

10. TERTIARY AND QUATERNARY SILICOFLAGELLATES, ACTINISCIDIANS, AND EBRIDIANS FROM THE EASTERN PACIFIC OFF PERU (LEG 112)¹

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ABSTRACT

Neogene and Quaternary silicoflagellates, actiniscidians, and ebridians are described from Sites 679 through 688 in the eastern Pacific off Peru. Five silicoflagellate zones and one horizon can be distinguished in the Neogene and Quaternary sequences. The encountered Eocene and Oligocene sequences are barren in silicoflagellates. Several hiatuses were noted in the Neogene and early Pleistocene sequences. Displaced silicoflagellates and ebridians from older strata were found occasionally, with a distinct increase in the Quaternary at Site 688. Distribution lists for species found are presented for Sites 682, 683, 685 and 688. Systematic discussion centers on the *Distephanus bioctonarius* group, with special reference to Hole 681A. Two new forms (*Distephanus bioctonarius* f. *decimarius* and *Distephanus speculum* subsp. *speculum* f. *pseudoseptenarius*) are described from the eastern Pacific Quaternary sequence.

INTRODUCTION

During Leg 112 of the Ocean Drilling Program (ODP) 10 sites (679 through 688) were occupied, and 27 holes were drilled in the forearc basins and the continental slope of the convergent margin off Peru (Fig. 1). The main objectives of Leg 112 were (1) to investigate the paleoceanographic conditions of the upper-slope basin deposits in connection with fluctuations of the upwelling system, (2) to reconstruct the vertical movement of the continental margin, (3) to study the nature and age of the transition zone that lies between the lower-slope accretionary complex and the metamorphic basement, and (4) to evaluate the geochemical processes connected with the upwelling system and diagenesis in organic-carbon-rich sediments. Most sites were aligned along two transects at 9°S (Sites 684, 683, and 685) and near 11°S (Sites 681, 680, 679, 688, and 682). Two additional sites were occupied in the Pisco Basin (Sites 686 and 687).

All holes yielded silicoflagellates, although some barren intervals were noted in the late Miocene to Holocene sequences in the upwelling areas. Paleogene sediments did not contain silicoflagellates or other siliceous fossils; these sediments were recovered only in the deeper Sites 682, 683, and 688 (Fig. 1). The silicoflagellate assemblages found at Sites 679 through 688 are discussed later, and fossil lists for selected samples for Sites 682, 683, 685, and 688 are presented in Tables 1 to 4. Actiniscidians and ebridians found during the silicoflagellate study were listed and are discussed for each site. Their distribution in selected samples from Sites 682, 683, and 685 is shown in Tables 1 through 3.

Frequencies are based on specimens found in three traverses, each 40 mm long, across routine smear slides viewed with a 12.5X ocular and a 25X objective: rare = 1–4 specimens, few = 5–14 specimens, common = 15–50 specimens, abundant = >50 specimens.

SILICOFLAGELLATE ZONATION

As outlined in Locker and Martini (1986a), a uniform silicoflagellate zonation from the middle Miocene onward is hampered by the distinct differentiation of assemblages between several regions of the oceans, whereas in the early Miocene and Paleogene silicoflagellate assemblages seem to be more uniform in all oceans. Therefore, a combination of silicoflagellate zones used during DSDP Leg 7 (Equatorial Pacific, Martini, 1971), Leg 33 (Central Pacific, Martini, 1976), and Leg 90 (Southwest Pacific, Locker and Martini, 1986a), with updated names for some silicoflagellate taxa, was used during Leg 112 off Peru (Fig. 2).

Five silicoflagellate zones and one horizon can be distinguished in the middle Miocene to Holocene interval. The early Miocene interval, which was encountered in Holes 682A and 688E, has a relatively low content of siliceous fossils. Because of low recovery and the rare occurrence of silicoflagellates, a detailed zonation was not possible. However, the presence of some *Naviculopsis* species and of the diatom *Rocella gelida* is indicative of this interval, which was termed *Naviculopsis* Assemblage (Fig. 2).

Together with the datum indicators some first (F) or last (L) occurrences of additional species are shown in Figure 2, which were found occasionally but could not be used for further subdivision because of their scattered occurrence in the investigated region. In addition, the presence of *Dictyocha perlaevis delicata* at Site 688, which was taken as zonal indicator for the *Dictyocha perlaevis delicata* Zone in Bukry (1976, Leg 34) or *Distephanus aculeatus* f. *aculeatus* (syn. *Distephanus boliviensis*) in some other cases, helped to identify the position of cores within the relatively broad silicoflagellate zonation.

Naviculopsis Assemblage

Definition. Interval below the last occurrence of *Naviculopsis* species especially *Naviculopsis quadratum*.

Occurrence. Found at Sites 682 and 688.

Remarks. This early Miocene interval is represented elsewhere by the *Naviculopsis navicula* Zone and part of the *Naviculopsis lata* Zone (Martini and Müller, 1976) or the *Naviculopsis iberica* Zone (Locker and Martini, 1986a). An additional marker in the lower part is the diatom *Rocella gelida* (Barron, 1985).

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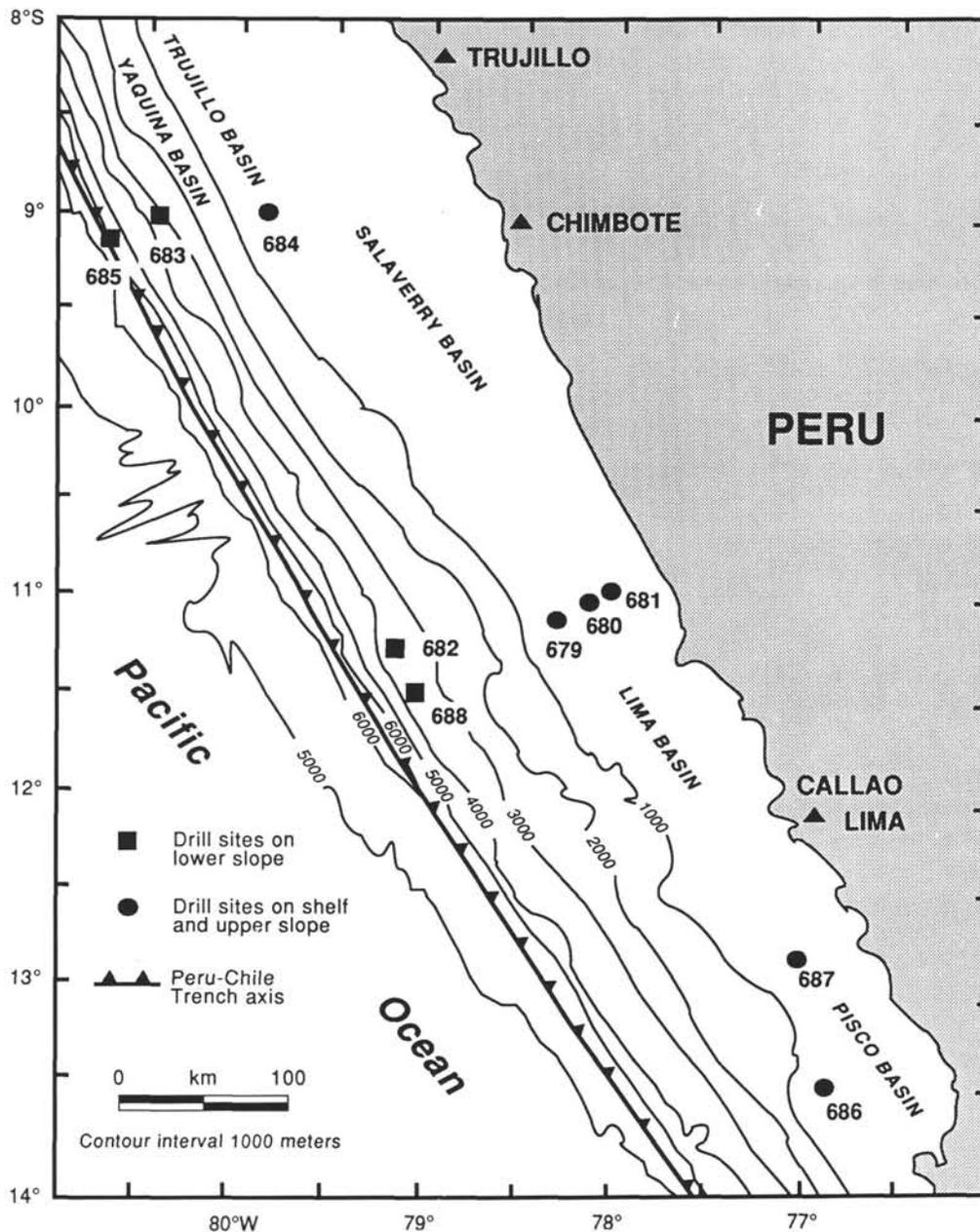


Figure 1. Location of sites drilled during Leg 112 in the eastern South Pacific off Peru.

Corbisema triacantha Zone

Definition. Interval from the last occurrence of *Naviculopsis quadratum* to the last occurrence of *Corbisema triacantha* (Martini, 1971, 1972). Lower to middle Miocene.

Occurrence. Found at Sites 682 and 688.

Remarks. Since the silicoflagellate assemblage in the lower Miocene is rather meager, the last occurrence of *Naviculopsis* species was used to evaluate the base of the *Corbisema triacantha* Zone at both sites. This zone contains the *Distephanus stauracanthus* Horizon in the upper part above the first occurrence of *Mesocena didon*, which was used to subdivide the *C. triacantha* Zone into a lower and an upper part by Locker and Martini (in press).

Distephanus stauracanthus Horizon

Definition. Interval from the first to the last occurrence of *Distephanus stauracanthus* (Martini, 1971). Middle Miocene.

Occurrence. Found at Sites 682, 683 and 688.

Remarks. Commonly *D. stauracanthus* f. *stauracanthus* is associated with *D. stauracanthus* f. *octagonus*. However, at Site 682 the latter was observed in Samples 112-682A-21X-CC and -22X-CC, well above the *D. stauracanthus* Horizon in Core 112-682A-31X and the last occurrence of *Corbisema triacantha*. A similar case was noted at Site 66 (Martini, 1971, Equatorial Pacific).

Dictyochoa varia Zone

Definition. Interval from the last occurrence of *Corbisema triacantha* to the first occurrence of *Dictyochoa messanensis stapedia* (Locker and Martini, 1986a, top changed). Middle to upper Miocene.

Occurrence. Encountered at Sites 679, 682, 683, 685 and 688.

Remarks. Since *Paramesocena circulus apiculata* is too rare in the samples off Peru, the first occurrence of *Dictyochoa*

Table 3. Distribution of silicoflagellates, actiniscidians, and ebridians in selected samples from Hole 685A and indication of silicoflagellate zones.

	<i>Corbisema hexacantha</i>	<i>Corbisema triacantha</i>	<i>Dictyocha epiodon</i>	<i>Dictyocha f. fibula</i>	<i>Dictyocha medusa</i>	<i>Dictyocha m. aculeata</i>	<i>Dictyocha m. aspinosa</i>	<i>Dictyocha m. m. aspinosa</i>	<i>Dictyocha m. stapedia</i>	<i>Dictyocha p. perlaevis</i>	<i>Dictyocha varia</i>	<i>Distephanus b. binonarius</i>	<i>Distephanus b. bioctonarius</i>	<i>Distephanus c. crux</i>	<i>Distephanus sp. 1</i>	<i>Distephanus s.s. pentagonus</i>	<i>Distephanus s.s. speculum</i>	<i>Distephanus sp. 2</i>	<i>Mesocena elliptica</i>	<i>Mesocena quadrangula</i>	<i>Naviculopsis biapiculata</i>	<i>Naviculopsis constricta</i>	<i>Naviculopsis lata</i>	<i>Paramesocena c. apiculata</i>	<i>Paramesocena c. circulus</i>	<i>Actiniscus ? elongatus</i>	<i>Actiniscus pentastertus</i>	<i>Ammochium serotinum</i>	<i>Hermesinella conata</i>	<i>Ebriopsis crenulata</i>	Silicoflagellate Zone							
1H, cc						R		F																														
2H, cc								F																														
3H, cc						R		F																														
4H, cc								C																														
5X, cc						R		F																														
6X, cc						R		F																														
7X, cc						R		F																														
8X, cc								F																														
9X, cc								F																														
10X, cc								R																														
11X, cc						F		R																														
12X, cc								R																														
13X, cc								R																														
14X, cc								R																														
15X, cc						R		R																														
16X, cc						R		R																														
17X, cc						R		R																														
18X, cc								R																														
19X, cc								R																														
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51X, cc			R																																			

680B-19X, CC, and -22X, CC, of probably early Pliocene age, rare *Distephanus crux* and a *Goniothecium* species were found. Because of the low diversity in species and barren intervals of the sequence, only the upper part can be placed in silicoflagellate zones. The interval from the top down to Sample 112-680A-3H, CC, belongs to the *Dictyocha messanensis aculeata* Zone, and the interval between Samples 112-680A-4H, CC, and -6H, CC, represents the *Mesocena quadrangula* Zone.

**Site 681 (10°58.60'S, 77°57.46'W;
water depth, 150.5 m)**

At this site, silicoflagellates are present throughout the Quaternary sequence, although some barren intervals were noted and are associated with abundant diatoms, rare sponge spicules, and, occasionally, with actiniscidians. As in the previous sites, specimens of the *Dictyocha messanensis* group were the most common forms observed. The lowest occurrences of *Distephanus bioctonarius* f. *bioctonarius* were noted

in Samples 112-681A-13X, CC, -681B-13X, CC, and -681C-9H, CC. A co-occurrence of this species with *Mesocena quadrangula* was found between Samples 112-681A-7H-1, 101-102 cm, and -10H, CC, and in Samples 112-681B-10H, CC and -681C-9H, CC, supporting a Pleistocene age assignment. However, the last occurrence of *M. quadrangula* may be higher in the sequence, since Cores 112-681A-5H (part) and -6H were barren in silicoflagellates. For details of the *D. bioctonarius* group, see the systematic reference section and Table 5.

**Site 682 (11°15.99'S, 79°03.73'W;
water depth, 3788.5 m)**

All core-catcher samples and some additional samples were studied for silicoflagellates, which are present from the top of the hole down to Core 112-682A-36X, covering the whole Neogene and Quaternary sequences, although their occurrence in the lowest Miocene is scarce owing to the low opal content of the sediments.

	Standard nannoplankton zones	Silicoflagellate zones	Datum indicators and additional species
Quat.	NN20/21	Dictyocha messanensis aculeata Zone	L M. quadrangula
	NN19	Mesocena quadrangula Zone	F D. messanensis aculeata
Pliocene	NN16	Dictyocha messanensis stapedia Zone	L P. circulus circulus
	NN13		
	NN12		L M. diodon
	NN11b		
upper Miocene	NN11a	Dictyocha varia Zone	L P. circulus apiculata
	NN10		F D. messanensis stapedia
	NN9		
middle Miocene	NN7	Corbisema triacantha Zone	L C. triacantha
	NN6		L D. stauracanthus
	NN5		F D. stauracanthus
	NN4		F M. diodon
lower Miocene	NN3	Naviculopsis Assemblage	L (N. quadratum)
	NN2		L (N. iberica)
	NN1		F (N. navicula)
			L Rocella gelida (diatom)

Figure 2. Silicoflagellate zones used for Leg 112 sites, first and last occurrences of important silicoflagellate species, and correlation to standard nannoplankton zones (SNZ, Martini, 1971, and this volume).

ical studies of silicoflagellates (Martini, 1971: frequency change "*D. fibula/D. rhombica*") and which takes place in the lower part of the late Miocene calcareous nannoplankton Zone NN11 (Martini, 1976), was noted in Core 112-682A-13X. In Samples 112-682A-21X, CC and -22X, CC, several specimens of *Distephanus stauracanthus* f. *octagonus* were encountered well above the occurrence of the *Distephanus stauracanthus* Horizon in Hole 682A. The base of the *Dictyocha varia* Zone was placed in Core 112-682A-28X, where the last occurrence of *Corbisema triacantha* was found. In Core 112-682A-31X, the *Distephanus stauracanthus* Horizon was identified. The base of the *Corbisema triacantha* Zone is between Cores 112-682A-34X and -35X, because in Sample 112-682A-35X-1, 21-22 cm, rare *Naviculopsis biapiculata* were encountered. This species has its last occurrence in the early Miocene.

The silicoflagellates are associated with common to abundant diatoms, rare to few sponge spicules, and, occasionally, with ebridians and actiniscidians. These include *Actiniscus pentasterias*, *A. ? elongatus* as well as *Parathranium clathra-*

tum and *Ammodoichium serotinum*, found in low numbers throughout the early Miocene to Quaternary sequences of Hole 682A. Below Core 112-682A-36X, samples are barren of these siliceous microfossils (For details, see Table 1).

**Site 683 (9°01.69'S, 80°24.40'W;
water depth, 3071.8 m)**

Silicoflagellates or actiniscidians are present from the top of Hole 683A down to Core 112-683A-45X (418 mbsf), covering part of the Neogene and the Quaternary intervals.

The Pliocene and Quaternary intervals (Cores 112-683A-1H to -28X, 0.0 to 228.2 mbsf) show close similarities with the previous Sites 680 to 682. *Dictyocha messanensis aculeata* was found only in Sample 112-683A-7H, CC (59.2 mbsf), but *Mesocena quadrangula* and *Distephanus bioctonarius* f. *bioctonarius* were observed in several samples. The lowest occurrence of *D. bioctonarius* f. *bioctonarius* was noted in Sample 112-683A-12X, CC (106.7 mbsf) within the range of *Mesocena quadrangula*, which occurs between Samples 112-683A-8H, CC and -13X-1, 38-39 cm

(68.7–126.1 mbsf). Between Cores 112-683A-16X and -22X (137.1–193.0 mbsf) *Distephanus speculum speculum* f. *pentagonus* is a frequently found constituent. *Dictyocha messanensis stapedia* and related forms that have a vertical bar were found down to Core 112-683A-25X (228.3 mbsf).

Below Core 112-683A-25X, the silicoflagellate assemblages show a distinct change, indicating a hiatus between Cores 112-683A-25X and -26X, with part of the lowest Pliocene and the upper Miocene intervals missing. *Corbisema triacantha* occurs from Core 112-683A-27X downward with dictyoid forms having a horizontal apical bar, most of which belong to *Dictyocha varia*, and are present from Core 112-683A-27X down to the base of the hole in varying abundance. The rather common occurrence of *Distephanus stauracanthus* f. *octagonus* in Cores 112-683A-27X, -29X, -31X to -33X, and again in Core 112-683A-38X, together with *D. stauracanthus* f. *stauracanthus* in Sample 112-683A-29X-1, 17–18 cm, indicates the *D. stauracanthus* Horizon, although most of the interval between Core 112-683A-27X and the terminal Core 112-683A-45X seems to represent disturbed slump material, but in a continuous sequence. The most common forms in this part of the interval are those of the *Distephanus crux* group. Within this sequence, Core 112-683A-30X is of special interest as it contains *Distephanus crux* and *Paramesocena circulus apiculata*. However, neither *Distephanus stauracanthus* f. *octagonus* nor *D. stauracanthus* f. *stauracanthus* was found. This core may represent a younger horizon, although it still contains rare *Corbisema triacantha*. This seems to agree with the determination of the late middle Miocene calcareous nannoplankton Zone NN8 (*Catinaster coalitus* Zone) in this particular core (Martini, this volume). For details, see Table 2.

Silicoflagellates were noted in Cores 112-683B-1X to -6X in Hole 683B and include *Dictyocha varia* and members of the *Distephanus crux* group, indicating a middle Miocene age. Below a hiatus, only a few displaced Miocene species were found in Cores 112-683B-8X and -9X; they might represent downhole contamination during coring. The Eocene section in Cores 112-683B-7X through -9X otherwise is barren in silicoflagellates.

Actiniscidians and ebridians were observed in various samples throughout Hole 683A and in Cores 112-683B-1X to -6X, with *Actiniscus pentasterias* as the most common species. *Actiniscus ? elongatus* was noted only between Cores 112-683A-19X and -39X in Hole 683A, and *Parathranium clathratum*, *Ammodochium serotinum*, as well as *Hermesinella conata* occur sporadically in the slumped material below Core 112-683A-25X in Hole 683A and down to Core 112-683B-6X in Hole 683B.

**Site 684 (8°59.59'S, 79°54.35'W;
water depth, 426.0 m)**

All core-catcher and some additional samples were studied for silicoflagellates in Hole 684A; none were investigated from Holes 684B and 684C. Three intervals with different silicoflagellate assemblages can be distinguished.

Core 112-684A-1H and most of Core 112-684A-2H contain a meager Quaternary assemblage that includes *Distephanus bioctonarius* f. *bioctonarius*, which has its lowest occurrence in this hole in Sample 112-684A-2H-4, 27–28 cm (10.7 mbsf).

In Cores 112-684A-3H to -6H, the most common silicoflagellates belong to *Dictyocha messanensis stapedia* and related forms having a vertical apical bar and *Distephanus speculum speculum* f. *speculum*. In Sample 112-684A-3H-4, 109–110 cm (20.4 mbsf) *Paramesocena circulus* and in

Sample 112-684A-5H, CC *Distephanus aculeatus* (syn. *D. boliviensis*) were found. Together with calcareous nannoplankton data for this part of the sequence (Martini, this volume), these species indicate a late Pliocene age for this interval.

Samples from Cores 112-684A-7H to -14X are dominated by *Distephanus crux* and *Dictyocha varia*. In Sample 112-684A-7H, CC (61.8 mbsf) rather frequent *Mesocena didon* were found, which ranges throughout the middle and late Miocene into the basal Pliocene (calcareous nannoplankton Zones NN5 to NN13). Rare *Paramesocena circulus* were noted in Samples 112-684A-8H-1, 9–10 cm (62.4 mbsf) and -12X, CC (98.1 mbsf). The assemblage of this interval can be placed in the late middle to early late Miocene *Dictyocha varia* Zone (Locker and Martini, 1986a).

Based on silicoflagellate assemblages and their age assignment, two hiatuses are postulated. The first is located in the lowest part of Core 112-684A-2H at approximately 15 mbsf with the lower Pleistocene and part of the upper Pliocene intervals missing, and the second between Cores 112-684A-6H and -7H at approximately 51 mbsf. Here, the lower Pliocene and most of the upper Miocene intervals are missing.

Actiniscidians and ebridians were found scattered throughout the sequence and include *Actiniscus pentasterias* between Samples 112-684A-7H, CC and -14X, CC, *A. ? elongatus* in Samples 112-684A-6H, CC, and -14X, CC, and *Parathranium clathratum* between Samples 112-684A-3H, CC and -13X, CC.

**Site 685 (9°06.78'S, 80°35.01'W;
water depth, 5070.8 m)**

All core-catcher and some additional samples in Hole 685A were studied for silicoflagellates and some other siliceous microfossils.

Cores 112-685A-1H to -22X (199.8 mbsf) contain Quaternary silicoflagellate assemblages, which are associated with abundant diatoms, frequent sponge spicules, and, occasionally, actiniscidians. The most common silicoflagellates belong to the *Dictyocha messanensis* group; *Dictyocha messanensis aculeata*, indicating a late Quaternary age, was found in Samples 112-685A-5X, CC (40.4 mbsf), -6X, CC (51.4 mbsf), and 685A-11X, CC (99 mbsf). *Mesocena quadrangula* was observed in Sample 112-685A-8X, CC (70.8 mbsf), but is more common in the interval from Core 112-685A-14X down to Core 112-685A-22X, and has its lowest occurrence in Sample 112-685A-22X, CC (199.8 mbsf). *Distephanus bioctonarius* f. *bioctonarius* is present in Core 112-688A-2H and in Sample 112-685A-16X, CC (142.2 mbsf).

Between Cores 112-685A-22X and -23X at approximately 200 mbsf, a hiatus (approx. 4.3 m.y. duration) divides the lower Pleistocene from the upper Miocene. The silicoflagellate assemblages in most samples between Samples 112-685A-23X, CC and -685A-51X, CC (203.6–459.1 mbsf) contain *Dictyocha varia*, members of the *Distephanus crux* group and *Distephanus speculum speculum* f. *speculum*. *Dictyocha messanensis stapedia* was noted in a few samples, and *Paramesocena circulus apiculata* was found in Samples 112-685A-28X, CC (255.7 mbsf) and -685A-32X, CC (286.6 mbsf). This interval seems to represent the late middle to early upper Miocene *Dictyocha varia* Zone. From Sample 112-685A-34X, CC (310 mbsf) downward, silicoflagellates and diatoms are highly fractured and not well preserved.

Reworked middle or upper Miocene silicoflagellates occur in Sample 112-685A-13X, CC (112.3 mbsf) of Quaternary age,

and reworked *Naviculopsis* species from the upper Oligocene/lower Miocene occur in the late Miocene Sample 112-685A-29X, CC (256.5 mbsf). In the basal part of Core 112-685A-43X, as well as in Cores 112-685A-44X (386.3–396.1 mbsf) and -50X (450.6 mbsf), early Miocene and Paleogene silicoflagellates, such as *Naviculopsis biapiculata*, *Naviculopsis lata*, *Naviculopsis foliacea*, and *Corbisema hexacantha*, outnumber the late Miocene silicoflagellates and indicate downslope slumping during the late Miocene.

Actiniscidians were found occasionally, but seem to occur more frequently in the Miocene interval. These forms include *Actiniscus pentasterias* throughout the sequence and *A. ? elongatus* between Samples 112-685A-28X, CC, and -80X, CC. Ebridians were noted in Sample 112-685A-26X, CC (232.1 mbsf) and below between Samples 112-685A-43X, CC, and -685A-5X, CC (386.5–451 mbsf). Displaced Eocene ebridians like *Ebriopsis crenulata* were found frequently in the lower part of Core 112-685A-43X and in Core 112-685A-44X. For details on the distribution of silicoflagellates, actiniscidians, and ebridians, see Table 3.

**Site 686 (13°28.81'S, 76°53.59'W;
water depth, 446.8 m)**

All core-catcher samples in Hole 686A were studied for silicoflagellates. Samples 112-686A-6H, CC, -8H, CC, -14X, CC, -17X, CC, and -22X, CC, were barren in silicoflagellates. In Hole 686B, only core-catcher samples from Core 112-686B-21X downward were examined.

Both sequences belong entirely in the Quaternary. The silicoflagellate assemblages are dominated by members of the *Dictyocha messanensis* group. *Mesocena quadrangula* was found in several levels from Sample 112-686A-7H, CC (55.6 mbsf) throughout the sequence down to Sample 112-686B-32X, CC, at the terminal depth of 303 mbsf, showing a rather long overlap with *Distephanus bioctonarius* f. *bioctonarius*. The latter was found between Samples 112-686A-1H, CC (4.9 mbsf) and -686B-32X, CC (303 mbsf). In Sample 112-686A-9X, CC, a single specimen that resembles *Dictyocha challengerii* (see Martini and Müller, 1976: Pl. 2, Fig. 8 and Pl. 8, Fig. 3) was observed. However, this specimen has six radial spines, lacks basal pikes, and may be displaced (Pl. 4, Fig. 6).

The interval between Cores 112-686A-1H and -6H can be placed in the *Dictyocha messanensis aculeata* Zone. Samples from Cores 112-686A-7H to -686B-32X belong to the *Mesocena quadrangula* Zone.

**Site 687 (12°51.78'S, 76°59.43'W;
water depth, 306.8 m)**

Only core-catcher samples from Hole 687A were studied for silicoflagellates. Sandy intervals recovered in Cores 112-687A-2H, -3H, and -8X to -11X were barren of silicoflagellates.

As usual, the Quaternary silicoflagellate assemblages are dominated by members of the *Dictyocha messanensis* group. *Mesocena quadrangula* was found in Samples 112-687A-4H, CC (36.0 mbsf) and -13X, CC (121.1 mbsf). *Distephanus bioctonarius* f. *bioctonarius* is present between Samples 112-687A-1H, CC (7.5 mbsf) and -17X, CC (158.3 mbsf).

In Sample 112-687A-15X, CC, *Distephanus aculeatus* and in Sample 112-687A-20X, CC, *Distephanus crux* were observed in single specimens obviously displaced from older strata.

**Site 688 (11°32.26'S, 78°56.57'W;
water depth, 3819.8 m)**

The silicoflagellate assemblages in all core-catcher samples of Hole 688A contain members of the *Dictyocha messanensis* group. *Distephanus speculum speculum* f. *speculum* was frequently found throughout the sequence, whereas f. *pentagonus* occurred in only a few samples. *Mesocena quadrangula* was observed in varying numbers between Sample 112-688A-8X, CC (68.5 mbsf) and Sample 112-688A-36X, CC (341.2 mbsf), in which it has its lowest occurrence at this site. This indicates a Pleistocene age for most of the sequence. *Distephanus bioctonarius* f. *bioctonarius* is surprisingly rare at this site and was found only in Samples 112-688A-1H, CC and -4H, CC (36.8 mbsf), well above the last occurrence of *Mesocena quadrangula*.

Two samples from Hole 688C at 351.0 (112-688C-1R-1, 75 cm) and 351.5 mbsf (112-688C-1R-1, bottom) contain *Dictyocha perlaevis delicata* and lack both *Mesocena quadrangula* and *Paramesocena circulus circulus*, which places these samples in the lowest Pleistocene or uppermost Pliocene (see also Bukry, 1976).

In Hole 688E *Mesocena quadrangula* occurs in Cores 112-688E-1R and -2R (350.0 to 356.0 mbsf), and *Dictyocha perlaevis delicata* has its lowest occurrence in Sample 112-688E-3R, CC, repeating data from the lowest part of Holes 688A and 688C.

Cores 112-688A-36X and -37X, as well as Cores 112-688E-2R and -3R, may be divided by a short hiatus separating the *Mesocena quadrangula* assemblage from the *Dictyocha perlaevis delicata* assemblage. A rather sudden change to a meager silicoflagellate assemblage between Samples 112-688E-3R, CC and -4R, CC also may indicate a hiatus. Between Samples 112-688E-4R, CC and -7R, CC, the silicoflagellate assemblage consists only of members of the *Distephanus speculum* group and of *Dictyocha messanensis stapedia*. In Sample 112-688E-8R, CC (421.7 mbsf), *Dictyocha varia* and members of the *Distephanus crux* group appear. An overlap between this assemblage and the occurrence of *Dictyocha messanensis stapedia* was not noted, and another hiatus is suspected. The late middle to early upper Miocene *Dictyocha varia* Zone was recognized between Samples 112-688E-8R, CC, and -11R, CC (421.7–441.2 mbsf). In Sample 112-688E-12R, CC, the last occurrence of *Corbisema triacantha* was found. Samples between 112-688E-14R-3, 13–14 cm, and -16R-1, 18–16 cm, can be placed in the *Distephanus stauracanthus* Horizon, with *D. stauracanthus* f. *stauracanthus* present throughout this interval. *Distephanus stauracanthus* f. *octogonus* was found in Sample 112-688E-16R, CC, indicating that the interval between Samples 112-688E-13R, CC, and -16R, CC (460.0–689.8 mbsf) can be placed in the upper part of the middle Miocene *Corbisema triacantha* Zone. *Mesocena diodon* was observed between Cores 112-688E-12R and -21R.

Cores 112-688E-17R, -18R, and -21R yielded only caved-in middle Miocene material from above. Samples from Cores 112-688E-19R, -20R, and -22R to -24R contain rare specimens of *Distephanus crux*, and Sample 112-688E-20R, CC, also contains *Corbisema triacantha*. These samples are also placed in the *Corbisema triacantha* Zone. Sample 112-688E-25R-1, 141 cm, certainly can be placed below the last occurrence of *Naviculopsis* species in the late lower Miocene because rare *Naviculopsis biapiculata* and *Naviculopsis trispinosa* were found. The latter species was reported by Perch-Nielsen (1975) in Eocene sediments from Leg 29 and seems to range into the lowest Miocene. In Samples 112-688E-25R-1, 15–16 cm and -25R, CC, *Rocella gelida* was noted, indicating the *Rocella gelida* Zone of Barron (1985), which straddles the

Oligocene/Miocene boundary. This agrees with the placement of Sample 112-688E-25R, CC in calcareous nannoplankton Zone NN1/NN2 (Martini, this volume). In Sample 112-688E-26R-1, 58 cm, a broken specimen of *Septenmesocena apiculata* was observed. The interval between Core 112-688E-27R and the terminal Core 112-688E-46R (593.0–775.0 mbsf) is barren in silicoflagellates. For details about the distribution of silicoflagellates at this site, see Table 4.

Displaced silicoflagellates from older strata are relatively common in the Quaternary silicoflagellate assemblage and include *Corbisema triacantha*, *Dictyocha varia*, and *Naviculopsis biapiculata*.

Actiniscidians and ebridians were noted occasionally and include *Actiniscus pentasterias* (Samples 112-688A-1H, CC, -36X, CC, 688E-7R, CC, -10R, CC, -11R, CC, -17R, CC, -20R, CC, and -26R-1, 58 cm), *Actiniscus ? elongatus* (Samples 112-688A-4H, CC, -36X, CC, and 688E-20R, CC), and *Parathranium clathratum* (Samples 112-688A-3H, CC, 688E-2R-1, 86 cm, and -12R, CC). Because of their scattered occurrence, these species are not included in Table 4.

SILICOFLAGELLATES IN PISCO BASIN DIATOMITES

During a field trip led by R. Garrison, a set of samples was collected for comparison along the exposures just north of the Hacienda Caucato Alto northwest of San Clemente. This section belongs to the upper diatomaceous member of the Miocene Pisco Formation and includes diatomites, bentonitic siltstones, and, occasionally, phosphorite bands. Samples were taken over an interval of about 25 m in the diatomites, with the uppermost sample at a distinct phosphorite band near the top of the ridge. Although diatoms are abundant in all samples, silicoflagellates are rare throughout. Rare to few *Distephanus speculum speculum* f. *speculum* were observed in all samples, whereas *Distephanus speculum speculum* f. *pentagonus* was found as single specimens in only two samples. Besides *Actiniscus pentasterias*, which is present in all samples, *Actiniscus ? elongatus* was noted in one sample. In the highest sample near the phosphorite band, calcareous nannoplankton also was observed in a poorly preserved, meager assemblage containing *Coccolithus pelagicus*, *Discoaster brouweri*, *Reticulofenestra pseudoumbilica*, and a small *Reticulofenestra* species. On the basis of these long-ranging species, an exact age assignment is not possible. Samples collected from laminated porcelanites of the Caballas Formation and banded mud rocks of the Paracas Formation exposed along the Playa Yumaque south of Paracas were barren of calcareous nannoplankton and silicoflagellates.

SYSTEMATIC REFERENCES AND REMARKS ON TAXA

Most silicoflagellate taxa found in the Leg 112 sediments off Peru have been discussed in detail in an earlier study by Locker and Martini (1986a, Leg 90), where references to authors and synonyms also can be found. In some cases, Bukry (1982, Leg 68) and Perch-Nielsen (1978, Leg 29) should be consulted. The actiniscidians and ebridians are discussed in Locker and Martini (1986b, Leg 90). With regard to the present material, all taxa found are listed, and remarks have been added only for new forms and for the *Distephanus bioctonarius* group.

Cannopilus depressus (Ehrenberg) Locker
Cannopiius hemisphaericus (Ehrenberg) Haeckel

Cannopilus sphaericus Gemeinhardt
Corbisema hexacantha (Schulz) Deflandre
Corbisema triacantha (Ehrenberg) Hanna (Pl. 1, Fig. 1)
Dictyocha concavata Dumitrica (Pl. 1, Fig. 4)
Dictyocha epoidon Ehrenberg
Dictyocha fibula Ehrenberg subsp. *fibula* (Pl. 5, Fig. 1)
Dictyocha medusa Haeckel (Pl. 5, Fig. 5)
Dictyocha messanensis subsp. *aculeata* (Lemmermann) f. *aculeata* (Pl. 1, Figs. 2, 3)
Dictyocha messanensis subsp. *aspinosa* (Bukry) Locker and Martini (Pl. 1, Fig. 5)
Dictyocha messanensis Haeckel subsp. *messanensis* f. *aspinosa*
Dictyocha messanensis subsp. *stapedia* (Haeckel) f. *stapedia* (Pl. 1, Figs. 6, 7; Pl. 5, Fig. 4)
Dictyocha perlaevis subsp. *delicata* Bukry (Pl. 1, Fig. 8)
Dictyocha perlaevis Frenguelli subsp. *perlaevis*
Dictyocha varia Locker (Pl. 1, Fig. 9)
Dictyocha sp. cf. *D. challengeri* Martini and Müller (Pl. 4, Fig. 6)

Distephanus aculeatus (Ehrenberg) f. *aculeatus* (Pl. 5, Fig. 7)
Distephanus aculeatus f. *ornamentum* (Ehrenberg)
Distephanus bioctonarius (Ehrenberg) nov. comb. (syn. *Octactis pulchra* Schiller)

Type species. *Mesocena bioctonaria* Ehrenberg, 1846.

Description. Basal ring, rounded to oval, with normally short radial spines. Spines may have considerable length in some late Pleistocene and Holocene specimens. Thin, apical ring near the basal ring, connected by slightly arched struts. No supporting pikes on the basal ring. Delicate apical ring easily breaks off, and specimens show a mesocenoid appearance.

Remarks. Ehrenberg (1846, 1854) described several closely related species under the genus name *Mesocena* from Peru and Chile. In a revision of the Ehrenberg collection, Locker (1974) designated a lectotype of *Mesocena bioctonaria* Ehrenberg and transferred the species with some doubts to the genus *Octactis* Schiller, 1925. In a more recent study, Ling and Takahashi (1985) pointed out that *Octactis* Schiller, 1925, is a synonym of *Distephanus* Stöhr, 1880. However, they did not correlate *Octactis pulchra* with one of Ehrenberg's taxa because of doubts about the true nature of the latter species. Most of Ehrenberg's specimens came from the same area as that investigated during Leg 112, and even though his original drawings are rather crude, the reexamination of Locker (1974) leaves no doubt that Ehrenberg's species are identical with forms found during Leg 112 off Peru. The so-called "membrane" mentioned in Locker (1974), which aroused some confusion, is an optical ghost effect and can be ignored in further discussions. Thus, *Distephanus pulchra* (Schiller) must be considered a synonym of *Distephanus bioctonarius* (Ehrenberg). In the present material *D. bioctonarius* is represented by 7- to 10-rayed forms named below. Their occurrence and numerical distribution in Hole 681A is shown in Table 5. All six-rayed specimens, which show superficial similarity, have supporting pikes on the basal ring and belong to *Distephanus speculum tenuis* Bukry.

Stratigraphic occurrence. Early Pleistocene to Holocene. First occurrence in relation to the first occurrence of *Mesocena quadrangula* is not uniform. At Sites 680, 681, and 687, it is prior to the first occurrence of *M. quadrangula*, at Sites 683 and 685, shortly after the first occurrence of *M. quadrangula*, and at the offshore Sites 682 and 688, it occurs even after the last occurrence of *M. quadrangula*.

Distephanus bioctonarius f. *binonarius* (Ehrenberg) nov. comb. (Pl. 3, Figs. 5, 6)

Table 5. Distribution of the *Distephanus bioctonarius* group, *D. speculum tenuis*, *D. speculum speculum* f. *octonarius*, and *Mesocena quadrangula* in selected samples of Hole 681A.

mbsf.	Sample	<i>Distephanus s. tenuis</i>	<i>Distephanus b. heptagonus</i>	<i>Distephanus b. bioctonarius</i>	<i>Distephanus b. binonarius</i>	<i>Distephanus b. decimarius</i>	<i>Distephanus s. octonarius</i>	<i>Mesocena quadrangula</i>	
0, 9	1H-1, 89-90 cm		6	38	2				Diphycha messanensis aculeata Zone
6, 5	1H, cc			7	2				
16, 2	2H, cc			5					
25, 3	3H, cc			1	1				
33, 7	4H, cc			9	2	2			
37, 7	5H-2, 26-27 cm			14	1				
40, 7	5H-4, 118-119 cm			1	1		5		
44, 5	5H, cc								0, 79 m. y.
44, 6	6H, cc								
55, 0	7H-1, 101-102 cm				1			2	Mesocena quadrangula Zone
67, 4	8H-1, 117-118 cm							6	
73, 6	9H-1, 60-61 cm			2				2	
82, 5	9H, cc			1				5	
82, 8	10H-1, 27-28 cm		1	2	1				
88, 2	10H, cc			3				1	
99, 2	11H, cc			1					Diphycha messanensis stapedia Zone
111, 2	12H, cc	3							
115, 4	13X, cc	3		3					
125, 1	14X, cc	7							
Total Hole	681A	13	7	87	11	2	5	16	
Total Leg	112	21	7	159	15	2	5		

Note: Numbers refer to specimens found in four traverses, each 40-mm long, across routine smear slides viewed with a 12.5X ocular and 25X objective.

Remarks. Nine-rayed form of *D. bioctonarius*. In the present material, found at Sites 680, 681, 684, 685, and 687 off Peru.

Distephanus bioctonarius f. *bioctonarius* (Ehrenberg) nov. comb. (Pl. 3, Figs. 3, 4)

Remarks. Most common and widespread 8-rayed form of the species. Numerous specimens found that are identical to Ehrenberg's figures and Locker's drawings of the originals.

Distephanus bioctonarius f. *decimarius* n.f. (Pl. 3, Figs. 7, 8)

Holotype. SM.B 13826 (Pl. 3, Figs. 7, 8)

Type locality. Eastern Pacific off Peru, Site 681, Sample 681A-4H, CC.

Diagnosis. 10-rayed form of *D. bioctonarius*.

Remarks. Very rare form in the investigated material. Found only at Site 681 off Peru.

Distephanus bioctonarius f. *heptagonus* (Ehrenberg) nov. comb. (Pl. 3, Figs. 1, 2)

Remarks. Relatively rare 7-rayed form of *D. bioctonarius*, found only at Site 681 off Peru during Leg 112.

Distephanus crux subsp. *bispinosus* Dumitrică

Distephanus crux (Ehrenberg) subsp. *crux* (Pl. 2, Fig. 1)

Distephanus speculum subsp. *giganteus* Bukry f. *giganteus* (Pl. 5, Fig. 3)

Distephanus speculum subsp. *speculum* f. *octonarius* (Ehrenberg) (Pl. 5, Fig. 6)

Distephanus speculum subsp. *speculum* f. *pentagonus* Lemmermann (Pl. 2, Fig. 2)

Distephanus speculum subsp. *speculum* f. *pseudofibula* Schulz (Pl. 2, Fig. 5)

Distephanus speculum subsp. *speculum* f. *pseudoseptenarius* n.f. (Pl. 2, Fig. 6)

Holotype. SM.B 13827 (Pl. 2, Fig. 6)

Type locality. Eastern Pacific off Peru, Site 679, Sample 112-679E-IX, CC.

Diagnosis. Seven-rayed form with the apical structure of *D. speculum* f. *pseudofibula*, but with seven connections to the basal ring.

Remarks. Very rare form in the investigated material. Found only at Site 679 off Peru.

Distephanus speculum subsp. *speculum* f. *septenarius* (Ehrenberg) (Pl. 2, Fig. 4)

Distephanus speculum (Ehrenberg) subsp. *speculum* f. *speculum* (Pl. 2, Fig. 3)

Distephanus speculum subsp. *tenuis* Bukry (Pl. 3, Figs. 9, 10)

Distephanus stauracanthus f. *octagonus* (Tsumura) (Pl. 2, Fig. 7)

Distephanus stauracanthus (Ehrenberg) f. *stauracanthus* (Pl. 2, Fig. 8)

Distephanus sp. (Pl. 2, Fig. 9)

Remarks. Eight-rayed specimen similar to *Distephanus bioctonarius*, but pikes on apical ring and three connected rods within apical ring. No basal pikes. Found in a *Distephanus speculum* f. *pseudofibula* dominated assemblage in Sample 112-679E-IX, CC, probably of early Pliocene age.

Mesocena diodon Ehrenberg (Pl. 4, Fig. 2)

Mesocena elliptica (Ehrenberg) Ehrenberg

Mesocena quadrangula Ehrenberg ex Haeckel (Pl. 4, Figs. 1, 3, 4)

Naviculopsis biapiculata (Lemmermann) Frenguelli (Pl. 3, Fig. 11)

Naviculopsis contracta (Schulz) Stradner (Pl. 5, Fig. 2)

Naviculopsis foliacea Deflandre

Naviculopsis lata (Deflandre) Frenguelli (Pl. 5, Fig. 9)

Naviculopsis trispinosa (Schulz) Gieser (Pl. 3, Figs. 12, 13)

Paramesocena circulus subsp. *apiculata* (Lemmermann) (Pl. 4, Fig. 5)

Paramesocena circulus (Ehrenberg) subsp. *circulus*

Septenmesocena apiculata (Schulz) Bachmann

Actiniscus pentasterias Ehrenberg

Cinctactiniscus ? sp. in Locker and Martini, 1986b (Pl. 3, Figs. 7, 8)

Foliactiniscus mirabilis Dumitrică

Ammodochium serotinum Locker and Martini

Ebriopsis crenulata Hovasse

Hermesinella conata (Deflandre) Locker and Martini

Parathranium clathratum (Ehrenberg) Deflandre

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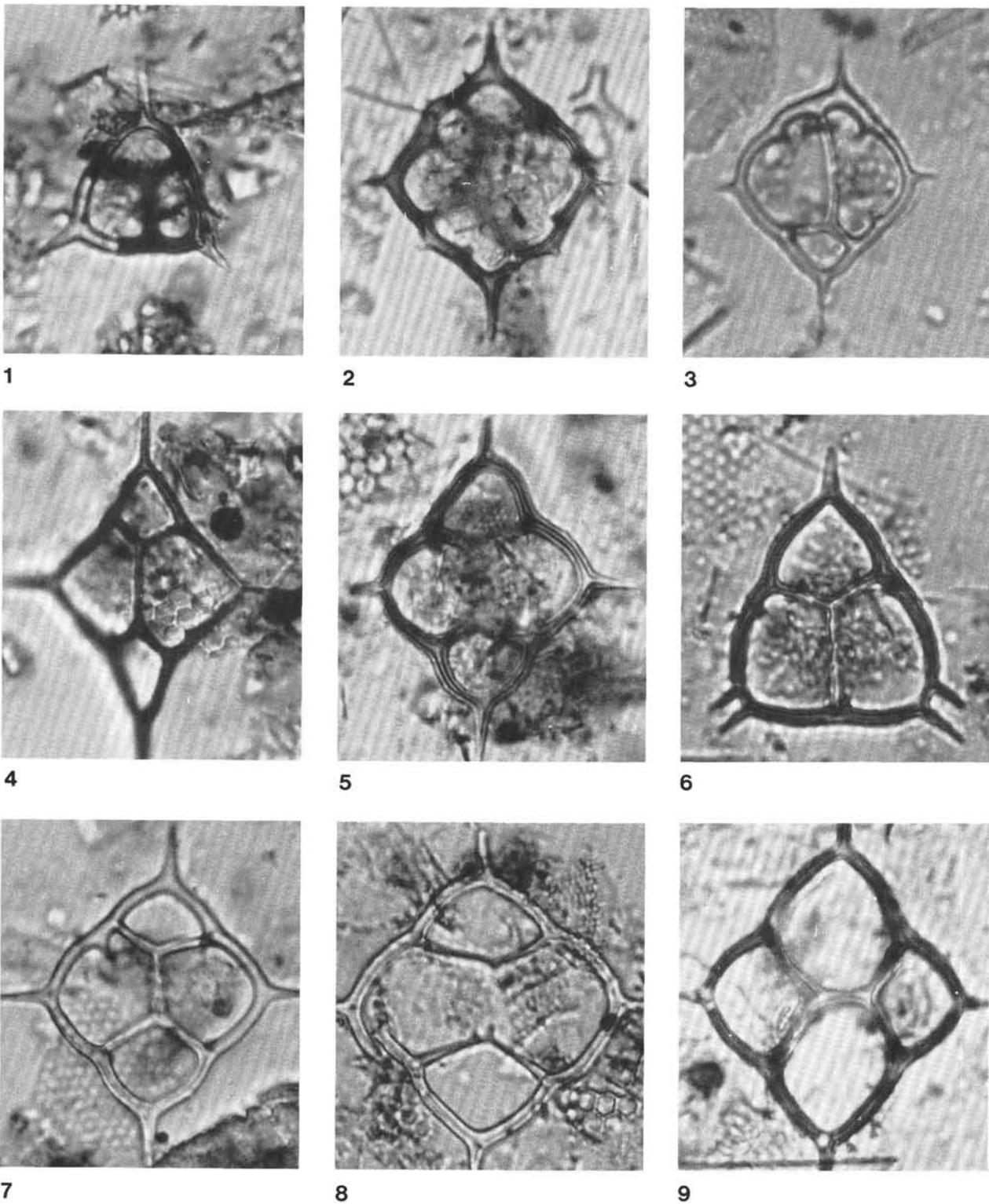
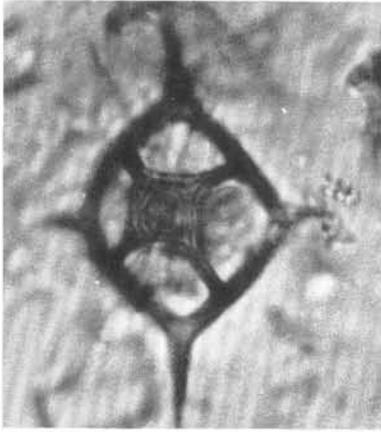
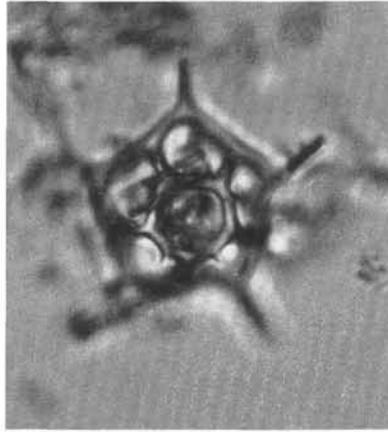


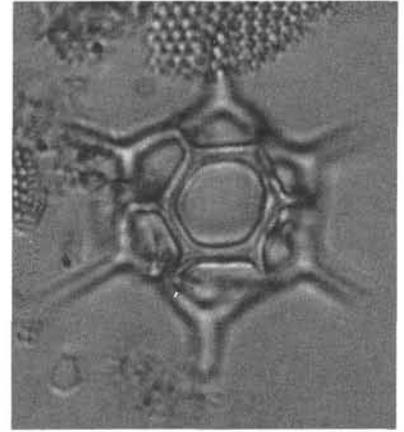
Plate 1. Neogene and Quaternary silicoflagellates (All specimens magnified 1180 \times). 1. *Corbisema triacantha* (Ehrenberg), displaced, Sample 112-688A-8X, CC, Quaternary. 2. *Dictyocha messanensis* subsp. *aculeata* (Lemmermann) f. *aculeata*, Sample 112-683A-7H, CC, Quaternary. 3. *Dictyocha messanensis* subsp. *aculeata* (Lemmermann) f. *aculeata*, aberrant specimen, Sample 112-688A-7H, CC, Quaternary. 4. *Dictyocha concavata* Dumutrică, displaced ?, Sample 112-688A-6H, CC, Quaternary. 5. *Dictyocha messanensis* subsp. *aspinosa* (Bukry), Sample 112-688E-7R-7, 19 cm, upper Miocene. 6. *Dictyocha messanensis* subsp. *stapedia* (Haeckel) f. *stapedia*, aberrant specimen, Sample 112-680A-1H, CC, Quaternary. 7. *Dictyocha messanensis* subsp. *stapedia* (Haeckel) f. *stapedia*, Sample 112-680A-1H, CC, Quaternary. 8. *Dictyocha perlaevis* subsp. *delicata* Bukry, Sample 112-688C-1R-1, 75 cm, upper Pliocene/Pleistocene. 9. *Dictyocha varia* Locker, Sample 112-684A-7H-6, 80–81 cm, upper Miocene.



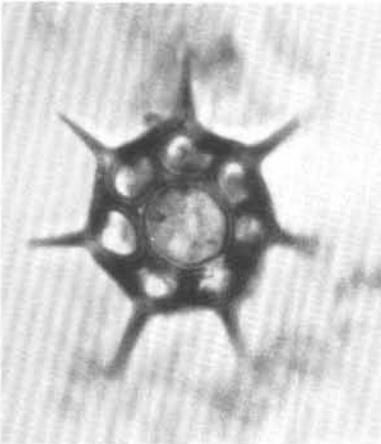
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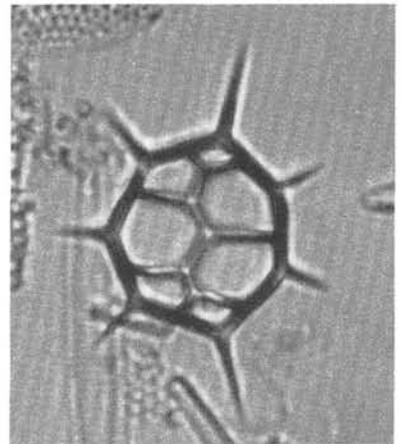
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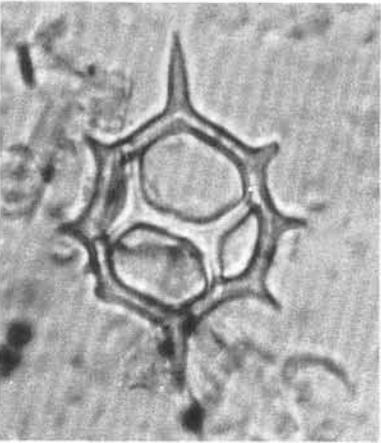
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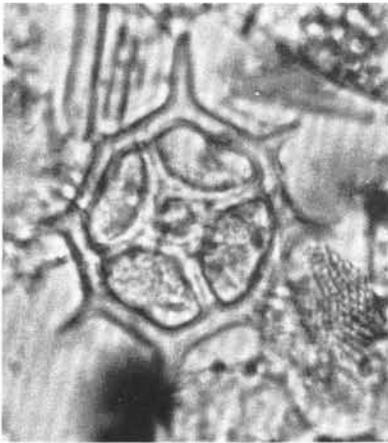
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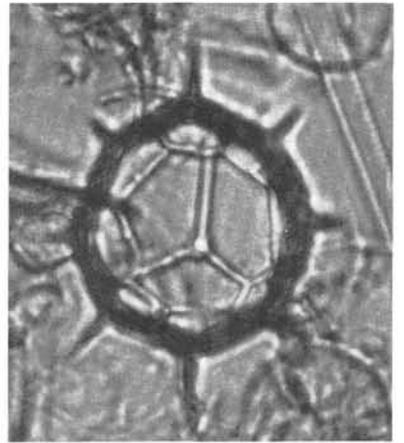
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Plate 2. Neogene and Quaternary silicoflagellates (All specimens magnified 1180 \times). 1. *Distephanus crux* (Ehrenberg) subsp. *crux*, Sample 112-684A-7H-6, 80–81 cm, upper Miocene. 2. *Distephanus speculum* subsp. *speculum* f. *pentagonus* (Lemmermann), Sample 112-688E-1R, CC, Quaternary. 3. *Distephanus speculum* (Ehrenberg) subsp. *speculum* f. *speculum*, Sample 112-679E-1X, CC, lower Pliocene. 4. *Distephanus speculum* subsp. *speculum* f. *septenarius* (Ehrenberg), Sample 112-688A-6H, CC, Quaternary. 5. *Distephanus speculum* subsp. *speculum* f. *pseudoseptenarius* n.f., holotype SM.B 13827, Sample 112-679E-1X, CC, lower Pliocene. 6. *Distephanus speculum* subsp. *speculum* f. *pseudoseptenarius* n.f., holotype SM.B 13827, Sample 112-679E-1X, CC, lower Pliocene. 7. *Distephanus stauracanthus* f. *octagonus* (Tsumura), Sample 112-679D-25X, CC, upper Miocene. 8. *Distephanus stauracanthus* (Ehrenberg) f. *stauracanthus*, Sample 112-688E-18R, CC, middle Miocene, 9. *Distephanus* sp., Sample 112-679E-1X, CC, lower Pliocene.

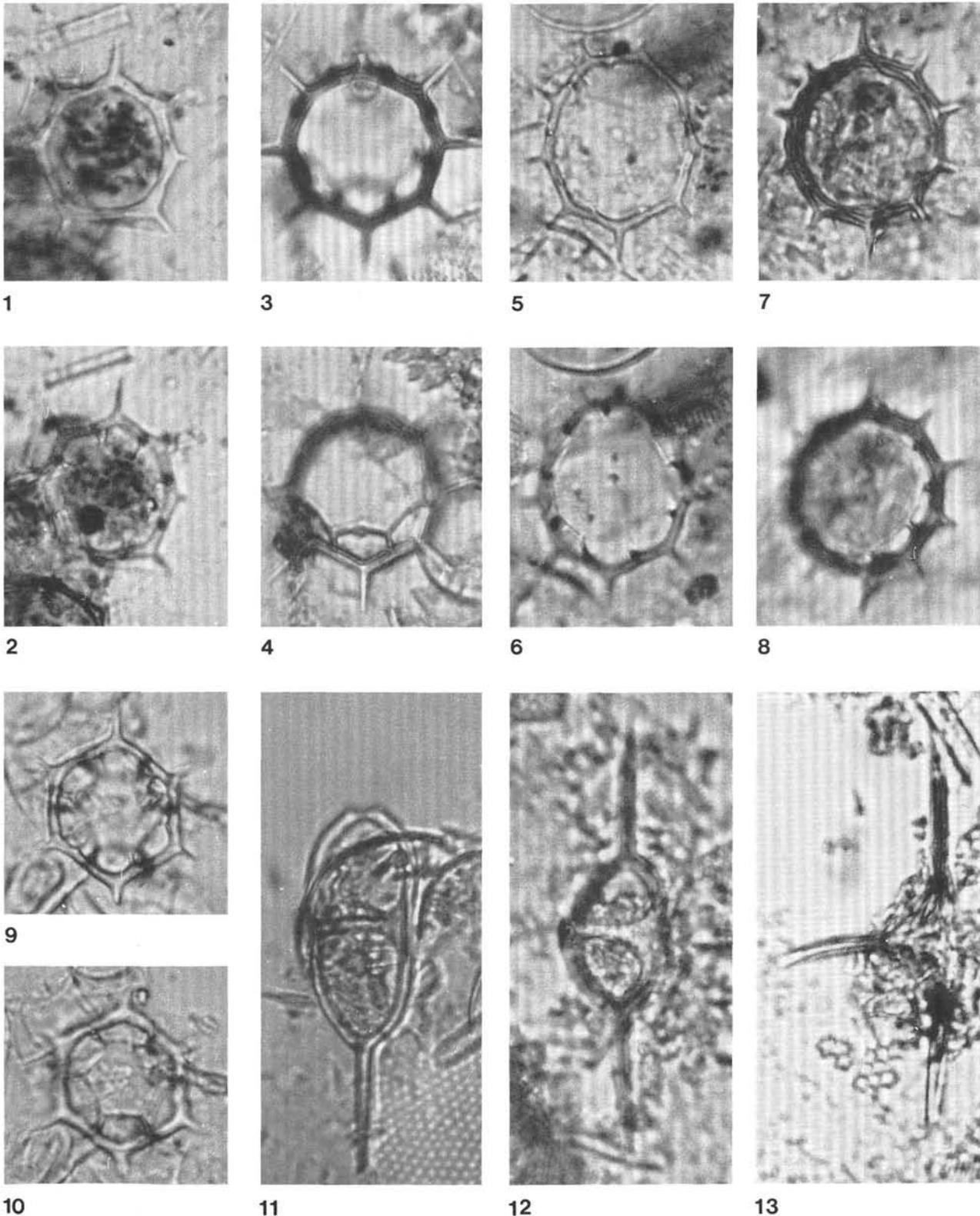
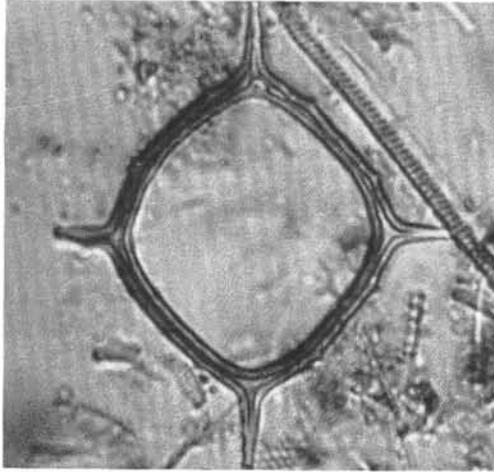
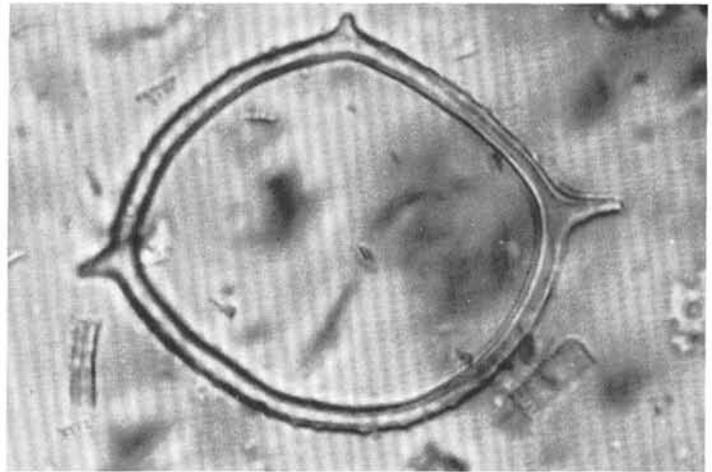


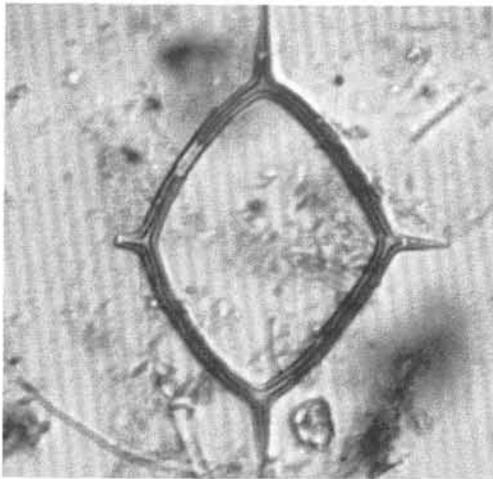
Plate 3. Neogene and Quaternary silicoflagellates (All specimens magnified 1180 \times). 1, 2. *Distephanus bioctonarius* f. *heptagonus* (Ehrenberg), Sample 112-681A-10H-1, 27-28 cm, Quaternary. 3, 4. *Distephanus bioctonarius* (Ehrenberg) f. *bioctonarius*, Sample 112-679D-2H, CC, Quaternary. 5, 6. *Distephanus bioctonarius* f. *binonarius* (Ehrenberg), Sample 112-680A-6H, CC, Quaternary. 7, 8. *Distephanus bioctonarius* f. *decimarius* n.f., holotype SM.B 13826, Sample 112-681A-4H, CC, Quaternary. 9, 10. *Distephanus speculum* subsp. *tenuis* Bukry, Sample 112-679D-2H, CC, Quaternary. 11. *Naviculopsis biapiculata* (Lemmermann), displaced, Sample 112-688A-23X, CC, Quaternary. 12, 13. *Naviculopsis trispinosa* (Schulz), two different specimens, Sample 112-688E-25R-1, 141 cm, lower Miocene.



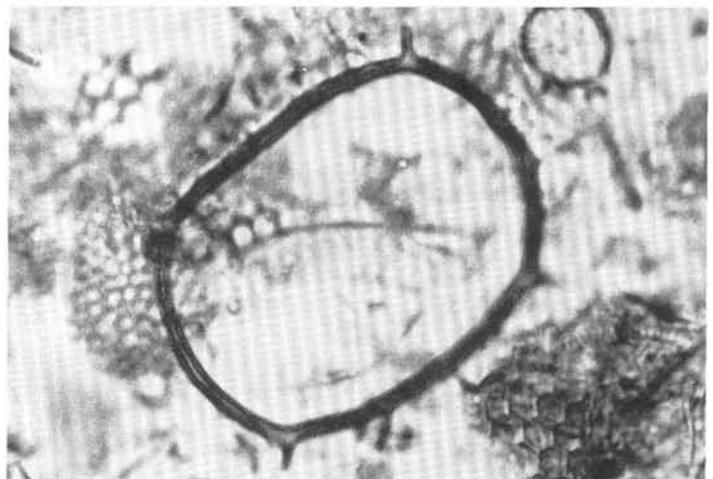
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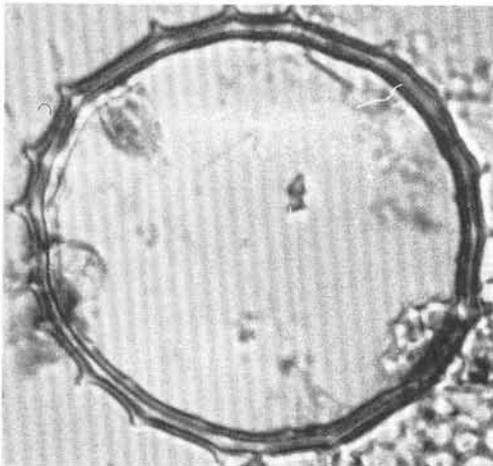
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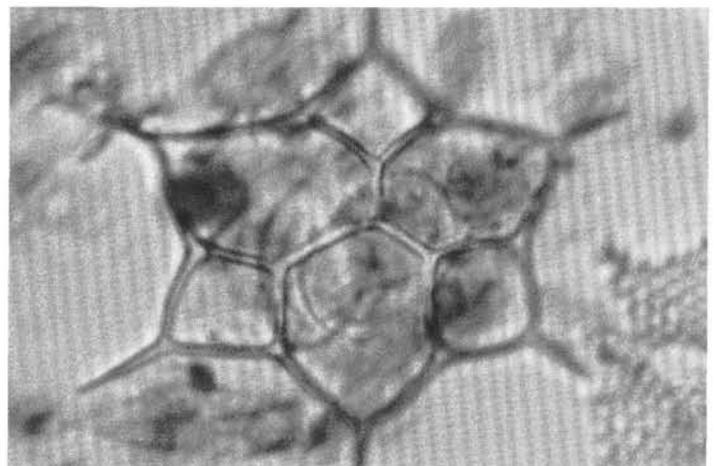
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Plate 4. Neogene and Quaternary silicoflagellates (All specimens magnified 1180×). 1, 3. *Mesocena quadrangula* Ehrenberg ex Haeckel, two different specimens, Sample 112-688A-18X, CC, Quaternary. 2. *Mesocena diodon* Ehrenberg, Sample 112-688E-14R, CC, middle Miocene. 4. *Mesocena quadrangula* Ehrenberg ex Haeckel, aberrant specimen, Sample 112-688E-2R, CC, Quaternary. 5. *Paramesocena circulus* (Ehrenberg) subsp. *circulus*, Sample 112-684A-3H-4, 103–104 cm, upper Pliocene. 6. *Dictyocha* sp., Sample 112-686A-9X, CC, Quaternary.

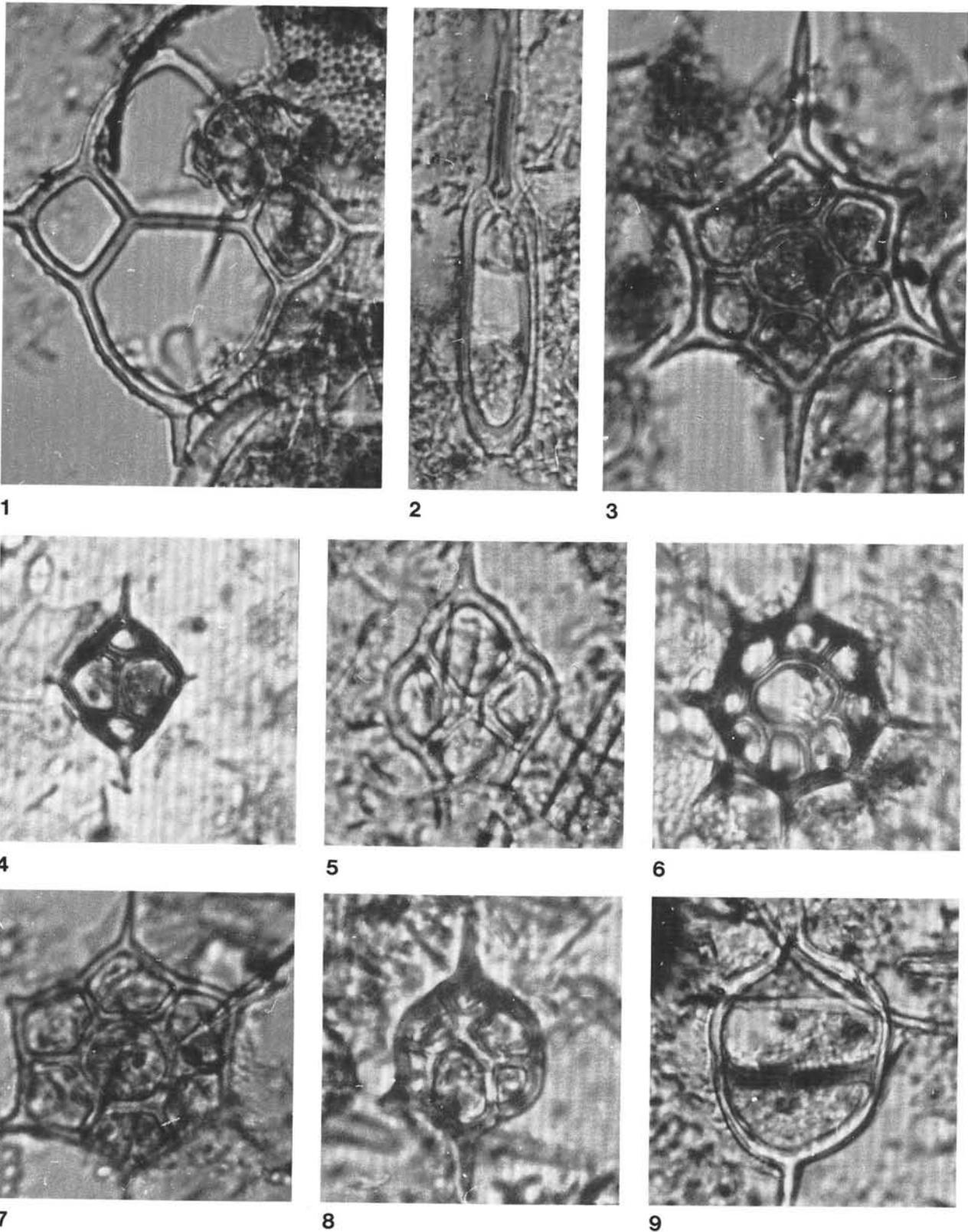


Plate 5. Neogene and Quaternary silicoflagellates (All specimens magnified 1180 \times). 1. *Dictyocha fibula* Ehrenberg subsp. *fibula*, Sample 112-682A-8X, CC, Pliocene. 2. *Naviculopsis constricta* (Schulz), Sample 112-685A-43X, CC, displaced, upper Miocene. 3. *Distephanus speculum* subsp. *giganteus* Bukry f. *giganteus*, Sample 112-688A-20X, CC, displaced, Quaternary. 4. *Dictyocha messanensis* subsp. *stapedia* (Haeckel) f. *stapedia*, Sample 112-688A-16X, CC, Quaternary. 5. *Dictyocha medusa* Haeckel, Sample 112-685A-36X, CC, upper Miocene. 6. *Distephanus speculum* subsp. *speculum* f. *octonarius* (Ehrenberg), Sample 112-681A-5H-4, 118-119 cm, Quaternary. 7. *Distephanus aculeatus* (Ehrenberg) f. *aculeatus*, Sample 112-688A-3H, CC, displaced, Quaternary. 8. *Distephanus* ? sp., aberrant specimen, Sample 112-685A-28X, CC, displaced, upper Miocene. 9. *Naviculopsis lata* (Deflandre), Sample 112-685A-29X, CC, displaced, upper Miocene.