60	246.97	24	R	70	PM				R	R		R		R	R	R		R	R	
27X-3, 57–60	248.47	21	F	50	MP		R			R		R	R					R	R	
27X-4, 57–60	249.97	21	C	71	MP	R		R					R			R		R		
27X-5, 57–60	251.47	21	A	44	MG	R			R	R			R						R	
28X-1, 57–59	255.17	40	R	25	MP		R	R		R		T			R	R	T	T	R	
28X-2, 48–50	256.58	40	T	12	P							R					T		R	
28X-3, 57–59	258.17	40	T	11	P							T	T					R	R	
28X-4, 56–58	259.66	40	R	16	MP			R		R		T						R	T	
28X-5, 57–59	261.17	40	C	18	MP				R			T					T	R		R
28X-6, 57–59	262.67	21	C	14	MP			R		R									R	R
29X-1, 57–59	264.77	21	T	0	P													Fragments		
29X-2, 57–59, to	266.27	21	T	0														Barren		
29X-3, 57–59	267.77	5	T	0														Barren		
29X-4, 57–59	269.27	40	T	11	PM													T	R	
29X-5, 57–59	270.77	21	A	26	MG	R														R
29X-6, 57–59	272.27	40	R	14	MP									R					R	
30X-1, 57–59	274.47	24	R	54	MG	R														
30X-2, 10–12	275.51	21	A	132	MP	F														
30X-3, 57–59	277.47	21	F	10	MP															R
30X-4, 57–59	278.97	21	A	76	MG	R														
30X-5, 57–59	280.47	21	C	11	MG															
30X-6, 57–59	281.97	21	R	17	PM		R					R			R			R		
31X-1, 57–59, to	284.07	5	T	0														Barren		
31X-5, 55–57	290.05	5	T	0														Barren		
31X-6, 56–58	291.56	40	C	17	MG			R		R		T							R	
32X-1, 57–58	293.77	24	A	32	MG	T				T		R						R	R	
32X-2, 57–58	295.27	21	A	37	MG	R		R		R									R	
32X-3, 53–54	296.73	21	A	54	MG	R														
32X-4, 58–59	298.28	24	A	73	MG	R													R	
32X-5, 58–59	299.78	21	C	48	MP	R												R		
32X-6, 56–57	301.26	21	F	26	PM	R				R		R								
33X-1, 57–59	303.37	21	A	110	MP	R						R						R	R	
33X-2, 57–59	304.87	21	A	64	MG	R														
33X-3, 57–59	306.37	21	A	128	MG	R														
33X-4, 56–58	307.86	21	A	60	MP	R				R										
33X-5, 57–59	309.37	21	A	27	MP	R														
33X-6, 57–59	310.87	21	A	81	MP	R														
34X-1, 57–59	313.07	40	T	4	PM															
34X-2, 57–59	314.57	40	A	67	MP			R				T	T						R	
34X-3, 57–59	316.07	40	A	58	MP	T	R			R		T							R	
34X-4, 57–59	317.57	40	C	23	PM									T					R	
34X-5, 9–11	318.60	21	R	12	PM					R		R	R			R			R	
35X-1, 30–31	320.51	21	T	0	P													Fragments		
35X-2, 9–10	321.80	21	R	9	PM										R	R				
35X-3, 9–10	323.30	21	T	5	PM															
35X-4, 9–10	324.80	21	T	6	PM					R			R							
35X-5, 9–10, to	326.30	21	T	0														Barren		
37X-2, 57–58	342.07	5	T	0														Barren		

Core, section, interval (cm)	*Corbisema triacantha* s.l.	*Corbisema* spp.	*Dictyocha bryonalis bryonalis*	*Dictyocha bryonalis* subsp. A	*Dictyocha bryonalis*, medusoid	*Dictyocha carentis carentis*	*Dictyocha carentis incerta*	*Dictyocha deflandrei*	*Dictyocha martinii*	*Dictyocha obliqua*	*Dictyocha precarentis*	*Dictyocha rotundata rotundata*	*Dictyocha rotundata secta*	*Dictyocha transitoria*	*Dictyocha* spp.	*Distephanus antiquus*	*Distephanus crux crux*	*Distephanus crux* subsp. A	*Distephanus norvegiensis*	*Distephanus paulii*
26X-4, 57–59	R					R	R	R				R								
26X-5, 57–59							R													
26X-6, 57–59																				
27X-1, 57–60	R		R			R		R				R	R		R					
27X-2, 57–60			R			R	F	F			R	F	R	R	R					
27X-3, 57–60		R	R			R	F	F			R	F	R		R				R	
27X-4, 57–60						R	R	R				R					C			
27X-5, 57–60					R			R				R	R				C			
28X-1, 57–59		R				R	R				T	R	R	T	R		R			
28X-2, 48–50			R			T	R	R												
28X-3, 57–59			T				R	R				R			T					
28X-4, 56–58			R			R	F	T				R	R							
28X-5, 57–59			R				R	R				R				R	F			
28X-6, 57–59			R				R	R				R				R	R			
29X-1, 57–59																				
29X-2, 57–59, to																				
29X-3, 57–59																				
29X-4, 57–59			T			R	R	R				R								
29X-5, 57–59			R			R	R										C			
29X-6, 57–59		T	T			R	R	R				R		R	T		T			
30X-1, 57–59			R									R								
30X-2, 10–12			F		R										C		R			
30X-3, 57–59								R				R	R							
30X-4, 57–59			R	F			R								R		R			
30X-5, 57–59			R	R			R				R	R								
30X-6, 57–59						R	R	R				R								
31X-1, 57–59, to																				
31X-5, 55–57																				
31X-6, 56–58			R			R	R	R			R	R			R					
32X-1, 57–58			R	R							T	R			R	R		R		
32X-2, 57–58			R	F			R	R				R					R			
32X-3, 53–54	R		F	F			R					R			R		R			
32X-4, 58–59	R		F	F	R		R				R			T			R	R		
32X-5, 58–59			F	F	R		R	R			R						R	R		
32X-6, 56–57	R		R	R																
33X-1, 57–59			R	C	R		R	R				R	R	R				R	R	
33X-2, 57–59			F	F	R	R		R				R						R		
33X-3, 57–59			F	F		R		R	R									R		
33X-4, 56–58	R		R	F	R	R		R				R					R	R		
33X-5, 57–59			R	R		R	R								R					
33X-6, 57–59			F	F	R												R			
34X-1, 57–59								R				R	R		R					
34X-2, 57–59			R	R		R	F	F				C	R	R	R	R				
34X-3, 57–59			F	R	R	R	R	R	T			F	T	T				T		
34X-4, 57–59		R	R	R	R	R	R	R				R	T	T	R					
34X-5, 9–11						R	R	R				R					R			
35X-1, 30–31																				
35X-2, 9–10					R	R	R									R				
35X-3, 9–10							R	R				R				R				
35X-4, 9–10							R													
35X-5, 9–10, to																				
37X-2, 57–58																				

Core, section, interval (cm)	*Distephanus specul.* f. *pentagonus*	*Distephanus specul.* f. *schulzii*	*Distephanus specul.* f. *septenarius*	*Distephanus speculum* f. *speculum*	*Distephanus speculum*, diverse	*Lyramula furcula*	*Mesocena quadrangula*	*Naviculopsis aspera*	*Naviculopsis biapiculata*	*Naviculopsis* aff. *constricta*	*Naviculopsis eobiapiculata*	*Naviculopsis minor*	*Naviculopsis* spp.	*Naviculopsis* spp., fragments	*Septamesocena apiculata glabra*	Silicoflagellate zone
26X-4, 57–59														P		
26X-5, 57–59										R						
26X-6, 57–59									T							
27X-1, 57–60									T	R						
27X-2, 57–60								R	T	R		R	R			
27X-3, 57–60										R	R	R				
27X-4, 57–60	R		R	R				R		R			R			
27X-5, 57–60	R			R	R							R	R			
28X-1, 57–59								R		T	R	R	R			
28X-2, 48–50										R		R				
28X-3, 57–59											R					
28X-4, 56–58	T									R		R				
28X-5, 57–59	R			R										P	T	
28X-6, 57–59							R							P		
29X-1, 57–59			Fragments													
29X-2, 57–59, to			Barren													
29X-3, 57–59			Barren													
29X-4, 57–59									R			R				
29X-5, 57–59	R													P		
29X-6, 57–59								T		T		R				
30X-1, 57–59	C			R							T				R	
30X-2, 10–12	A			R							R				R	*Cannopilus hemisphaericus* Zone
30X-3, 57–59	R											R				
30X-4, 57–59	C			R							R				R	
30X-5, 57–59	R									R						
30X-6, 57–59								R	R		R					
31X-1, 57–59, to			Barren													
31X-5, 55–57			Barren													
31X-6, 56–58				R				T	R			T			T	
32X-1, 57–58	F								R	R	R	R			R	
32X-2, 57–58	F			R							R					
32X-3, 53–54	C									R	R				R	
32X-4, 58–59	C								R		R				R	
32X-5, 58–59	C													P	R	
32X-6, 56–57	F			R										P	R	
33X-1, 57–59	A	R		R						R			R		R	
33X-2, 57–59	C													P	R	
33X-3, 57–59	A										R				R	
33X-4, 56–58	C			R	R										R	
33X-5, 57–59	F	R													R	
33X-6, 57–59	A	R													R	
34X-1, 57–59																
34X-2, 57–59	R	R						T	R	R	T	R				
34X-3, 57–59	R	F									T	T			T	
34X-4, 57–59	T							T		R	R					
34X-5, 9–11																
35X-1, 30–31			Fragments													
35X-2, 9–10														P		Unzoned interval
35X-3, 9–10										R						
35X-4, 9–10													R			
35X-5, 9–10, to			Barren													Barren
37X-2, 57–58			Barren													

Note: For definition of species abundance and preservation, see text.

Table 3. Hole 908A, stratigraphic distribution of ebridians, actiniscidians, and synuraceans in upper Oligocene and Miocene–Pliocene sediments.

Hole 908A, core, section, interval (cm)	Depth (mbsf)	Slide area (%)	Diatom abundance	Specimens counted	Preservation	*Macrora stella*	Synuraceans, indet.	*Actiniscus elongatus*	*Actiniscus pentasterias* s.l.	*Carduifolia gracilis*	*Carduifolia onopordoides*	*Carduifolia* spp.	*Foliactiniscus atlanticus*	Actiniscidians, indet.	*Ammodochium danicum*	*Ammodochium doliolum*	*Ammodochium pyramidale*	*Ammodochium rectangulare*	*Ammodochium serotinum*	*Ammodochium* sp. A	*Ammodochium* spp.	*Ditripodium* spp.	*Ebriopsis crenulata*	*Falsebria ambigua*	*Falsebria rossica*	*Haplohermesinum cornuta*	*Haplohermesinum hovassei*	*Haplohermesinum* sp. A	*Hermesinella conata*	*Hermesinella fenestrata*	*Hermesinella paraconata*	*Hermesinella schulzii*	*Hermesinella* cf. *transversa*	*Hermesinopsis exigua*	*Hermesinopsis valida*	*Hermesinopsis* sp. A	*Hermesinopsis* spp.	*Hermesinum acus*	*Hermesinum geminum*	*Hermesinum obliquum*	*Pseudammodochium dictyoides*	*Pseudammodochium eximium*	*Pseudammodochium* sp. A	*Pseudammodochium* sp. B	*Pseudammodochium* spp.	*Spongebria marthae*	*Thranium* sp.	Ebridians, indet.	Ebridian assemblage	Silicoflagellate zone
						Syn.		Actiniscidians							Ebridians																																			
13X-1, 78–82, to	111.18	5	B	0							Barren																					Barren																	Barren	Barren
16X-4, 48–53	144.18	5	T	0							Barren																					Barren																		
17X-1, 52–54	149.22	24	R	30	PM										T			R		R	R			R	R										R							R		R				F		
17X-2, 52–54	150.72	21	R	25	PM										R					R	R																							R				F		
17X-3, 52–54	152.22	21	T	0	P						Fragments																					Fragments																		
17X-4, 52–54	153.72	21	T	12	P															R	R														R									R				F		
17X-5, 52–54, to	155.22	21	T	0	P						Fragments																					Fragments																		
17X-7, 09–12	157.79	5	T	0	P						Fragments,																					Fragments																		
18X-1, 58–60	158.78	40	R	38	PM										R			T		R	R			R	T								R		R		R					R		R			R	C		
18X-2, 58–60	160.28	21	T	25	PM										R					F	R			R											R									F				R	Undesignated assemblage	Unzoned interval
18X-3, 58–60	161.78	21	T	10	PM										R					R	R														R									R				R		
18X-4, 58–60	163.28	5	T	0							Barren																					Barren																		
18X-5, 58–60	164.78	21	T	11	PM										R					R	R												R		R													R		
18X-6, 58–60	166.28	21	T	6	PM										R																		R		R													R		
19X-1, 56–59, to	168.36	5	T	0							Barren																					Barren																		
20X-4, 57–60	182.47	5	T	0							Barren																					Barren																		
20X-5, 57–60	183.97	24	T	21	PM				R	R										R	R				R								R		R							T		R		R		F		
20X-6, 57–60	185.47	5	B	0							Barren																					Barren																		
21X-1, 56–57	187.66	40	R	37	MP		R		R	R								T		R	R				R										R	R					R	R	R	R		R		F		
21X-2, 56–57	189.16	21	A	45	MP				C	R		R			R					R	R						R							R	T	R	R					F	R					R	Undesignated assemblage	
21X-3, 57–58	190.67	21	A	23	MP				F				R							R							R		R						R							R				R		R		
21X-4, 56–57	192.16	40	R	23	PM				R	R					R	R				T					R									T	T						R	R	R	R		R		R		
21X-5, 56–57	193.66	21	A	38	MP				F	R	R		R		R	R				R	R		R								R			R		R						R	R	R		R		R		
21X-6, 57–58	195.17	21	A	41	MP				C	R			R		R					R	R			R							R				R							R	R	R		R		R		
22X-1, 57–59	197.27	40	R	12	MP				R	R										R	R		T	R										T								R	R	T				R		
22X-2, 57–59	198.77	21	F	15	MP				F						R					R			R											R	R	R												R		
22X-3, 57–59	200.27	24	C	41	PM				C	R			R							R	R		R				R				R			R										R	R	R		R		
22X-4, 57–59	201.77	40	R	20	PM				R	R	R				T					T	R				R										R	R					R	R	R	R				R		
22X-5, 56–58	203.26	40	R	15	PM										R					R	R														R							R	R	R				R		*Cannopilus hemisphaericus* Zone
23X-1, 59–60	206.89	40	T	19	PM													R		R	R		R																			R		R				R	*Hermesinella paraconata* Assemblage	
23X-2, 59–60	208.39	40	F	62	MP				R		R				R	R				R	R		T	R	T									R	R	R					T	F	R	R	R	R		F		
23X-3, 59–60	209.89	21	A	54	MP				F	R	R	R					F			R	R		R					R			R				T							F	R					F		
23X-4, 59–60	211.39	21	A	53	MP				C	F	R	R	R				R			R				R							R				R					R	R	R	R	R	R			F		
23X-5, 59–60	212.89	21	A	37	MP				R	R			R				R			R	R		R								R				R	R					R	R	R	R				R		
23X-6, 59–60	214.39	21	C	33	MP				R	R			R		R		R			R			R												R						R	R	R	R		R		R		
24X-1, 58–59	216.58	40	R	28	MP		R		T	R						R				T			R	R	T									R	R	T					R	R	R	R		R		F		
24X-2, 58–59	218.08	21	C	56	MP				F	F							R			R	R	R	R	R							T			T	R	R			R			F	R	R				F		
24X-3, 58–59	219.58	21	F	64	MP		R	R	C	F	R									R	R		R																			R	R	R	R	R		F		
24X-4, 58–59	221.08	21	C	64	MP			R	F	R	R		R		R				R	R	R		R	R		R			T					R							R	F	F	R	R	R		F		
24X-5, 58–59	222.58	40	R	24	P														T	R			R											R	R	T					T	R	R	R	R	T		F		
24X-6, 58–59	224.08	21	C	99	MP				F	R	R				R			R		F	R		R	R	R									R	R					T		F	F	F				F		
25X-1, 56–60	226.16	21	A	68	MP			R	F	R					R		R			F	R		R										R	R	R							F	R	R	R			F		
25X-2, 56–60	227.66	40	R	59	PM				R	R										R	F		T	R	R									R	R							F	R	R	R	R		F		
25X-3, 58–62	229.18	40	F	89	MP			R	R										R	F	R		R	R	R									R	F	T					T	F	R	F	R	R		C	Undesignated assemblage	*Distephanus paulii* Subzone
25X-4, 55–59	230.65	21	C	48	MG				F	R			R		R	R			R		R									R				R	R	T						F	R	R	R			F		
25X-5, 56–59	232.16	21	A	58	MP	R			F	F			R							F	R		R	R		R						R		R	R						R	F	R	R	R	R		R		
26X-1, 57–59	235.77	40	R	33	MP	R			R	T								R		R	R			R											R						R	R	R	R	R	R		F		
26X-2, 57–59	237.27	21	A	34	MG	R			F	F					R					R		R													R		R		R	R		R		R				R		
26X-3, 57–59	238.77	40	A	50	MG	R			F	R							R		R	F	R				R		R		R			R									R	F	R	R				F		
26X-4, 57–59	240.27	40	R	13	MP													R		R			T	T												R						T	R	R		R		R		
26X-5, 57–59	241.77	40	T	9	P															R	R																					R						R		

Table 3 (continued).

Hole 908A, core, section, interval (cm)	Depth (mbsf)	Slide area (%)	Diatom abundance	Specimens counted	Preservation	*Macrora stella*	Synuraceans, indet.	*Actiniscus elongatus*	*Actiniscus pentasterias* s.l.	*Carduifolia gracilis*	*Carduifolia onopordoides*	*Carduifolia* spp.	*Foliactiniscus atlanticus*	Actiniscidians, indet.	*Ammodochium danicum*	*Ammodochium doliolum*	*Ammodochium pyramidale*	*Ammodochium rectangulare*	*Ammodochium serotinum*	*Ammodochium* sp. A	*Ammodochium* spp.	*Ditripodium* spp.	*Ebriopsis crenulata*	*Falsebria ambigua*	*Falsebria rossica*	*Haplohermesinum cornuta*	*Haplohermesinum hovassei*	*Haplohermesinum* sp. A	*Hermesinella conata*	*Hermesinella fenestrata*	*Hermesinella paraconata*	*Hermesinella schulzii*	*Hermesinella* cf. *transversa*	*Hermesinopsis exigua*	*Hermesinopsis valida*	*Hermesinopsis* sp. A	*Hermesinopsis* spp.	*Hermesinum acus*	*Hermesinum geminum*	*Hermesinum obliquum*	*Pseudammodochium dictyoides*	*Pseudammodochium eximium*	*Pseudammodochium* sp. A	*Pseudammodochium* sp. B	*Pseudammodochium* spp.	*Spongebria marthae*	*Thranium* sp.	Ebridians, indet.	Ebridian assemblage	Silicoflagellate zone
26X-6, 57–59	243.27	40	T	6	P															R	R																											R	Undesignated assemblage	*Cannopilus hemisphaericus* Zone
27X-1, 57–60	245.47	40	T	20	PM									R		R				R	R		R												T						R	R	R		R	R		R		
27X-2, 57–60	246.97	24	R	87	PM									R	R	R		R	R	F	R				R									R	R	R	R				R	F	F	C	R	R		C		
27X-3, 57–60	248.47	21	F	59	MP				R						R					R	R				R									R	R	R					R	F	R	F		R		F		
27X-4, 57–60	249.97	21	C	51	MP				R						R	R	R			R	R					R								R	R	R					R	R		F		R		F		
27X-5, 57–60	251.47	21	A	24	MG				F	R										R	R														R							R		R				R		
28X-1, 57–59	255.17	40	R	29	MP				R	T	R					R				F	R		R	R											R	T					R	R	R	R	R	R		R		
28X-2, 48–50	256.58	40	T	12	P															R					R											R					R	R	R					R		
28X-3, 57–59	258.17	40	T	10	P															R				R																		R		R				R		
28X-4, 56–58	259.66	40	R	45	MP		R		F	R	T				R			T		R	R		R	T	T									R		R					R	R	R	F	R	T		F		
28X-5, 57–59	261.17	40	C	41	MP				F	R						R				R			R							T								F				R	R	R		R		F	*Hermesinum acus* Assemblage	
28X-6, 57–59	262.67	21	C	39	MP				F	R					R			R		R	R		R															R		R		F		R				F		
29X-1, 57–59	264.77	21	T	12	P				R	R					R	R				R	R														T							R		R		R		R	Undesignated assemblage	
29X-2, 57–59, to	266.27	21	T	0							Fragments																					Fragments																		
29X-3, 57–59	267.77	5	T	0							Barren																					Barren																		
29X-4, 57–59	269.27	40	T	21	PM						T									R					R										T	R						R	R	R		R		F		
29X-5, 57–59	270.77	21	A	45	MG	R			F	F			R				R			R	R		R			R			R							R						R	R	R				F		
29X-6, 57–59	272.27	40	R	25	MP				R		R				R		T			R	R		R	R	R									T	R							R	R	R				R		
30X-1, 57–59	274.47	24	A	19	MG				F	R							R		R	R					R																R				R			R		
30X-2, 10–12	275.51	21	A	27	MP	R			F	R						R	R		R	R									R										R							R		F		
30X-3, 57–59	277.47	21	F	43	MP				F	R						R	R			R	R		R	R	R										R						R	R	R	R				F		
30X-4, 57–59	278.97	21	A	69	MG	R		R	C	R			F	R			R			R	R					R			R	R		R										R	R	R				F		
30X-5, 57–59	280.47	21	C	33	MG				F	R					R						R		R						R				R		T	R						R	R					R		
30X-6, 57–59	281.97	21	R	27	PM										R	R				F	R													R	R							R	R	R		R		R		
31X-1, 57–59, to	284.07	5	T	0							Barren																					Barren																		
31X-5, 55–57	290.05	5	T	0							Barren																					Barren																		
31X-6, 56–58	291.56	40	C	47	MG				F	R			R				R	T		R			R						R												T	F	R	F		R		F		
32X-1, 57–58	293.77	24	A	20	MG				R	R			T				R			R		R				R						T							T		R	R		R		T		R		
32X-2, 57–58	295.27	21	A	37	MG			R	F	F	R						R			R	R		R		R			R													R	R	R					F		
32X-3, 53–54	296.73	21	A	43	MG	R		R	F	F			R				R			R	R				R			R	R													R						R		
32X-4, 58–59	298.28	24	A	55	MG			R	F	F			R				R			R	R								R	R		R			R							R	T					F		
32X-5, 58–59	299.78	21	C	54	MP				F	C			R				R				R								R	R									R			R		R	R			F		
32X-6, 56–57	301.26	21	F	19	PM				R	R							R			R	R		R	R															R			R						R		
33X-1, 57–59	303.37	21	A	56	MP	R			F	F			R				R			R	R		R						R			R			R				R		R	F	R	R				F		
33X-2, 57–59	304.87	21	A	35	MG				F	R			R					R		R										R						R			R			R		R		R		R		
33X-3, 57–59	306.37	21	A	44	MG	R			F	F			R				R						R									R			R				R			R						F		
33X-4, 56–58	307.86	21	A	30	MP	R			F	R							R										R		R												R	R				R		R		
33X-5, 57–59	309.37	21	A	18	MP	F			F	R			R																																			R		
33X-6, 57–59	310.87	21	A	36	MP	F			F	R					R		R																		R				R									R		
34X-1, 57–59	313.07	40	T	9	PM				R	R		R								R	R																				T		T	T				R		
34X-2, 57–59	314.57	40	A	144	MP	F			F	R		R	R	R			T			F	R		R		R							R		R	R	F		F	T		R	C	T	C	R			C	*Hermesinum acus* Assemblage	
34X-3, 57–59	316.07	40	A	101	MP	R			F	R				T	R		R			F	F	R	T				R								R	R		F	T	R	R	T		C	R			C		
34X-4, 57–59	317.57	40	C	48	PM				F	R					R					R	R			R		T									R	R		T			R	R	R	R		R		F		
34X-5, 9–11	318.60	21	R	12	PM														R	R	R			R												R								R				R	Undesignated assemblage	Unzoned interval
35X-1, 30–31	320.51	21	T	2	P											R																																R		
35X-2, 9–10	321.80	21	F	26	P				F	R										R	R								R												R			R				F		
35X-3, 9–10	323.30	21	R	5	P																															R						R						R		
35X-4, 9–10	324.80	21	R	12	P				R												R																					R	R					R		
35X-5, 9–10, to	326.30	21	T	0							Barren																					Barren																	Barren	Barren
37X-2, 57–58	342.07	5	T	0							Barren																					Barren																		

Note: For definition of species abundance and preservation, see text.

Table 4. Hole 913B, stratigraphic distribution of silicoflagellates in middle Eocene to lower Oligocene and middle Miocene sediments.

Core, section, interval (cm)	Depth (mbsf)	Slide area (%)	Diatom abundance	Specimens counted	Preservation	*Cannopilus hemisphaericus*	*Corbisema angularis*	*Corbisema apiculata*	*Corbisema elata*	*Corbisema hexacantha*	*Corbisema katharinae*	*Corbisema regina*	*Corbisema spinosa*	*Corbisema triacantha* s.l.	*Corbisema* cf. *triacantha*	*Corbisema* sp. A	*Corbisema* spp.	*Dictyocha bryonalis bryonalis*	*Dictyocha carentis carentis*	*Dictyocha challengeri*	*Dictyocha eocaenica*	*Dictyocha fibula*	*Dictyocha fibula* s.l.	*Dictyocha* cf. *mutabilis*	*Dictyocha* sp. A	*Dictyocha* sp. B	*Dictyocha* spp.	*Distephanus antiquus*	*Distephanus crux crux*	*Distephanus specul.* f. *pentagonus*	*Distephanus specul.* f. *speculum*	*Distephanus speculum*, diverse	*Distephanus speculum*, fenestrate	*Naviculopsis biapiculata*	*Naviculopsis constricta*	*Naviculopsis* aff. *constricta*	*Naviculopsis foliacea*	*Naviculopsis* spp.	*Naviculopsis* spp., fragments	*Septamesocena apicul. apiculata*	*Septamesocena apicul. evexa*	*Septamesocena apicul. glabra*	*Septamesocena oamaruensis*	Silicoflagellate zone
151-913B-																																												
19W-1,132–134, to	376.52	5	B	0																			B																					Barren
19W-3, 133–135	379.53	5	B	0																			B																					
19W-4, 76–78	380.46	45	T	2	P												R		R										T															Unzoned interval
19W-4, 144–148	381.14	40	C	5	P	R											R		T								R		R													T		
20R-1, 83–87, to	424.33	5	B	0																			B																					Unzoned interval
24R-1, 115–118	463.15	5	B	0																			B																					
24R-2, 116–119	464.66	40	R	3	MG								T	T			R				R						R				T								P					
24R-3, 117–120	466.17	40	R	4	MP									R			T										R	R											P		R			
24R-4, 111–114	467.61	40	C	5	P			R						R				R	T			T			T																R			
24R-CC	471.60	21	A	77	MP			R	C	R		R		C			R	R			F	R					R									R					R			*Corbisema hexacantha* Zone
25R-1, 114–117	472.74	21	A	399	MP			R	A	R	R	F		A		R	C	R		R	F	R	R		R											R		R			F			
25R-2, 114–117	474.24	24	A	162	MG			R	A	R	R	R		C	R			R					R		R										R	R					R			
25R-3, 114–117	475.74	24	A	39	PM			R	F		R	R		F					R	R			R		R		R									R					R			
25R-4, 112–115	477.22	24	A	54	MP			R	R	R	R	R		F									F		R							R	R		R					R	F			
25R-5, 112–115	478.72	24	A	25	MP			R	R	R		R		R									R		R								T		R		R			R	R			
25R-6, 113–115	480.23	24	A	57	MP			R		R		R		F						R			R		R											R	F	R		C	R			
25R-CC	481.10	24	C	26	MP			R	R			R		R			R			R			R												R		R				R			
26R-1, 113–115	482.23	40	A	4	MP				R			T		R						R															T		R							
26R-2, 113–115	483.73	21	A	86	MG			F				R		F	R		R			F			F		F		R								R	R	F			R	F			
26R-3, 113–115	485.23	21	C	5	MP			R			R																										R				R			
26R-4, 113–115	486.73	21	A	77	MP		R		F		R	R		C	F	F	R			R	R		R					R					R						P	R	R			
26R-5, 113–115	488.23	24	A	167	MP			R	R	R	F	R		A		C		R	R	R	F		R				R					R	R		R	R					R			
26R-6, 110–112	489.70	40	A	280	MG		R	C	F	R	F	C	R	A		F	R				R		R	R		F					R	R					R				R			
26R-CC	490.70	40	C	29	P		T		R			F		F			R		R				R			R		T								R					R			Unzoned interval
27R-1, 113–117	491.83	40	A	140	MG			R	C		R	C		R	C				T		R		R			C				R			R				R			R			F	
27R-2, 113–117	493.33	40	A	36	MP			R	T		R	T					R			F	R		R				R						R					R			F			
27R-3, 113–117	494.83	21	T	1	M																																	R						
27R-4, 113–117	496.33	21	F	2	P							R															R																	
27R-5, 118–122	497.88	21	T	1	P												R																											
27R-6, 113–117, to	499.39	5	B	0																			B																					Barren
50R-4, 113–117	717.50	5	B	0																			B																					

Note: For definition of species abundance and preservation, see text.

Table 5. Hole 913B, stratigraphic distribution of ebridians and actiniscidians in middle Eocene to lower Oligocene and middle Miocene sediments.

Core, section, interval (cm)	Depth (mbsf)	Slide area (%)	Diatom abundance	Specimens counted	Preservation	*Actiniscus* cf. *elongatus*	*Actiniscus pentasterias* s.l.	*Carduifolia gracilis*	Actiniscidians, indet.	*Ammodochium fletcheri*	*Ammodochium novum*	*Ammodochium pyramidale*	*Ammodochium rectangulare*	*Ammodochium serotinum*	*Ammodochium* spp.	*Ebriopsis acuta*	*Ebriopsis antiqua*	*Ebriopsis crenulata*	*Ebriopsis* sp. A	*Ebriopsis* spp.	*Haplohermesinum cornuta*	*Haplohermesinum hovassei*	*Haplohermesinum* spp.	*Hermesinella* cf. *transversa*	*Hermesinella* spp.	*Hermesinopsis aplanata*	*Hermesinopsis* cf. *caulleryi*	*Hermesinopsis*? sp. B	*Hermesinopsis* spp.	*Hovassebria brevispinosa*	*Parebriopsis symmetrica*	*Pseudammodochium dictyoides*	*Pseudammodochium* sp. C	*Pseudammodochium* spp.	*Spongebria curta*	*Spongebria miocenica*	Ebridians, indet.	Ebridian assemblage	Silicoflagellate zone
						Actinisc.				Ebridians																													
151-913B-																																							
19W-1, 132–134, to	376.52	5	B	0																		Barren																Barren	Barren
19W-3, 133–135	379.53	5	B	0																		Barren																	
19W-4, 76–78	380.46	45	T	123	MP		C	T																												A	R	*Spongebria miocenica* Zone	
19W-4, 144–148	381.14	40	C	158	MP		C	T				T		C	R																			T	F	A	C		
20R-1, 83–87, to	424.33	5	B	0																		Barren																Undesignated assemblage	Unzoned interval
24R-1, 115–118	463.15	5	B	0																		Barren																	
24R-2, 116–119	464.66	40	R	7	MG		R			R								R	R			T						R	T					R					
24R-3, 117–120	466.17	40	R	17	MP		R											R								R		R									F		
24R-4, 111–114	467.61	40	C	131	MG		R	R			R					F				R			R				T	A	T			R					C	*Ebriopsis acuta* Assemblage	
24R-CC	471,60	21	A	789	MP	R	R		R		C				R	R			R	R	R	R					R	A		P	A	F	R	F			C		*Corbisema hexacantha* Zone
25R-1, 114–117	472.74	21	A	387	MG	R		R			F					F			F		R	R		R	R		C	A		P	F	R	R	R			C		
25R-2, 114–117	474.24	24	A	97	MG		R	R							R	R	R		R			R		F			F	C		P	F	R	F	R			F		
25R-3, 114–117	475.74	24	A	53	MP	R		R			R		T			F	R		F			R		R			R	F		P	R	R	F				R		
25R-4, 112–115	477.22	24	A	68	MP	R		R	R		R		F			R	R		R		R	R				T	R	C		P	T	R	R				F		
25R-5, 112–115	478.72	24	A	37	MP	R	R	R			R					R					R			R				F		P		R	R	R			R		
25R-6, 113–115	480.23	24	A	119	MP	F	C	R			R					F	R		R					R			R	C		P	C	R	R				F		
25R-CC	481.10	24	C	65	MP			R								R	R		R					R				C	F	P		R	R	R			C		
26R-1, 113–115	482.23	40	A	296	MG	T		R					R			R	F		T	R		T						A	R	P	R	R	R				C		
26R-2, 113–115	483.73	21	A	115	MG			R					R		R		R		R									A	R	P		R					C		
26R-3, 113–115	485.23	21	C	31	MP			R					R			F											R	F		P			R				R		
26R-4, 113–115	486.73	21	A	209	MP			F					C		R	R	R		R								R	A		P							C		
26R-5, 113–115	488.23	24	A	207	MP			F					A			R			R				F			R		C		P		R					C		
26R-6, 110–112	489.70	40	A	319	MG			F					A			F	R		R			R	R		T		R	A		P	R	R	R	T			C		
26R-CC	490.70	40	C	77	MP			R							R										T			A	T	P				T			F		Unzoned interval
27R-1, 113–117	491.83	40	A	142	MG			R								R		R	R		R				T			A	R		T	R	F				F		
27R-2, 113–117	493.33	40	A	25	MP			R							R	R	R											F		P		R		R			R		
27R-3, 113–117	494.83	21	T	1	P																																R	Undesignated assemblage	
27R-4, 113–117	496.33	21	F	8	P												R		R						R			R									R		
27R-5, 118-122	497.88	21	T	2	P												R																						
27R-6, 113–117, to	499.39	5	B	0																		Barren																Barren	Barren
50R-4, 113–117	717.50	5	B	0																		Barren																	

Note: For definition of species abundance and preservation, see text.

FO of *M. diodon* is indicated in Chron C5ADr of Hole 642C, Norwegian Sea (Locker and Martini, 1989; Bleil, 1989), which correlates to upper Zone NN5. The age can be given as 14.7 Ma (recalculated from Locker and Martini, 1989).

FO/LO of *Distephanus stauracanthus*

The FO and LO of *D. stauracanthus* are used to define the *Distephanus stauracanthus* Subzone in Atlantic and Pacific Ocean holes. In Locker and Martini (1989), both events were placed in Zone NN6, but some indications are given also for Zone NN7. In Hole 408 (Bukry, 1979), North Atlantic, the FO and LO of *D. stauracanthus* are possibly in Zones CN5b/6 = Zones NN7/8. In DSDP Hole 555 (Bukry, 1985a), North Atlantic, both events are indicated for Zones NN7/8 (Backman, 1984). In Hole 470 (Bukry, 1981a), Northeast Pacific, the LO may be in Zone CN5b = Zone NN7. Since the nannoplankton evidence is rather indistinct for this interval, both events are further placed into Zone NN6, comparable to many Atlantic and Pacific holes. Based on these results, the LO of *D. stauracanthus* may be approximately correlated to the top of Zone NN6, corresponding to an age of 13.2 Ma (Wei and Peleo-Alampay, 1993).

LO of *Corbisema triacantha*

The LO of *C. triacantha* delimits the upper *Corbisema triacantha* Zone. Since *C. triacantha* represents a warm-adapted species, the LO may have occurred earlier in higher latitudes than in lower ones. Sometimes sub-top occurrences of *D. stauracanthus* or supra-top occurrences of *C. hemisphaericus* or *Cannopilus depressus* roughly indicate the top of this zone. Nevertheless, increasing evidence indicates that the LO of *C. triacantha* is in Zone NN7. This applies for Holes 408 (Bukry, 1979) and 555 (Bukry 1985a) of the northern Atlantic, where Zones CN5b/6 = Zones NN7/8 are found. This proves right also for Holes 173 (Ling, 1977) and 469 (Bukry, 1981a) in the northeastern Pacific, where foraminifer cross correlation and direct nannoplankton evidence indicate Zone CN5b = Zone NN7. According to these interpretations, the LO of *C. triacantha* is indicated here in the middle of Zone NN7, corresponding to an age of 12.2 Ma (Wei and Peleo-Alampay, 1993).

LO of *Paramesocena circulus apiculata* to LO of *Mesocena quadrangula*

The events of *Paramesocena circulus apiculata, Mesocena diodon, Distephanus aculeatus, Distephanus speculum* f. *octonarius* and *Mesocena quadrangula* are well defined in Holes 642C and 644A of the Norwegian Sea (Locker and Martini, 1989). Using Wei and Peleo-Alampay (1993) as a source, only the ages were recalculated (Table 1).

SITE SUMMARIES

Site 908

Hole 908A (78°23.112′N, 1°21.637′E, 1284.5 m of water depth) was drilled on the Hovgård Ridge which delimits the Boreas Basin to the north. The site was positioned on top of Hovgård Ridge to investigate the tectonic, sedimentological, and paleoceanographic history of this topographic element in the middle of the Fram Strait (Myhre, Thiede, Firth, et al., 1995). The sedimentary sequence recovered was divided into two lithological units. Lithologic Unit I (0–185 mbsf, Quaternary to Pliocene) consists of interbedded clayey or silty muds, clayey silts, and silty clays. Lithologic Unit II (185–345 mbsf, Oligocene) comprises predominantly biosilica-bearing silty clays. Most of the samples studied from Cores 151-908A-17X to 35X contain poorly to moderately preserved siliceous microfossils, such as diatoms, silicoflagellates, ebridians, actiniscidians, chrysophyceans, radiolarians, and sponge spicules.

Silicoflagellates (Table 2)

Samples 151-908A-13X-1, 78–82 cm, through 16X-4, 48–53 cm, are barren of silicoflagellates. The interval from Sample 151-908A-17X-1, 52–54 cm, to 20X-6, 57–60 cm, displays poorly preserved assemblages which are probably all reworked from older, mainly Paleogene, strata. Strong reworking is indicated especially by *Lyramula furcula,* which occurs only in upper Cretaceous sediments. No age diagnostic silicoflagellates could be found for that interval.

The sequence from Sample 151-908A-21X-1, 56–57 cm, to 35X-4, 9–10 cm, is characterized by changing preservational conditions. Intervals that have moderately preserved assemblages clearly alternate with intervals that have poorly preserved assemblages. The bulk of species obviously occurs throughout the column without major differentiation. But some species within intervals of better preservation hint at an influence of North Atlantic surface-water. Such species are *Cannopilus hemisphaericus, Distephanus crux, D. paulii, D. speculum, Septamesocena apiculata* subsp. *glabra,* and some *Naviculopsis* taxa.

The co-occurrence of *C. hemisphaericus* and *C. jouseae* indicates that the entire sequence from Sample 151-908A-21X-1, 56–57 cm, to 34X-3, 57–59 cm, belongs in the *Cannopilus hemisphaericus* Zone, which is of late Oligocene age. The restricted occurrence of *D. paulii* marks a distinct interval or subzone within this zone. Assuming the FO of *Cannopilus hemisphaericus* is in the middle of nannoplankton Zone NP24 (Fig. 2), Chron C9r may be present below 320 m.

The interval from Sample 151-908A-34X-4, 57–59 cm, to 35X-4, 9–10 cm, remains unzoned, because diagnostic silicoflagellates are missing. Samples 151-908A-35X-5, 9–10 cm, through 37X-2, 57–58 cm, are barren of silicoflagellates.

Ebridians and Actiniscidians (Table 3)

Samples 151-908A-13X-1, 78–82 cm, through 16X-4, 48–53 cm, are barren of ebridians and other siliceous flagellates. The interval from Sample 151-908A-17X-1, 52–54 cm, to 20X-6, 57–60 cm, contains a limited number of species which are mainly reworked from Paleogene strata. A single specimen of *Thranium* sp. found in Sample 151-908A-18X-1, 58–60 cm, is probably autochthonous. It hints at a time interval from the middle Miocene to the earliest Pliocene (see Locker and Martini, 1989). Hence, the paleomagnetic sequence above the hiatus at about 186 m (Myhre, Thiede, Firth, et al., 1995) may represent Chron C3 or C3A.

The sequence from Sample 151-908A-21X-1, 56–57 cm, to 35X-4, 9–10 cm, is characterized by several ebridian and actiniscidian species, such as *Carduifolia gracilis, Ebriopsis crenulata, Hermesinopsis exigua,* and other taxa. A distinct interval is indicated by *Hermesinella paraconata,* which ranges from Sample 151-908A-21X-5, 56–57 cm, to 24X-2, 58–59 cm. Two short intervals, covering Samples 151-908A-28X-5, 57–59 cm, and 28X-6, 57–59 cm, and Samples 151-908A-34X-2, 57–59 cm, to 34X-4, 57–59 cm, are characterized by *Hermesinum acus.* The entire sequence correlates with the *Cannopilus hemisphaericus* Zone of silicoflagellates, which is of late Oligocene age.

Samples 151-908A-35X-5, 9–10 cm, through 37X-2, 57–58 cm, from the basal part of the hole are barren of ebridians and other siliceous flagellates.

Site 913

Hole 913B (75°29.356′N, 06°56.810′W, 3318.4 m of water depth) was drilled in the deep Greenland Basin on oceanic crust slightly older than Anomaly 24B. The site was planned as the northernmost end-member of a transect along the East Greenland margin to investigate the evolution of the East Greenland Current, the formation of deep-water in the Greenland Basin, and the onset of Northern Hemisphere glaciation (Myhre, Thiede, Firth, et al., 1995). The sedimentary sequence recovered was divided into three lithological units. Lithologic Unit I (0–3 mbsf, Quaternary) consists of interbedded clays, silts, sands, and biocarbonate-bearing clays. Lithologic Unit II (3–388 mbsf, Quaternary to Miocene) comprises interbedded clayey to silty muds, silty clays, and clayey silts. Lithologic Unit III (388–770 mbsf, Miocene to Eocene) consists of interbedded massive and laminated silty clays, various biosilica-bearing clayey sediments, laminated clays, and silty clays and muds. Samples studied from Cores 151-913B-19W to 50R revealed that siliceous microfossils are present only in certain intervals, especially in Core 151-913B-19W and Cores 151-913B-24R to 27R. The microfossil assemblages comprise poorly to moderately preserved diatoms, silicoflagellates, ebridians, actiniscidians, chrysophyceans, radiolarians, and sponge spicules.

Silicoflagellates (Table 4)

Samples 151-913B-19W-1, 132–134 cm, through 19W-3, 133–135 cm, are barren of silicoflagellates. Samples 151-913B-19W-4, 76–78 cm, and 19W-4, 144–148 cm, contain rare specimens of *Cannopilus hemisphaericus* and *Distephanus crux,* which suggests an interval above the FAD of *C. hemisphaericus* in Oligocene time (Fig. 2).

The interval from Sample 151-913B-20R-1, 83–87 cm, to 24R-1,115–118 cm, is barren of silicoflagellates. Most peculiar is the occurrence of many radiolarian fragments in Sample 151-913B-24R-1, 115–118 cm, which suggests a horizon of strong reworking.

Samples 151-913B-24R-2, 116–119 cm, to 24R-4, 111–114 cm, contain a few nondiagnostic silicoflagellate skeletons. The sequence from Sample 151-913B-24R-CC to 26R-6, 110–112 cm, displays highly diversified assemblages comprising *Corbisema hexacantha, C. regina, Dictyocha challengeri, Naviculopsis foliacea,* and other species. The consistent occurrence of *C. hexacantha* in these samples indicates the *Corbisema hexacantha* Zone of middle to late Eocene age (Fig. 2).

The interval from Sample 151-913B-26R-CC to 27R-5, 118–122 cm, remains unzoned, because diagnostic silicoflagellates are missing. Samples 151-913B-27R-6, 113–117 cm, through 50R-4, 113–117 cm, are barren of silicoflagellates.

Ebridians and Actiniscidians (Table 5)

Samples 151-913B-19W-1, 132–134 cm, through 19W-3, 133–135 cm, are barren of ebridians and other siliceous flagellates. Samples 151-913B-19W-4, 76–78 cm, and 19W-4, 144–148 cm, are dominated by *Spongebria miocenica* and *Actiniscus pentasterias.* According to the results of analysis of Hole 642C, the occurrence of *Spongebria miocenica* clearly points at a middle Miocene interval around Chron C5B, corresponding to upper Zone NN4 and Zone NN5 (Locker and Martini, 1989).

The sequence from Sample 151-913B-20R-1, 83–87 cm, to 24R-1, 115–118 cm, is barren both of ebridians and other siliceous flagellates. Samples 151-913B-24R-2, 116–119 cm, and 24R-3, 117–120 cm, contain only rare specimens of ebridians and actiniscidians. However, from Sample 151-913B-24R-4, 111–114 cm, to 27R-2, 113–117 cm, highly diversified assemblages follow. Most common are specimens of *Hermesinopsis* sp. B. The entire interval can be characterized by the joint occurrence of three *Ebriopsis* species, under which *Ebriopsis acuta* dominates. The whole sequence correlates, more or less, with the *Corbisema hexacantha* Zone of silicoflagellates, which is of middle to late Eocene age.

The interval from Sample 151-913B-27R-3, 113–117 cm, to 27R-5, 118–122 cm, contains only a few undiagnostic ebridians. Samples 151-913B-27R-6, 113–117 cm, through 50R-4, 113–117 cm, are barren of ebridians and other siliceous flagellates.

PALEOCEANOGRAPHIC IMPLICATIONS

Although DSDP Leg 38 and ODP Leg 104 yielded Paleogene sediments from the Norwegian-Greenland Sea, our knowledge of the early history of this ocean is still very limited. As long as sediment sequences and respective time equivalents are delivered in short fragments, the history can be reconstructed only piece by piece. However, high-resolution studies of sediment sequences recovered during ODP Leg 151 will help to decifer the Paleogene evolution of the Norwegian-Greenland Sea.

Silicoflagellate species are important indicators for paleoenvironmental changes during the past. Special ecological adaptations of species may explain the distribution of warm and cold surface-water masses. Certain species found at different localities may indicate connections between widely separated oceanic regions, either via broad shelf areas or via oceanic gateways.

During the late Cretaceous, the Norwegian-Greenland Sea was probably a shallow and narrow seaway (Ziegler, 1982) with some surface-water exchange to the Arctic Ocean, as indicated by the reworked upper Cretaceous silicoflagellate *Lyramula furcula* found in Miocene–Pliocene sediments of Hole 908A. In the Late Cretaceous, the Arctic Ocean was a high-productivity area that produced high amounts of siliceous plankton, including various silicoflagellate species (see Ling et al., 1973; Bukry, 1981c, 1985b).

The history of the Norwegian-Greenland Sea as a deep ocean started when rifting and drifting commenced in the early Eocene at about 54.7 Ma (Eldholm et al., 1989). From the early middle Eocene, only silicoflagellate assemblages containing *Naviculopsis minor* and *Corbisema spinosa* are known from DSDP Hole 343 (Martini and Müller, 1976), which may be endemic. During late middle and late Eocene, the Norwegian-Greenland Sea was probably well connected to the Arctic Ocean and adjoining regions, as can be deduced from similar silicoflagellate assemblages. Both in Arctic Core Fl-422 (Bukry, 1984) and in Norwegian-Greenland Sea Holes 340 (Martini and Müller, 1976) and 913B, middle to late Eocene silicoflagellate assemblages containing *Corbisema spinosa* and *Corbisema hexacantha* were found.

Some ebridian species provide additional data for paleoceanographic comparisons. The occurrence of *Ammodochium fletcheri* in Hole 913B appears most remarkable, because it was first recorded from Core Fl-422 of the Arctic Ocean (Ling, 1985), which is correlated to the middle to upper Eocene *Corbisema hexacantha* Zone (Bukry, 1984). *Parebriopsis symmetrica,* first described from the upper Eocene to lower Oligocene of Vema Site 43 on the Vøring Plateau (Perch-Nielsen, 1978), was also found in the Eocene sequence of Hole 913B on the East Greenland margin.

The time interval from the late Eocene to the early Oligocene is insufficiently known, although respective sediments have been described from DSDP Holes 338 and 339 (Martini and Müller, 1976). The late Oligocene interval, however, is now well documented by sediments from Hole 908A that contain silicoflagellate assemblages with *Cannopilus hemisphaericus* and *Cannopilus jouseae.* In this context, a special aspect of these assemblages must be discussed.

The late Oligocene assemblages recovered at Site 908 show several fluctuations in their composition. Well preserved assemblages include, beside a host of other species, *Cannopilus hemisphaericus, Dictyocha bryonalis, Distephanus crux, D. paulii, D. speculum,* and *Septamesocena apiculata* subsp. *glabra* (Table 2). Owing to the general habitus of skeletons, these assemblages probably indicate a restricted influence of surface-water from the North Atlantic. This is confirmed by upper Oligocene assemblages found at Silstrup in Denmark that solely include *Cannopilus hemisphaericus, Distephanus crux, Distephanus speculum,* and *Septamesocena apiculata* subsp.

glabra (von Salis, 1993). In contrast, less well-preserved assemblages do not exhibit those species, but they contain *Corbisema lammellifera, Dictyocha carentis, D. deflandrei, D. rotundata,* and *Distephanus antiquus.* This may be explained either by changing preservational conditions or by changing paleoceanographic connections. Since many species of the latter assemblages were thoroughly described from the West Siberian Platform and the Ural Strait (Glezer, 1970), paleoceanographic connections via the Arctic Ocean or the Barents Sea may be indicated.

Some ebridian species contribute additional paleoceanographic data. *Hermesinum geminum,* which is continously present in the deeper part of Hole 908A, was first described from the upper Eocene and the Oligocene of DSDP Hole 280 and from the upper Oligocene of DSDP Hole 278 in the southwestern Pacific (Perch-Nielsen, 1975). It was also indicated for the upper Eocene of the Vøring Plateau in the Norwegian Sea (Perch-Nielsen, 1975, 1978). *Ammodochium pyramidale,* which is present throughout the upper Oligocene of Hole 908A, reaches into the lower and middle Miocene of Hole 642C in the Norwegian Sea (Locker and Martini, 1989).

The assemblages of siliceous flagellates demonstrate that a permanent surface-water exchange may have existed between the Norwegian-Greenland Sea, the Arctic Ocean, and probably also the Barents Sea during Eocene and Oligocene times. Minor surface-water input from the North Atlantic is indicated by certain silicoflagellate species for the late Oligocene.

TAXONOMY

Taxonomic data of silicoflagellates, ebridians, and other siliceous flagellates are presented in an alphabetical list of species, subspecies, and forms. The data were summarized from Loeblich et al. (1968), from Locker (1974), and from DSDP/ODP publications. All taxa were treated as outlined in Locker and Martini (1986).

More than 15 taxa of silicoflagellates and ebridians were recognized as new, but most of them will be described elsewhere. Only three ebridian species that characterize middle to upper Eocene and upper Oligocene assemblages are introduced here as new. They are described according to the requirements of the International Code of Botanical Nomenclature (Greuter, 1994). The holotypes are deposited in the Senckenberg Museum, Frankfurt/Main, Germany.

Silicoflagellates

Genus: *Cannopilus* Haeckel, 1887

Cannopilus hemisphaericus (Ehrenberg, 1845) Haeckel, 1887: Plate 1, fig. 2.
Cannopilus cf. *hemisphaericus* (Ehrenberg, 1845) Haeckel, 1887: Not figured.
Cannopilus jouseae Bachmann in Ichikawa et al., 1964: Plate 1, fig. 3.

Genus: *Corbisema* Hanna, 1928

Corbisema angularis Bukry, 1984: Not figured.
Corbisema apiculata (Lemmermann, 1901) Hanna, 1931: Plate 1, fig. 13.
Corbisema archangelskiana (Schulz, 1928) Frenguelli, 1940: Plate 4, fig. 5.
Corbisema convexa (Bukry, 1978) Locker and Martini, 1986: Plate 1, fig. 4.
Corbisema elata (Glezer, 1962) Locker and Martini, 1987: Plate 1, fig. 7.
Corbisema glezerae Bukry, 1976: Plate 1, fig. 8.
Corbisema globulata (Bukry, 1976) Locker and Martini, 1987: Plate 1, fig. 9.
Corbisema hastata (Lemmermann, 1901) Frenguelli, 1940: Not figured.
Corbisema hexacantha (Schulz, 1928) Deflandre, 1950: Plate 1, fig. 6.
Corbisema katharinae Bukry, 1976: Plate 1, fig. 15.
Corbisema lamellifera subsp. *constricta* (Glezer, 1964): Not figured.
Corbisema lamellifera subsp. *hastata* (Glezer, 1964): Not figured.
Corbisema lamellifera (Glezer, 1962) subsp. *lamellifera:* Plate 1, fig. 14.
Corbisema reducta (Glezer, 1964) n. comb.: Plate 1, fig. 10.
Basionym: *Dictyocha elata* var. *media* f. *reducta* Glezer, 1964; p. 51, pl. 1, fig. 8.
Corbisema regina Bukry, 1984: Plate 1, fig. 11.
Corbisema spinosa Deflandre, 1950: Plate 1, fig. 5.
Corbisema toxeuma Bukry, 1978: Not figured.
Corbisema triacantha s.l. (Ehrenberg, 1845) Hanna, 1931: Plate 1, fig. 12.
Corbisema cf. *triacantha* (Ehrenberg, 1845) Hanna, 1931: Not figured.
Corbisema sp. A: Plate 1, fig. 16.
Description: Basal ring constructed of basal bars which are strongly curved to the outside. Basal bars without basal pikes. Apical structure consisting of three bars which arise moderately and meet in the center.
Corbisema spp.
Remarks: This category includes rare occurences of *C. glezerae, C. regina,* and *C. toxeuma* in Hole 908A, and of *C. convexa, C. globulata, C. lamellifera,* and *C. reducta* in Hole 913B.

Genus: *Dictyocha* Ehrenberg, 1840

Dictyocha bryonalis Bukry, 1984 subsp. *bryonalis:* Plate 2, fig. 5.
Dictyocha bryonalis subsp. A: Plate 2, fig. 6.
Description: Basal ring rhomboidal and with distinctly inflected basal bars. Basal bars often without basal pikes. Apical structure consisting of a short apical bar and four struts. Apical bar aligned with the short axis and twisted anticlockwise.
Dictyocha carentis (Glezer, 1964) subsp. *carentis* n. comb.: Plate 2, fig. 1.
Basionym: *Dictyocha frenguellii* var. *carentis* Glezer, 1964; p. 52, pl. 1, figs. 12–16.
Dictyocha carentis subsp. *incerta* (Glezer, 1964) n. comb.: Plate 2, fig. 2.
Basionym: *Dictyocha frenguellii* var. *carentis* f. *incerta* Glezer, 1964; p. 52, pl. 1, figs. 15–16.
Dictyocha challengeri Martini and Müller, 1976: Plate 4, fig. 4.
Dictyocha deflandrei Frenguelli ex Glezer, 1966: Plate 2, fig. 3.
Dictyocha eocaenica (Krotov ex Glezer, 1960) Martini, 1981: Plate 4, fig. 7.
Dictyocha fibula Ehrenberg, 1840: Not figured.
Dictyocha fibula s.l. Ehrenberg, 1840: Not figured.
Dictyocha frenguellii Deflandre, 1950: Plate 2, fig. 7.
Dictyocha martinii (Bukry, 1975) n. comb.: Not figured.
Basionym: *Dictyocha aspera* subsp. *martinii* Bukry, 1975; p. 854, pl. 2, figs. 5–8.
Dictyocha cf. *mutabilis* Deflandre, 1950: Not figured.
Dictyocha obliqua Glezer, 1964: Plate 2, fig. 10.
Dictyocha precarentis Bukry, 1976: Plate 2, fig. 8.
Dictyocha rotundata Jouse, 1955 subsp. *rotundata:* Plate 2, fig. 4.
Dictyocha rotundata subsp. *secta* (Glezer, 1962) n. comb.: Not figured.
Basionym: *Dictyocha rotundata* var. *secta* Glezer, 1962; p. 152, figs. 5z–k.
Dictyocha transitoria Deflandre, 1932: Plate 2, fig. 9.
Dictyocha sp. A: Plate 3, fig. 11.
Description: Basal ring elongated rhomboidal and with straight basal bars. Basal bars relatively thick and with basal pikes. Apical structure consisting of an apical bar and four struts. Apical bar aligned with the long axis and strikingly thin.
Dictyocha sp. B: Plate 4, fig. 6.
Description: Basal ring elongated ovoidal. Basal bars without basal pikes. Apical structure consisting of a short apical bar and four struts. Apical bar aligned with the short axis. Radial spines only along the long axis of the basal ring.
Dictyocha spp.
Remarks: This category includes rare occurrences of *D. eocaenica* in Hole 908A, and of *D. precarentis, D. rotundata,* and *D. transitoria* in Hole 913B.

Genus: *Distephanus* Stöhr, 1880

Distephanus antiquus Glezer, 1964: Plate 2, fig. 11.
Distephanus crux (Ehrenberg, 1841) Haeckel, 1887 subsp. *crux:* Plate 3, fig. 1.
Distephanus crux subsp. A: Plate 3, fig. 2.
Description: Basal ring rhomboidal composed of irregularly inflected basal bars. Basal bars with basal pikes. Apical structure consisting of a large apical ring and four struts. Radial spines relatively long.
Distephanus norvegiensis Perch-Nielsen, 1976: Plate 2, fig. 12.
Distephanus paulii (Shaw and Ciesielski, 1983) n. comb.: Plate 3, fig. 3.
Basionym: *Distephanus crux* subsp. *paulii* Shaw and Ciesielski, 1983; p. 713, pl. 11, figs. 2–3, 5–6.
Distephanus speculum f. *pentagonus* (Lemmermann, 1901) Locker and Martini, 1986: Plate 2, fig. 13.
Distephanus speculum f. *schulzii* n. nom.: Plate 2, fig. 14.
Remarks: This form is regarded as a variant of *Distephanus speculum.* Since *Distephanus speculum* var. *pentagonus* Lemmermann, 1901 is preoccupied by forms with an apical ring, for the taxon *Dictyocha fib-*

ula var. *pentagona* Schulz, 1928 the new name *Distephanus speculum* f. *schulzii* is proposed.

Basionym: *Dictyocha fibula* var. *pentagona* Schulz, 1928; p. 255, figs. 41a–b.

Distephanus speculum f. *septenarius* (Ehrenberg, 1845) Locker and Martini, 1986: Plate 2, fig. 16.

Distephanus speculum (Ehrenberg, 1840) Haeckel, 1887 f. *speculum:* Plate 2, fig. 15.

Distephanus speculum (Ehrenberg, 1840), diverse forms

Distephanus speculum (Ehrenberg, 1840) fenestrate forms

Genus: *Lyramula* Hanna, 1928

Lyramula furcula Hanna, 1928: Plate 1, fig. 1.

Genus: *Mesocena* Ehrenberg, 1841

Mesocena quadrangula Ehrenberg ex Haeckel, 1887: Plate 3, fig. 12.

Genus: *Naviculopsis* Frenguelli, 1940

Naviculopsis aspera (Schulz, 1928) Perch-Nielsen, 1976: Plate 3, fig. 5.

Naviculopsis biapiculata (Lemmermann, 1901) Frenguelli, 1940: Plate 3, fig. 6.

Naviculopsis constricta (Schulz, 1928) Frenguelli, 1940: Plate 3, fig. 10.

Naviculopsis aff. *constricta* (Schulz, 1928) Frenguelli, 1940: Plate 3, fig. 7.

Naviculopsis danica Perch-Nielsen, 1976: Plate 3, fig. 13.

Naviculopsis eobiapiculata Bukry, 1978: Plate 3, fig. 9.

Naviculopsis foliacea Deflandre, 1950: Plate 3, fig. 8.

Naviculopsis minor (Schulz, 1928) Frenguelli, 1940: Plate 3, fig. 4.

Naviculopsis punctilia Perch-Nielsen, 1976: Not figured.

Naviculopsis spp.

Remarks: This category includes rare occurrences of *N. danica, N. foliacea,* and *N. punctilia* in Hole 908A, and of *N. minor* in Hole 913B.

Genus: *Septamesocena* Bachmann, 1970

Septamesocena apiculata (Schulz, 1928) Bachmann, 1970 subsp. *apiculata:* Plate 4, fig. 2.

Septamesocena apiculata subsp. *evexa* Bukry, 1985: Plate 4, fig. 3.

Septamesocena apiculata subsp. *glabra* (Schulz, 1928) n. comb.: Plate 4, fig. 1.

Basionym: *Mesocena polymorpha* var. *triangula* f. *glabra* Schulz, 1928; p. 237, figs. 3b–c.

Septamesocena oamaruensis (Schulz, 1928) n. comb.: Not figured.

Basionym: *Mesocena oamaruensis* Schulz, 1928; p. 240, figs. 10a–b.

Ebridians

Genus: *Ammodochium* Hovasse, 1932

Ammodochium danicum Deflandre, 1951: Plate 5, fig. 1.

Ammodochium complexum Dumitrica and Perch-Nielsen, 1978: Not figured.

Ammodochium doliolum Hovasse, 1932: Plate 5, fig. 5.

Ammodochium fletcheri Ling, 1985: Plate 5, fig. 4.

Ammodochium novum Perch-Nielsen, 1978: Plate 5, fig. 13.

Ammodochium pyramidale Hovasse, 1943: Plate 5, fig. 3.

Ammodochium rectangulare (Schulz, 1928) Deflandre, 1933: Plate 5, fig. 2.

Ammodochium serotinum Locker and Martini, 1986: Plate 5, fig. 12.

Ammodochium sp. A: Plate 5, fig. 6.

Description: Barrel-like skeletons. Proclades and opisthoclades pierced by large openings. Triode in lateral view with small openings near the margin.

Ammodochium spp.

Remarks: This category includes mainly undetermined specimens, but also some occurrences of *A.fletcheri* in Hole 908A, and of *A. complexum* in Holes 908A and 913B.

Genus: *Ditripodium* Hovasse, 1932

Ditripodium amphora Hovasse, 1943: Not figured.

Ditripodium latum Hovasse, 1932: Plate 6, fig. 11.

Ditripodium spp.

Remarks: The few occurrences of *D. amphora* and *D. latum* in Hole 908A are summarized in this category.

Genus: *Ebriopsis* Hovasse, 1932

Ebriopsis antiqua (Schulz, 1928) Hovasse, 1932: Plate 6, fig. 2.

Ebriopsis crenulata Hovasse, 1932: Plate 6, fig. 3.

Ebriopsis sp. A: Plate 6, fig. 5.

Description: Skeletons circular or ovoidal in outline and distinctly compressed. Clades twisted in such a manner that two pseudotriodes arise.

Ebriopsis spp.

Remarks: This category includes unidentified specimens from Hole 913B.

Genus: *Falsebria* Deflandre, 1951

Falsebria ambigua Deflandre, 1951: Not figured.

Falsebria rossica Deflandre, 1950: Plate 5, fig. 28.

Genus: *Haplohermesinum* Hovasse, 1943

Haplohermesinum cornuta (Dumitrica and Perch-Nielsen, 1975) n. comb.: Plate 5, fig. 19.

Basionym: *Ebriopsis cornuta* Dumitrica and Perch-Nielsen, 1975; Perch-Nielsen (1975), p. 880, pl. 2, figs. 8–9.

Haplohermesinum hovassei Locker and Martini, 1989: Plate 5, fig. 20.

Haplohermesinum sp. A: Plate 5, fig. 21.

Description: Skeletons basket-like. One opisthocladian opening is reduced so that the skeleton appears asymmetrical.

Genus: *Hermesinella* Deflandre, 1934

Hermesinella conata (Deflandre, 1951) Locker and Martini, 1986: Plate 5, fig. 14.

Hermesinella fenestrata Frenguelli, 1951: Plate 5, fig. 16.

Hermesinella schulzii (Hovasse, 1932) Locker and Martini, 1989: Plate 5, fig. 17.

Hermesinella cf. *transversa* Deflandre, 1934: Plate 5, fig. 18.

Hermesinella spp.

Remarks: This category includes unidentified specimens from Hole 913B.

Genus: *Hermesinopsis* Deflandre, 1934

Hermesinopsis aplanata (Deflandre, 1950) n. comb.: Plate 5, fig. 26.

Basionym: *Ebriopsis aplanata* Deflandre, 1950; p. 159, figs. 1–2.

Hermesinopsis cf. *caulleryi* Deflandre, 1934: Plate 5, fig. 22.

Hermesinopsis exigua (Deflandre, 1951) n. comb.: Plate 5, fig. 23.

Basionym: *Ebriopsis exigua* Deflandre, 1951; p. 27, 66, figs. 62–64.

Hermesinopsis valida (Deflandre, 1934) n. comb.: Plate 5, fig. 25.

Basionym: *Parebria valida* Deflandre, 1934; p. 91, figs. 33–36.

Hermesinopsis sp. A: Plate 6, fig. 4.

Description: Small skeletons ovoidal and with distinct indentions at the margin. Opisthocladian openings have different size.

Hermesinopsis sp. B: Plate 5, fig. 24.

Description: Small skeletons basket-like and elongated. Syncladal ring pierced by a set of small openings. Actines of the triaene often with a small opening at the margin.

Hermesinopsis spp.

Remarks: This category includes mainly unidentified specimens of Holes 908A and 913B, but also some occurrences of *H. valida* in Hole 913B.

Genus: *Hermesinum* Zacharias, 1906

Hermesinum geminum Dumitrica and Perch-Nielsen, 1975: Plate 6, fig. 7.

Hermesinum obliquum Locker and Martini, 1986: Plate 6, fig. 6.

Genus: *Hovassebria* Deflandre, 1936

Hovassebria brevispinosa (Hovasse, 1932) Deflandre, 1936: Plate 5, fig. 29.

Genus: *Parebriopsis* Hovasse, 1932

Parebriopsis symmetrica Dumitrica and Perch-Nielsen, 1978: Plate 5, fig. 27.

Genus: *Pseudammodochium* Hovasse, 1932

Pseudammodochium dictyoides Hovasse, 1932: Plate 5, fig. 7.

Pseudammodochium eximium Deflandre, 1951: Plate 5, fig. 8.
Pseudammodochium sp. A: Plate 5, fig. 10.
Description: Skeletons urn-like and somewhat elongated. Wall relatively thick and pierced by many small pores. Triode thick and without pores near the margin.
Pseudammodochium sp. B: Plate 5, fig. 11.
Description: Skeletons broadly urn-like. Wall relatively thick and pierced with a resticted number of large pores. Triode thick and with pores near the margin.
Pseudammodochium sp. C: Plate 5, fig. 9.
Description: Skeletons urn-like and strongly elongated. Wall thin and pierced by many small pores. Triode thin and without pores near the margin.
Pseudammodochium spp.
Remarks: This category includes mainly unidentified specimens of Holes 908A and 913B.

Genus: *Spongebria* Deflandre, 1950

Spongebria curta Locker and Martini, 1989: Plate 6, fig. 10.
Spongebria marthae Deflandre, 1950: Plate 5, fig. 30.
Spongebria miocenica Locker and Martini, 1989: Plate 6, fig. 16.

Genus: *Thranium* Hovasse, 1932

Thranium sp.: Plate 6, fig. 17.

Actiniscidians

Genus: *Actiniscus* Ehrenberg, 1841

Actiniscus elongatus Dumitrica, 1968: Plate 6, fig. 12.
Actiniscus cf. *elongatus* Dumitrica, 1968: Not figured.
Actiniscus pentasterias s.l. Ehrenberg, 1841: Plate 6, fig. 15.

Genus: *Carduifolia* Hovasse, 1932

Carduifolia gracilis Hovasse, 1932: Plate 6, fig. 19.
Carduifolia lata Hovasse, 1932: Plate 6, fig. 13.
Carduifolia onopordoides Hovasse, 1932: Plate 6, fig. 18.
Carduifolia spp.
Remarks: This category includes unidentified specimens of Hole 908A, but also rare occurrences of *C. lata*.

Genus: *Foliactiniscus* Dumitrica, 1973

Foliactiniscus atlanticus Perch-Nielsen, 1978: Plate 6, fig. 14.

Synuraceans

Genus: *Macrora* Hanna, 1932

Macrora stella (Azpeitia, 1911) Hanna, 1932: Plate 6, fig. 20.

DESCRIPTION OF NEW TAXA

Ebriopsis acuta n. sp.

Holotype: SM.B 16144; Plate 6, Fig. 1.
Type locality: Site 913, East Greenland margin, Sample 151-913B-25R-1, 114–117 cm, middle to upper Eocene.
Diagnosis: Skeletons drop-like in outline and distinctly compressed. Clades twisted in such a manner that two pseudotriodes arise.
Remarks: This species is clearly differentiated against other species of the genus by its drop-like outline.
Occurrence: Consistently found from Sample 151-913B-24R-4, 111–114 cm, to 27R-2, 113–117 cm. Nominate species of the *Ebriopsis acuta* Assemblage, middle to upper Eocene.

Hermesinella paraconata n. sp.

Holotype: SM.B 16145; Plate 5, Fig. 15.
Type locality: Site 908, Fram Strait, Sample 151-908A-21X-6, 57–58 cm, upper Oligocene.
Diagnosis: Skeletons basket-like. One set of proclades and opisthoclades is strongly reduced to a broad tip pierced by a small opening.
Remarks: This species is differentiated against other species of the genus by one strongly reduced set of proclades and opisthoclades.
Occurrence: Found from Sample 151-908A-21X-5, 56–57 cm, to 24X-2, 58–59 cm. Nominate species of the *Hermesinella paraconata* Assemblage, upper Oligocene.

Hermesinum acus n. sp.

Holotype: SM.B 16146, Plate 6, Figs. 8, 9.
Type locality: Site 908, Fram Strait, Sample 151-908A-28X-6, 57–59 cm, upper Oligocene.
Diagnosis: Skeletons needle-like. Proclades strongly reduced to a knob-like set of bars.
Remarks: There is no other species of the genus that has such a strongly reduced skeleton, like a needle in appearance.
Occurrence: Found in two distinct intervals, in Samples 151-908A-28X-5, 57–59 cm, and 28X-6, 57–59 cm, and in Samples 151-908A-34X-2, 57–59 cm, to 34X-4, 57–59 cm. Nominate species of the *Hermesinum acus* Assemblages, upper Oligocene.

ACKNOWLEDGMENTS

Thanks are due the Deutsche Forschungsgemeinschaft, Bonn, for supporting the present study. I gratefully acknowledge various discussions with D. Spiegler and T. Wolf, both of Kiel, and E. Martini, Frankfurt. Also helpful were discussions with the members of the Kiel Postcruise Meeting. I thank E. Martini, Frankfurt, K. von Salis, Zurich, and an unknown reviewer for their careful reviews.

REFERENCES

Backman, J., 1984. Cenozoic calcareous nannofossil biostratigraphy from the northeastern Atlantic Ocean—Deep Sea Drilling Project Leg 81. *In* Roberts, D.G., and Schnitker, D., et al., *Init. Repts. DSDP,* 81: Washington (U.S. Govt. Printing Office), 403–428.

Barron, J.A., Bukry, D., and Poore, R.Z., 1984. Correlation of the middle Eocene Kellogg Shale of northern California. *Micropaleontology,* 30:138–170.

Bleil, U., 1989. Magnetostratigraphy of Neogene and Quaternary sediment series from the Norwegian Sea: Ocean Drilling Program, Leg 104. *In* Eldholm, O., Thiede, J., Taylor, E., et al., *Proc. ODP, Sci. Results,* 104: College Station, TX (Ocean Drilling Program), 829–901.

Bukry, D., 1975. Silicoflagellate and coccolith stratigraphy, Deep Sea Drilling Project, Leg 29. *In* Kennett, J.P., Houtz, R.E., et al., *Init. Repts. DSDP,* 29: Washington (U.S. Govt. Printing Office), 845–872.

————, 1978a. Cenozoic coccolith and silicoflagellate stratigraphy, offshore northwest Africa, Deep Sea Drilling Project Leg 41. *In* Lancelot, Y., Seibold, E., et al., *Init. Repts. DSDP,* 41: Washington (U.S. Govt. Printing Office), 689–707.

————, 1978b. Cenozoic coccolith, silicoflagellate, and diatom stratigraphy, Deep Sea Drilling Project Leg 44. *In* Bensen, W.E., Sheridan, R.E., et al., *Init. Repts. DSDP,* 44: Washington (U.S. Govt. Printing Office), 807–863.

————, 1978c. Cenozoic silicoflagellate and coccolith stratigraphy, northwestern Atlantic Ocean, Deep Sea Drilling Project Leg 43. *In* Bensen, W.E., Sheridan, R.E., et al., *Init. Repts. DSDP,* 44: Washington (U.S. Govt. Printing Office), 775–805.

————, 1979. Coccolith and silicoflagellate stratigraphy, northern Mid-Atlantic Ridge and Reykjanes Ridge, Deep Sea Drilling Project Leg 49. *In* Luyendyk, B.P., Cann, J.R., et al., *Init. Repts. DSDP,* 49: Washington (U.S. Govt. Printing Office), 551–581.

————, 1981a. Silicoflagellate stratigraphy of offshore California and Baja California, Deep Sea Drilling Project Leg 63. *In* Yeats, R.S., Haq, B.U., et al., *Init. Repts DSDP,* 63: Washington (U.S. Govt. Printing Office), 539–557.

————, 1981b. Synthesis of silicoflagellate stratigraphy for Maestrichtian to Quaternary marine sediments. *In* Warme, T.E., Douglas, R.C., and Winterer, E.L. (Eds.), *The Deep Sea Drilling Project: A Decade of Progress.* Spec. Publ.—Soc. Econ. Paleontol. Mineral., 32:433–444.

———, 1981c. Cretaceous Arctic silicoflagellates. *Geo-Mar. Lett.,* 1:57–63.
———, 1984. Paleogene paleoceanography of the Arctic Ocean is constrained by the middle or late Eocene age of USGS Core Fl-422: evidence from silicoflagellates. *Geology,* 12:199–201.
———, 1985a. Cenozoic silicoflagellates from Rockall Plateau, Deep Sea Drilling Project Leg 81. *In* Roberts, D.G., Schnitker, D., et al., *Init. Repts. DSDP,* 81: Washington (U.S. Govt. Printing Office), 547–563.
———, 1985b. Correlation of late Cretaceous Arctic silicoflagellates from Alpha Ridge. *In* Jackson, H.R., Mudie, P.J., and Blasco, S.M. (Eds.), *Pap.—Geol. Surv. Can.,* 84–22:125–135.
———, 1987. Eocene siliceous and calcareous phytoplankton, Deep Sea Drilling Project Leg 95. *In* Poag, C.W., Watts, A.B., et al., *Init. Repts. DSDP,* 95: Washington (U.S. Govt. Printing Office), 395–415.
Cande, S.C., and Kent, D.V., 1992. A new geomagnetic polarity time scale for the Late Cretaceous and Cenozoic. *J. Geophys. Res.,* 97:13917–13951.
Deflandre, G., 1934. Nomenclature du squelette des Ebriacées et description de quelques formes nouvelles. *Ann. Protist.,* 4:75–96.
———, 1950. Contribution a l'étude des silicoflagellidés actuels et fossiles. *Microscopie,* 2:117–142.
———, 1951. Recherches sur les ébriédiens: paléo-biologie, evolution, systématique. *Bull. Biol. Fr. Belg.,* 85:1–84.
Eldholm, O., Thiede, J., and Taylor, E., 1989. Evolution of the Vøring volcanic margin. *In* Eldholm, O., Thiede, J., Taylor, E., et al., *Proc. ODP, Sci. Results,* 104: College Station, TX (Ocean Drilling Program), 1033–1065.
Eldholm, O., Thiede, J., Taylor, E., et al., 1989. *Proc. ODP, Sci. Results,* 104: College Station, TX (Ocean Drilling Program).
Glezer, Z.I., 1962. K voprosu o filogeneze kremnevykh zhgutikovykh vodoroslei (On the phylogeny of silicoflagellates). *Paleontol. Zhurnal,* 1:146–156.
———, 1964. Novye kremnevye zhgutikovye vodorsl:paleogena SSSR. *Akad. Nauk. SSSR, Novosti Sistematiki Rasteniy, Otdel. Ottisk,* 46–58.
———, 1970. Silicoflagellatophyceae. *In* Gollerbakh, M.M. (Ed.), *Cryptogamic Plants of the USSR:* Jerusalem (Israel Program for Scientific Translations).
Greuter, W. (Ed.), 1994. *International Code of Botanical Nomenclature.* Reg. Vegetab., 131:1–120.
Lemmermann, E., 1901. Silicoflagellatae. *Ber. Dtsch. Bot. Ges.,* 19:247–271.
Ling, H.Y., 1977. Late Cenozoic silicoflagellates and ebridians from the eastern North Pacific region. *In* Saito, T., and Ujiie, H. (Eds.), *Proc. First Int. Congr. Pacific Neogene Stratigraphy,* 1:205–233.
———, 1985. Early Paleogene silicoflagellates and ebridians from the Arctic Ocean. *Trans. Proc. Paleontol. Soc. Jpn.,* 138: 79–93.
Ling, H.Y., McPherson, L.M., and Clark, D.L., 1973. Late Cretaceous (Maestrichtian?) silicoflagellates from the Alpha Cordillera of the Arctic Ocean. *Science,* 180:1360–1361.
Locker, S., 1974. Revision der Silicoflagellaten aus der Mikrogeologischen Sammlung von C.G. Ehrenberg. *Eclogae Geol. Helv.,* 67:631–646.
Locker, S., and Martini, E., 1986. Silicoflagellates and some sponge spicules from the southwest Pacific, DSDP Leg 90. *In* Kennett, J.P., von der Borch, C.C., et al., *Init. Repts. DSDP,* 90: Washington (U.S. Govt. Printing Office), 887–924.
———, 1989. Cenozoic silicoflagellates, ebridians, and actiniscidians from the Vøring Plateau (ODP Leg 104). *In* Eldholm, O., Thiede, J., Taylor, E., et al., *Proc. ODP, Sci. Results,* 104: College Station, TX (Ocean Drilling Program), 543–585.
Loeblich, A., III, Loeblich, L.A., Tappan, H., and Loeblich, A.R., Jr., 1968. Annotated index of fossil and recent silicoflagellates and ebridians with descriptions and illustrations of validly proposed taxa. *Mem.—Geol. Soc. Am.,* 106:1–319.
Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In* Farinacci, A. (Ed.), *Proc. 2nd Int. Conf. Planktonic Microfossils Roma:* Rome (Ed. Tecnosci.), 2:739–785.
———, 1979. Calcareous nannoplankton and silicoflagellate biostratigraphy at Reykjanes Ridge, northeastern North Atlantic (DSDP Leg 49, Sites 407 and 409). *In* Luyendyk, B.P., Cann, J.R., et al., *Init. Repts. DSDP,* 49: Washington (U.S. Govt. Printing Office), 533–549.
Martini, E., and Müller, C., 1976. Eocene to Pleistocene silicoflagellates from the Norwegian-Greenland Sea (DSDP Leg 38). *In* Talwani, M., Udintsev, G., et al., *Init. Repts. DSDP,* 38: Washington (U.S. Govt. Printing Office), 857–895.
Müller, C., 1970. Nannoplankton-Zonen der Unteren Meeresmolasse Bayerns. *Geol. Bavar.,* 63:107–118.
———, 1976. Tertiary and Quaternary calcareous nannoplankton in the Norwegian-Greenland Sea, DSDP, Leg 38. *In* Talwani, M., Udintsev, G., et al., *Init. Repts. DSDP,* 38: Washington (U.S. Govt. Printing Office), 823–841.
———, 1979. Calcareous nannofossils from the North Atlantic (Leg 48). *In* Montadert, L., Roberts, D.G., et al., *Init. Repts. DSDP,* 48: Washington (U.S. Govt. Printing Office), 589–639.
Myhre, A.M., Thiede, J., Firth, J.V., et al., 1995. *Proc. ODP, Init. Repts.,* 151: College Station, TX (Ocean Drilling Program).
Okada, H., and Bukry, D., 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). *Mar. Micropaleontol.,* 5:321–325.
Perch-Nielsen, K., 1975. Late Cretaceous to Pleistocene archaeomonads, ebridians, endoskeletal dinoflagellates, and other siliceous microfossils from the subantarctic southwest Pacific, DSDP, Leg 29. *In* Kennett, J.P., Houtz, R.E., et al., *Init. Repts. DSDP,* 29: Washington (U.S. Govt. Printing Office), 873–907.
———, 1978. Eocene to Pliocene archaeomonads, ebridians, and endoskeletal dinoflagellates from the Norwegian Sea, DSDP Leg 38. *In* Talwani, M., Udintsev, G., et al., *Init. Repts. DSDP,* 38 (Suppl.): Washington (U.S. Govt. Printing Office), 147–175.
———, 1985. Silicoflagellates. *In* Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 811–846.
Schulz, P., 1928. Beiträge zur Kenntnis fossiler und rezenter Silicoflagellaten. *Bot. Arch.,* 21:225–292.
Shaw, C.A., and Ciesielski, P.F., 1983. Silicoflagellate biostratigraphy of middle Eocene to Holocene subantarctic sediments recovered by Deep Sea Drilling Project Leg 71. *In* Ludwig, W.J., Krasheninnikov, V.A., et al., *Init. Repts. DSDP,* 71 (Pt. 2): Washington (U.S. Govt. Printing Office), 687–737.
Talwani, M., Udintsev, G., et al., 1976. *Init. Repts. DSDP,* 38: Washington (U.S. Govt. Printing Office).
von Salis, K., 1993. First Oligocene silicoflagellates from N. Europe (Silstrup, Denmark). *Zitteliana,* 20:79–86.
Wei, W., and Peleo-Alampay, A., 1993. Updated Cenozoic nannofossil magnetobiochronology. *INA. Newsl.,* 15:15–21.
Ziegler, P.A., 1982. *Geological Atlas of Western and Central Europe:* The Hague (Shell International Petroleum).

Date of initial receipt: 11 July 1995
Date of acceptance: 24 January 1996
Ms 151SR-102

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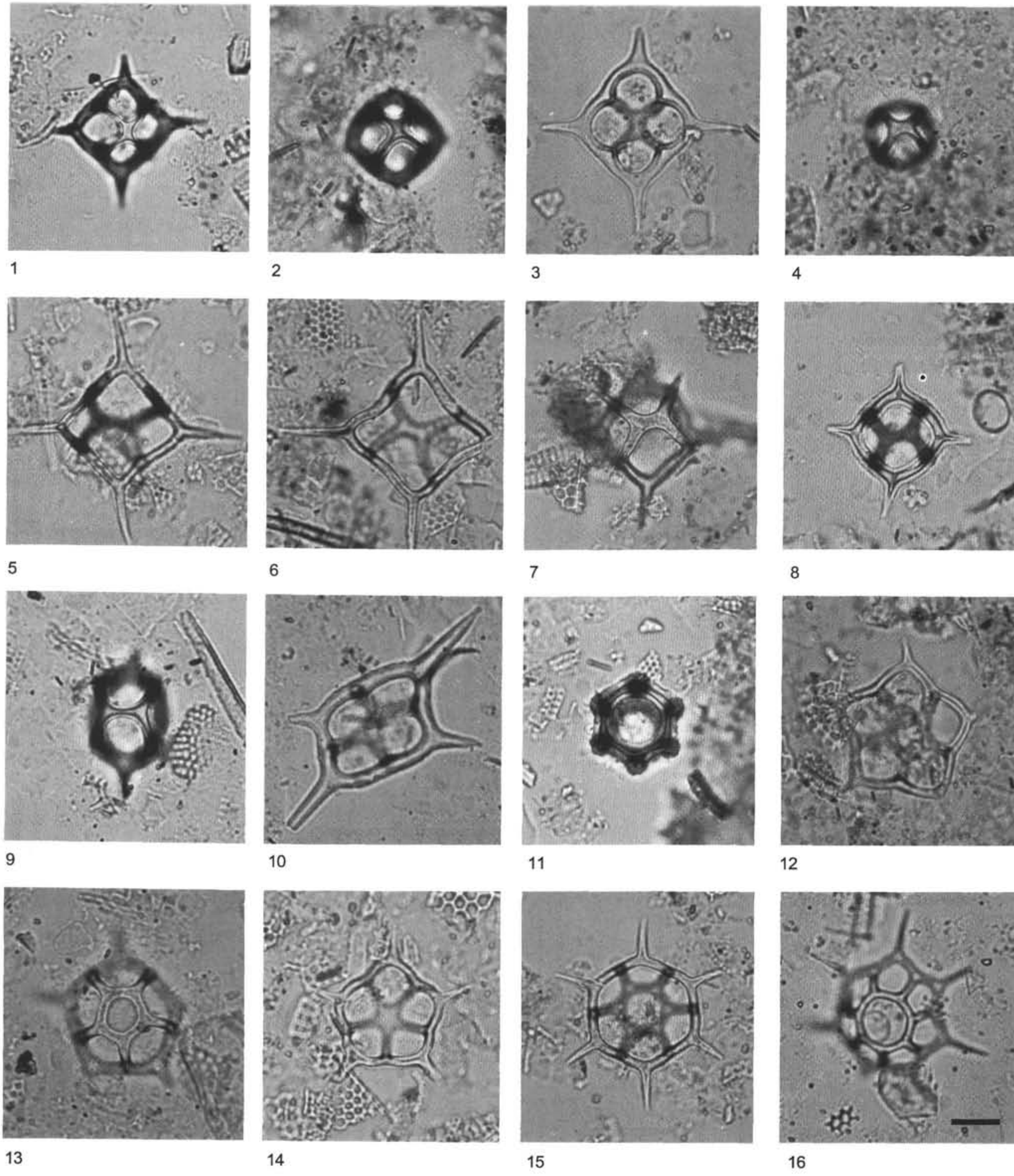


Plate 1. Middle to upper Eocene, upper Oligocene, and Miocene–Pliocene silicoflagellates. All specimens magnified 800×, bar = 10 um. **1.** *Lyramula furcula* Hanna, Sample 151-908A-18X-3, 58–60 cm, Miocene–Pliocene. **2.** *Cannopilus hemisphaericus* (Ehrenberg), Sample 151-908A-23X-4, 59–60 cm, Oligocene. **3.** *Cannopilus jouseae* Bachmann, Sample 151-908A-28X-4, 56–58 cm, Oligocene. **4.** *Corbisema convexa* (Bukry), Sample 151-908A-18X-2, 58–60 cm, Miocene–Pliocene. **5.** *Corbisema spinosa* Deflandre, Sample 151-908A-28X-6, 57–59 cm, Oligocene. **6.** *Corbisema hexacantha* (Schulz), Sample 151-913B-25R-2, 114–117 cm, Eocene. **7.** *Corbisema elata* (Glezer), Sample 151-913B-24R-CC, Eocene. **8.** *Corbisema glezerae* Bukry, Sample 151-908A-27X-3, 57–60 cm, Oligocene. **9.** *Corbisema globulata* (Bukry), Sample 151-908A-23X-2, 59–60 cm, Oligocene. **10.** *Corbisema reducta* (Glezer), Sample 151-908A-21X-4, 56–57 cm, Oligocene. **11.** *Corbisema regina* Bukry, Sample 151-913B-26R-6, 110–112 cm, Eocene. **12.** *Corbisema triacantha* (Ehrenberg), Sample 151-908A-24X-2, 58–59 cm, Oligocene. **13.** *Corbisema apiculata* (Lemmermann), Sample 151-908A-25X-2, 56–60 cm, Oligocene. **14.** *Corbisema lamellifera* (Glezer) subsp. *lamellifera*, Sample 151-908A-17X-2, 52–54 cm, Miocene–Pliocene. **15.** *Corbisema katharinae* Bukry, Sample 151-913B-26R-5, 113–115 cm, Eocene. **16.** *Corbisema* sp. A, Sample 151-913B-26R-5, 113–115 cm, Eocene.

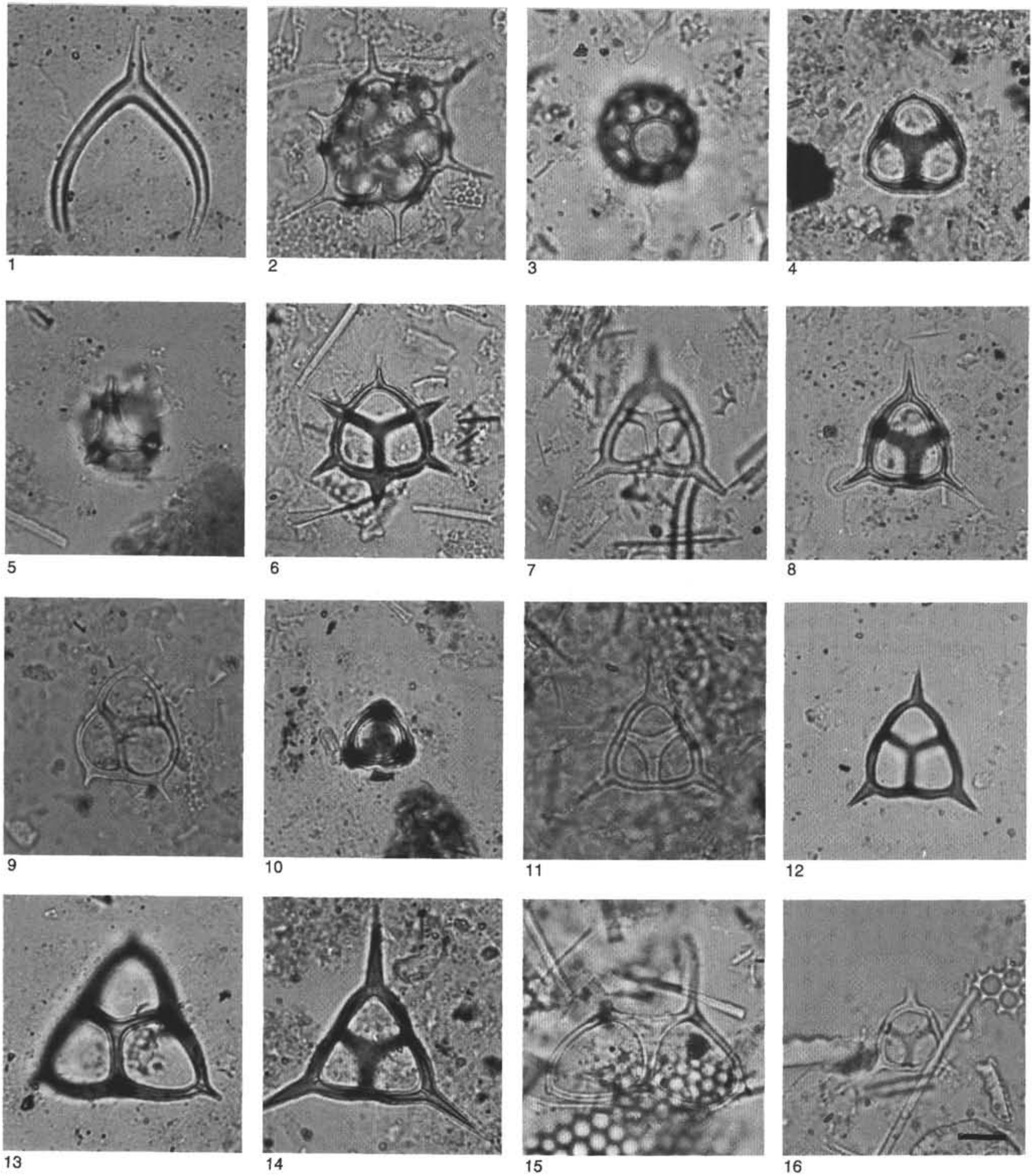


Plate 2. Upper Oligocene and Miocene–Pliocene silicoflagellates. All specimens magnified 800×, bar = 10 um. **1.** *Dictyocha carentis* (Glezer) subsp. *carentis,* Sample 151-908A-25X-1, 56–60 cm, Oligocene. **2.** *Dictyocha carentis* subsp. *incerta* (Glezer), Sample 151-908A-20X-5, 57–60 cm, Miocene–Pliocene. **3.** *Dictyocha deflandrei* Frenguelli, Sample 151-908A-30X-3, 57–59 cm, Oligocene. **4.** *Dictyocha rotundata* Jouse subsp. *rotundata*, Sample 151-908A-17X-2, 52–54 cm, Miocene–Pliocene. **5.** *Dictyocha bryonalis* Bukry subsp. *bryonalis,* Sample 151-908A-33X-2, 57–59 cm, Oligocene. **6.** *Dictyocha bryonalis* subsp. A, Sample 151-980A-32X-1, 57–58 cm, Oligocene. **7.** *Dictyocha frenguellii* Deflandre, Sample 151-908A-30X-2, 10–12 cm, Oligocene. **8.** *Dictyocha precarentis* Bukry, Sample 151-908A-32X-4, 58–59 cm, Oligocene. **9.** *Dictyocha transitoria* Deflandre, Sample 151-908A-24X-6, 58–59 cm, Oligocene. **10.** *Dictyocha obliqua* Glezer, Sample 151-908A-22X-4, 57–59 cm, Oligocene. **11.** *Distephanus antiquus* Glezer, Sample 151-908A-28X-5, 57–59 cm, Oligocene. **12.** *Distephanus norvegiensis* Perch-Nielsen, Sample 151-908A-27X-3, 57–60 cm, Oligocene. **13.** *Distephanus speculum* f. *pentagonus* (Lemmermann), Sample 151-908A-27X-5, 57–60 cm, Oligocene. **14.** *Distephanus speculum* f. *schulzii* n. nom., Sample 151-908A-34X-3, 57–59 cm, Oligocene. **15.** *Distephanus speculum* (Ehrenberg) f. *speculum,* Sample 151-908A-25X-4, 55–59 cm, Oligocene. **16.** *Distephanus speculum* f. *septenarius* (Ehrenberg), Sample 151-908A-24X-4, 58–59 cm.

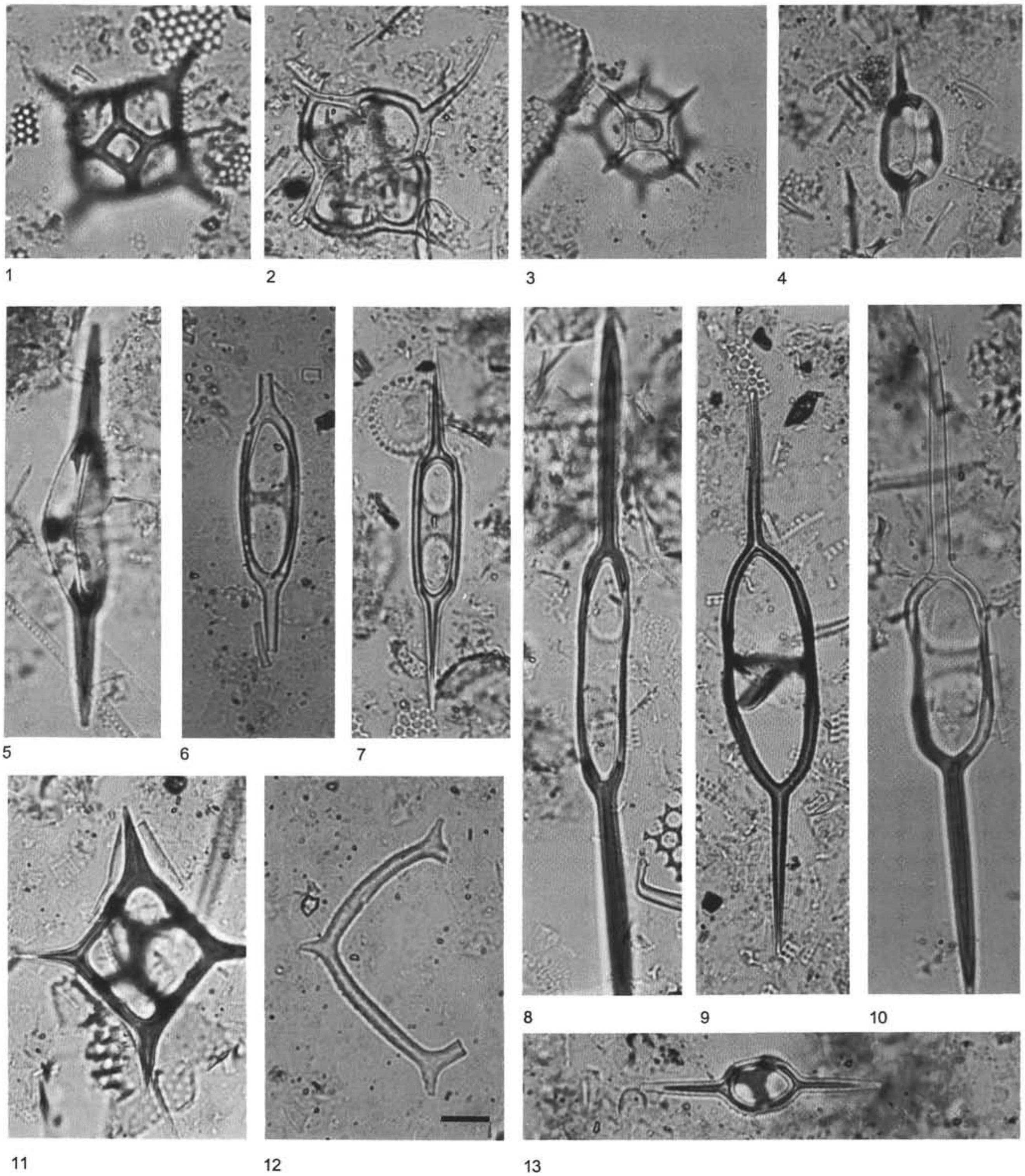


Plate 3. Middle to upper Eocene and upper Oligocene silicoflagellates. All specimens magnified 800×, bar = 10 um. **1.** *Distephanus crux* (Ehrenberg) subsp. *crux*, Sample 151-908A-21X-3, 57–58 cm, Oligocene. **2.** *Distephanus crux* subsp. A, Sample 151-908A-33X-3, 57–59 cm, Oligocene. **3.** *Distephanus paulii* (Shaw and Ciesielski), Sample 151-908A-25X-4, 55–59 cm, Oligocene. **4.** *Naviculopsis minor* (Schulz), Sample 151-908A-24X-6, 57–59 cm, Oligocene. **5.** *Naviculopsis aspera* (Schulz), Sample 151-908A-26X-2, 57–59 cm, Oligocene. **6.** *Naviculopsis biapiculata* (Lemmermann), Sample 151-908A-24X-1, 58–59 cm, Oligocene. **7.** *Naviculopsis* aff. *constricta* (Schulz) sensu Perch-Nielsen, Sample 151-908A-34X-2, 57–59 cm, Oligocene. **8.** *Naviculopsis foliacea* Deflandre, Sample 151-913B-26R-2, 113–115 cm, Eocene. **9.** *Naviculopsis eobiapiculata* Bukry, Sample 151-908A-24X-4, 58–59 cm, Oligocene. **10.** *Naviculopsis constricta* (Schulz), Sample 151-913B-26R-5, 113–115 cm, Eocene. **11.** *Dictyocha* sp. A, Sample 151-913B-26R-2, 113–115 cm, Eocene. **12.** *Mesocena quadrangula* Ehrenberg, Sample 151-908A-21X-1, 56–57 cm, Oligocene. **13.** *Naviculopsis danica* Perch-Nielsen, Sample 151-908A-26X-1, 57–59 cm, Oligocene.

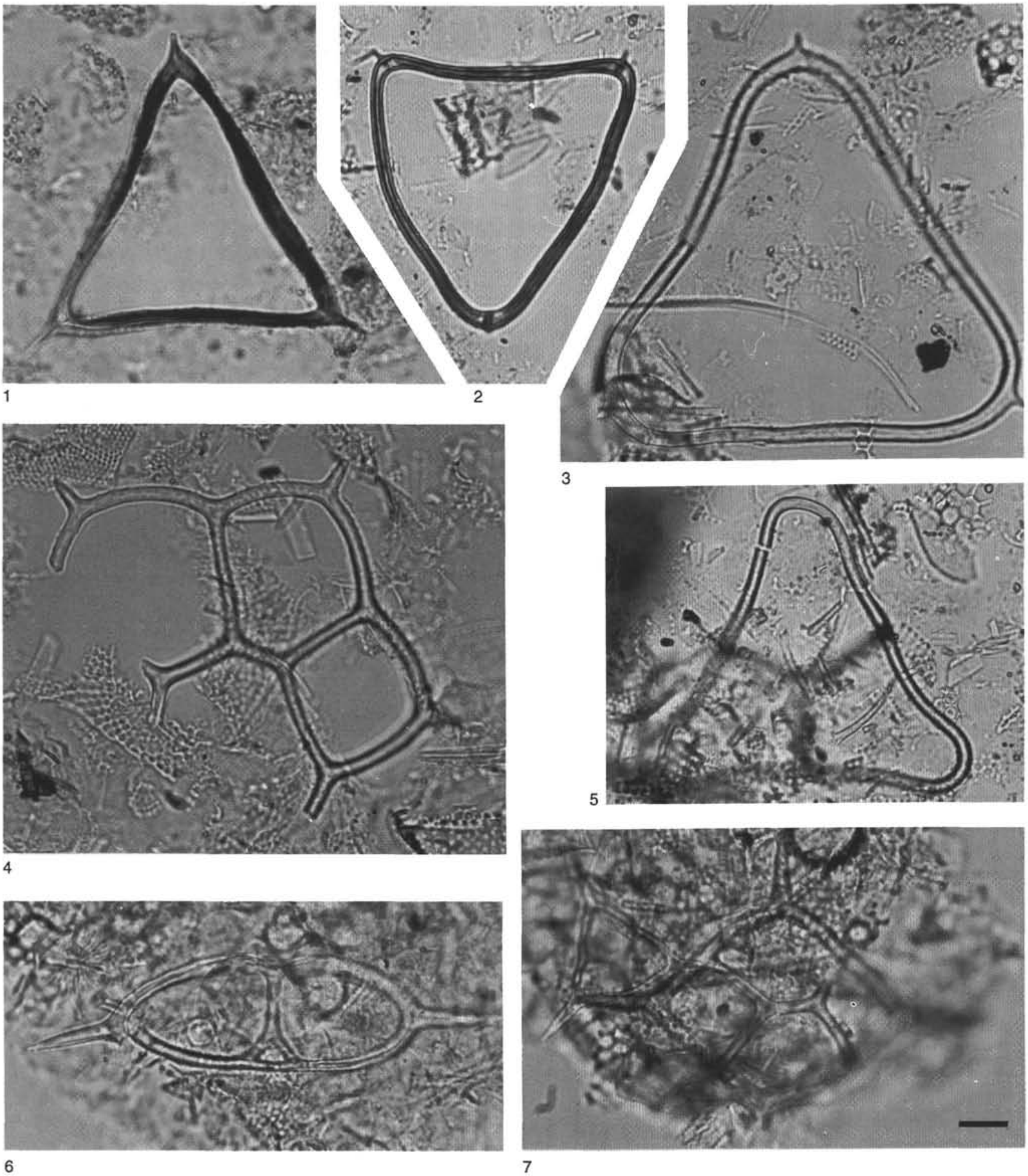
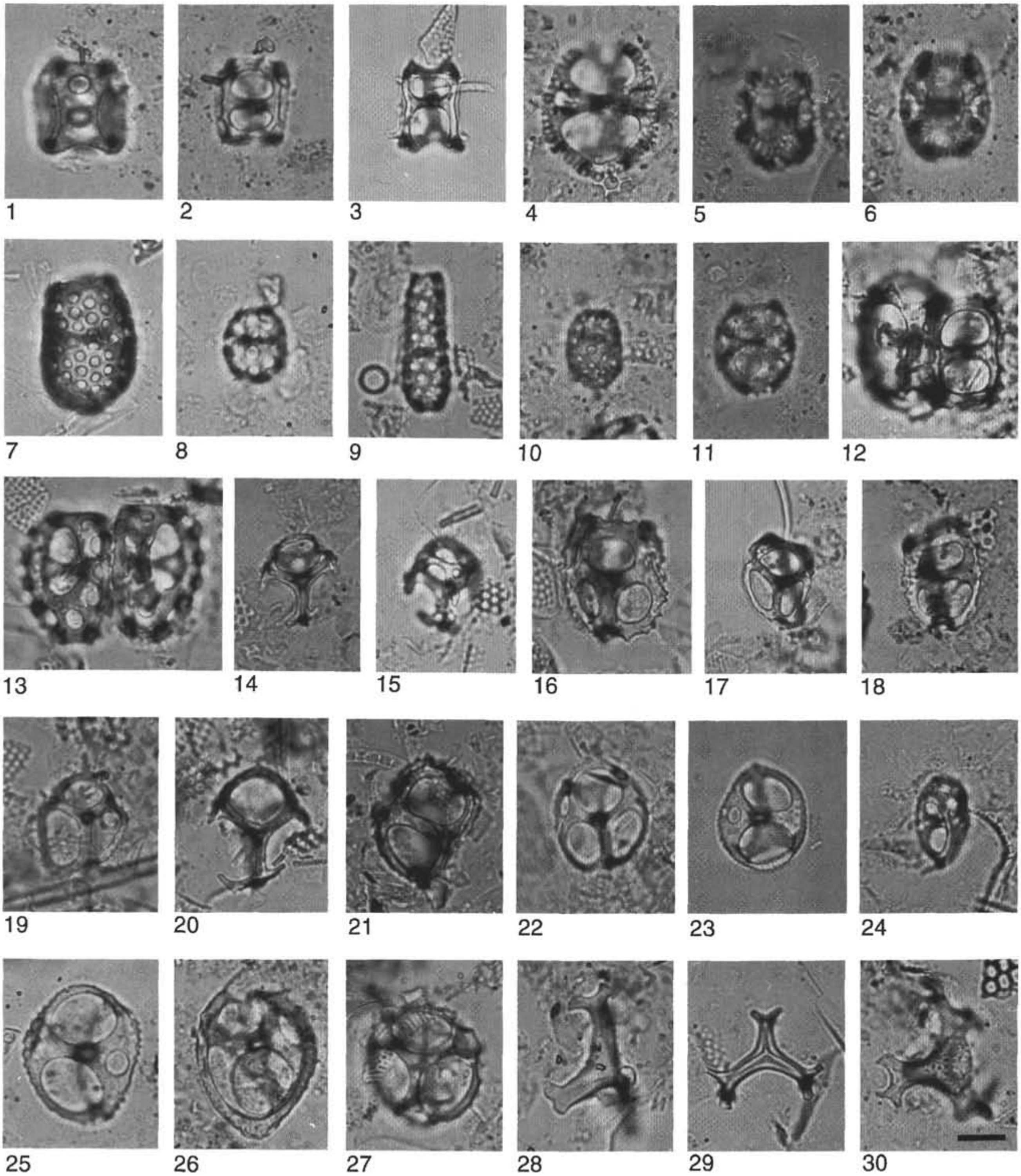


Plate 4. Middle to upper Eocene and upper Oligocene silicoflagellates. All specimens magnified 800×, bar = 10 um. **1.** *Septamesocena apiculata* subsp. *glabra* (Schulz), Sample 151-908A-23X-2, 59–60 cm, Oligocene. **2.** *Septamesocena apiculata* (Schulz) subsp. *apiculata*, Sample 151-913B-25R-6, 113–115 cm, Eocene. **3.** *Septamesocena apiculata* subsp. *evexa* (Bukry), Sample 151-913B-26R-2, 113–115 cm, Eocene. **4.** *Dictyocha challengeri* Martini and Müller, Sample 151-913B-26R-2, 113–115 cm, Eocene. **5.** *Corbisema archangelskiana* (Schulz), Sample 151-908A-25X-1, 56–60 cm, Oligocene. **6.** *Dictyocha* sp. B, Sample 151-913B-26R-6, 110–112 cm, Eocene. **7.** *Dictyocha eocaenica* (Krotov), Sample 151-913B-27R-1, 113–117 cm, Eocene.

Plate 5. Middle to upper Eocene, upper Oligocene, middle Miocene, and Miocene–Pliocene ebridians. All specimens magnified 800×, bar = 10 um. **1.** *Ammodochium danicum* Deflandre, Sample 151-908A-18X-2, 58–60 cm, Miocene–Pliocene. **2.** *Ammodochium rectangulare* (Schulz), Sample 151-908A-23X-1, 59–60 cm, Oligocene. **3.** *Ammodochium pyramidale* Hovasse, Sample 151-908A-30X-1, 57–59 cm, Oligocene. **4.** *Ammodochium fletcheri* Ling, Sample 151-908A-27X-2, 57–60 cm, Oligocene. **5.** *Ammodochium doliolum* Hovasse, Sample 151-908A-21X-4, 56–57 cm, Oligocene. **6.** *Ammodochium* sp. A, Sample 151-908A-22X-4, 57–59 cm, Oligocene. **7.** *Pseudammodochium dictyoides* Hovasse, Sample 151-913B-26R-1, 113–115 cm, Eocene. **8.** *Pseudammodochium eximium* Deflandre, Sample 151-908A-26X-1, 57–59 cm, Oligocene. **9.** *Pseudammodochium* sp. C, Sample 151-913B-25R-2, 114–117, Eocene. **10.** *Pseudammodochium* sp. A, Sample 151-908A-26X-4, 57–59 cm, Oligocene. **11.** *Pseudammodochium* sp. B, Sample 151-908A-17X-4, 52–54 cm, Miocene–Pliocene. **12.** *Ammodochium serotinum* Locker and Martini, Sample 151-913B-19W-4, 144–148 cm, Miocene. **13.** *Ammodochium novum* Perch-Nielsen, Sample 151-913B-24R-CC, Eocene. **14.** *Hermesinella conata* (Deflandre), Sample 151-908A-32X-4, 58–59 cm, Oligocene. **15.** *Hermesinella paraconata* n. sp., holotype, Sample 151-908A-21X-6, 57–58 cm, Oligocene. **16.** *Hermesinella fenestrata* Frenguelli, Sample 151-913B-26R-CC, Eocene. **17.** *Hermesinella schulzii,* Sample 151-908A-32X-4, 58–59 cm, Oligocene. **18.** *Hermesinella* cf. *transversa* Deflandre, Sample 151-908A-18X-1, 58–60 cm, Miocene–Pliocene. **19.** *Haplohermesinum cornuta* (Dumitrica and Perch-Nielsen), Sample 151-913B-24R-CC, Eocene. **20.** *Haplohermesinum hovassei* Locker and Martini, Sample 151-908A-26X-3, 57–59 cm, Oligocene. **21.** *Haplohermesinum* sp. A, Sample 151-908A-32X-2, 57–58 cm, Oligocene. **22.** *Hermesinopsis* cf. *caulleryi* Deflandre, Sample 151-913B-25R-1, 114–117 cm, Eocene. **23.** *Hermesinopsis exigua* (Deflandre), Sample 151-908A-24X-1, 58–59 cm, Oligocene. **24.** *Hermesinopsis*? sp. B, Sample 151-913B-25R-4, 112–115 cm, Eocene. **25.** *Hermesinopsis valida* (Deflandre), Sample 151-908A-27X-4, 57–60 cm, Oligocene. **26.** *Hermesinopsis aplanata* (Deflandre), Sample 151-913B-24R-3, 117–120 cm, Oligocene? **27.** *Parebriopsis symmetrica* Dumitrica and Perch-Nielsen, Sample 151-908A-27X-5, 57–60 cm, Oligocene. **28.** *Falsebria rossica* Deflandre, Sample 151-908A-17X-1, 52–54 cm, Miocene–Pliocene. **29.** *Hovassebria brevispinosa* (Hovasse), Sample 151-913B-25R-5, 112–115 cm, Eocene. **30.** *Spongebria marthae* Deflandre, Sample 151-908A-25X-3, 58–62 cm, Oligocene.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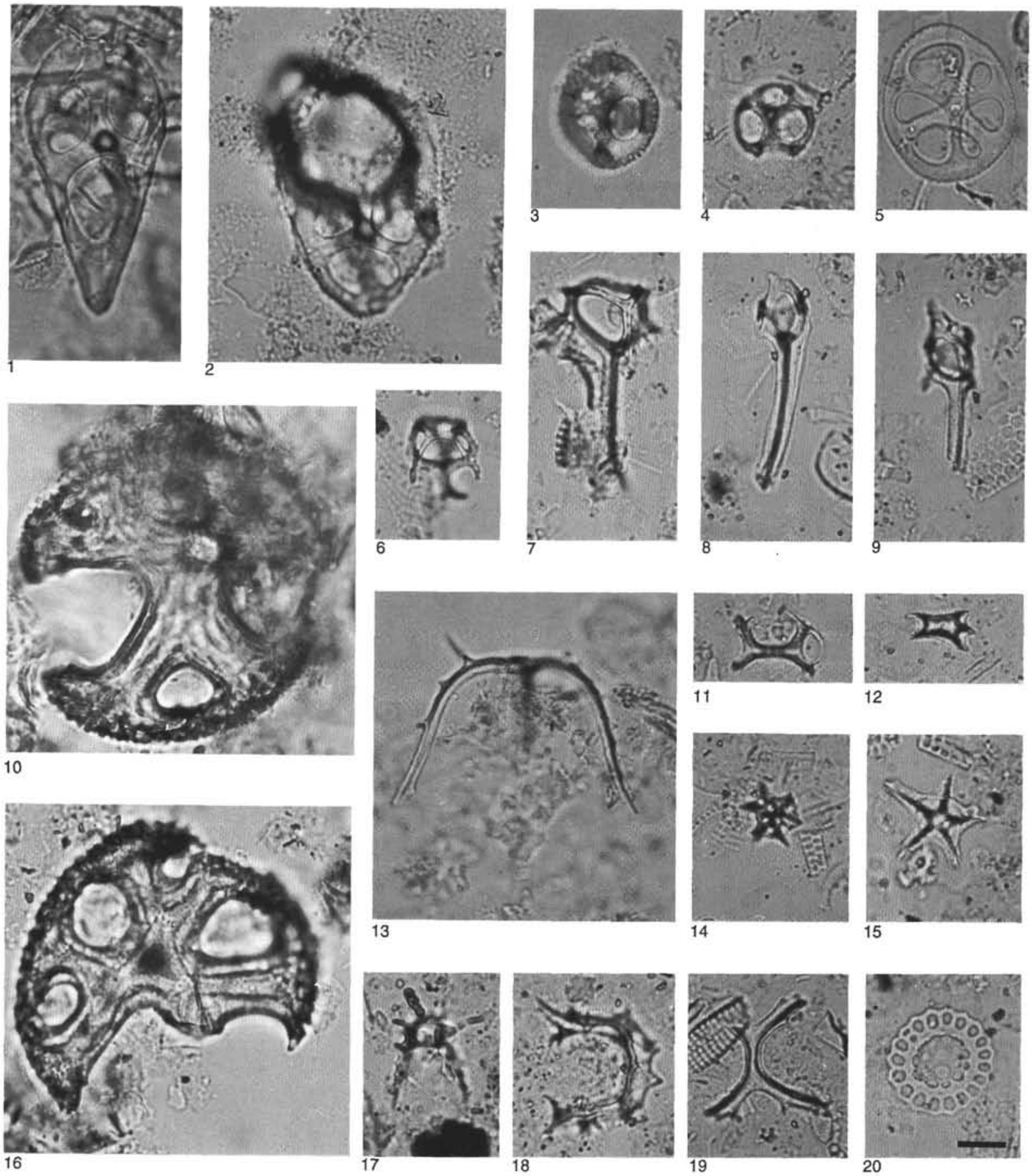

Plate 6. Middle to upper Eocene, upper Oligocene, middle Miocene, and Miocene–Pliocene ebridians, actiniscidians, and synuraceans. All specimens magnified 800×, bar = 10 um. **1.** *Ebriopsis acuta* n. sp., holotype, Sample 151-913B-25R-1, 114–117 cm, Eocene. **2.** *Ebriopsis antiqua* (Schulz), Sample 151-913B-27R-4, 113–117 cm, Eocene. **3.** *Ebriopsis crenulata* Hovasse, Sample 151-908A-23X-2, 59–60 cm, Oligocene. **4.** *Hermesinopsis* sp. A, Sample 151-908A-21X-5, 56–57 cm, Oligocene. **5.** *Ebriopsis* sp. A, Sample 151-913B-26R-2, 113–115 cm, Eocene. **6.** *Hermesinum obliquum* Locker and Martini, Sample 151-908A-23X-4, 59–60 cm, Oligocene. **7.** *Hermesinum geminum* Dumitrica and Perch-Nielsen, Sample 151-908A-33X-2, 57–59 cm, Oligocene. **8, 9.** *Hermesinum acus* n. sp., holotype (8) and syntype (9), Sample 151-908A-28X-6, 57–59 cm, Oligocene. **10.** *Spongebria curta* Locker and Martini, Sample 151-913B-19W-4, 144–148 cm, Miocene. **11.** *Ditripodium latum* Hovasse, Sample 151-908A-24X-2, 58–59 cm, Oligocene. **12.** *Actiniscus elongatus* Dumitrica, Sample 151-908A-25X-3, 58–62 cm, Oligocene. **13.** *Carduifolia lata* Hovasse, Sample 151-908A-23X-4, 59–60 cm, Oligocene. **14.** *Foliactiniscus atlanticus* Perch-Nielsen, Sample 151-908A-25X-4, 55–59 cm, Oligocene. **15.** *Actiniscus pentasterias* Ehrenberg, Sample 151-908A-30X-5, 57–59 cm, Oligocene. **16.** *Spongebria miocenica* Locker and Martini, Sample 151-913B-19W-4, 144–148 cm, Miocene. **17.** *Thranium* sp., Sample 151-908A-18X-1, 58–60 cm, Miocene–Pliocene. **18.** *Carduifolia onopordoides* Hovasse, Sample 151-908A-29X-6, 57–59 cm, Oligocene. **19.** *Carduifolia gracilis* Hovasse, Sample 151-908A-29X-5, 57–59 cm, Oligocene. **20.** *Macrora stella* (Azpeitia), Sample 151-908A-26X-1, 57–59 cm, Oligocene.