

17. BIOSTRATIGRAPHY AND PALEOECOLOGY OF NEOGENE AND OLIGOCENE SILICOFAGELLATES FROM CORES RECOVERED DURING ANTARCTIC LEG 28, DEEP SEA DRILLING PROJECT

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INTRODUCTION

During Leg 28 of the Deep Sea Drilling Project, sixteen holes were drilled at eleven sites: one site on the Naturaliste Plateau, five sites between the Southeast Indian Ridge and the Wilkes Land coast of Australia, one site on the Antarctic continental rise distal to the Ross Sea, and four sites in the Ross Sea. All sites, with the exception of Site 264, lie south of the present position of the Antarctic Convergence and within Subantarctic or Antarctic waters. In the present study of silicoflagellate biostratigraphy and paleoecology, eleven holes from eight of these Leg 28 sites are utilized (Table 1, Figure 1).

At Site 264, drilled on the Naturaliste Plateau, silicoflagellates were recorded only in one core of upper Eocene calcareous nannofossil ooze. The three pelagic sites (Sites 266, 267, 269) located in the highly productive waters south of the Southeast Indian Ridge all contain abundant silicoflagellates in Plio-Pleistocene sedimentary sequences. Upper Miocene to middle middle Miocene sections (Sites 266, 267, 269, 274) are generally barren or contain low-diversity, cold-water assemblages, whereas lower middle Miocene to lower Miocene silicoflagellate assemblages are more diverse and contain frequent warm-water cosmopolitan species. A unique 140-meter-thick lower Oligocene sequence with an abundant and diverse assemblage of relatively warm-water silicoflagellates was drilled on the continental rise at Site 274. Site 274 provides an abundance of data on the stratigraphic distribution of Oligocene silicoflagellates; until now, such information has been relatively sparse. At almost all sites the consistent presence and abundance of silicoflagellates is exceeded only by that of the diatoms.

Continuous or near continuous coring and a relatively high rate of recovery at two sites (Sites 266 and 274) has provided a nearly complete stratigraphic sequence of Neogene and Oligocene silicoflagellate assemblages. A biostratigraphic zonation is established for most of the Neogene and Oligocene and includes fifteen zones and two subzones. Paleomagnetically dated *Eltanin* piston cores (Table 2), representing the Brunhes through Gilbert magnetic epochs, have been used to relate the zonal scheme to paleomagnetic chronostratigraphy. Whenever possible, older silicoflagellate zones have been related to calcareous nannofossil stratigraphy. Noticeable differences between this silicoflagellate zonation and other previously established zonations (Figure 2) underscores the provinciality of most Neogene silicoflagellate assemblages in the Antarctic and Subantarctic. Only a few cosmopolitan zones, such as the middle Miocene *Corbisema triacantha* Zone and the lower Miocene *Naviculopsis* Zones, are recognized.

A newly developed silicoflagellate paleotemperature technique (Ciesielski, 1974) has been utilized for a detailed study of early Pliocene sedimentary sequences in six *Eltanin* piston cores and two Leg 28 drill cores. The delineated silicoflagellate paleotemperatures suggest that a dramatic change in the thermal structure of the Southern Ocean occurred during the Gilbert magnetic epoch, with a fluctuating drop in surface water temperatures from more than 10°C (present-day northernmost Subantarctic) to less than 2.0°C (present-day Antarctic). Inferred surface water temperatures between 4.30 and 3.95 m.y. B. P. are suggested as being too warm for the existence of the West Antarctic ice sheet during that time.

Relative paleotemperature (Ts) values for the Miocene and Oligocene sequences at Sites 266 and 274

TABLE 1
Holes Drilled During Leg 28, DSDP

Hole	Latitude	Longitude	Water Depth (m)	Pene- tration (m)	No. of Cores	Meters Cored	Meters Recovered
264	34° 58.13'S	112° 02.68'E	2873	215.5	15	142.5	65.2
266	56° 24.13'S	110° 06.70'E	4173	384.0	24	219.5	145.2
267	59° 15.74'S	104° 29.30'E	4564	219.5	7	58.0	25.9
267A	59° 15.74'S	104° 29.30'E	4564	70.5	3	28.5	11.6
267B	59° 14.55'S	104° 29.94'E	4539	323.0	10	95.0	53.5
269	61° 40.57'S	140° 04.21'E	4285	397.5	11	103.0	38.8
271	76° 43.27'S	175° 02.86'E	562	554.0	24	233.0	15.3
272	77° 07.62'S	176° 45.61'W	629	443.0	48	439.0	162.0
273	74° 32.29'S	174° 37.57'E	495	76.0	9	76.0	27.9
273A	74° 32.29'S	174° 37.57'E	495	346.5	29	256.5	55.5
274	68° 59.81'S	173° 25.64'E	3326	421.0	45	421.0	279.1

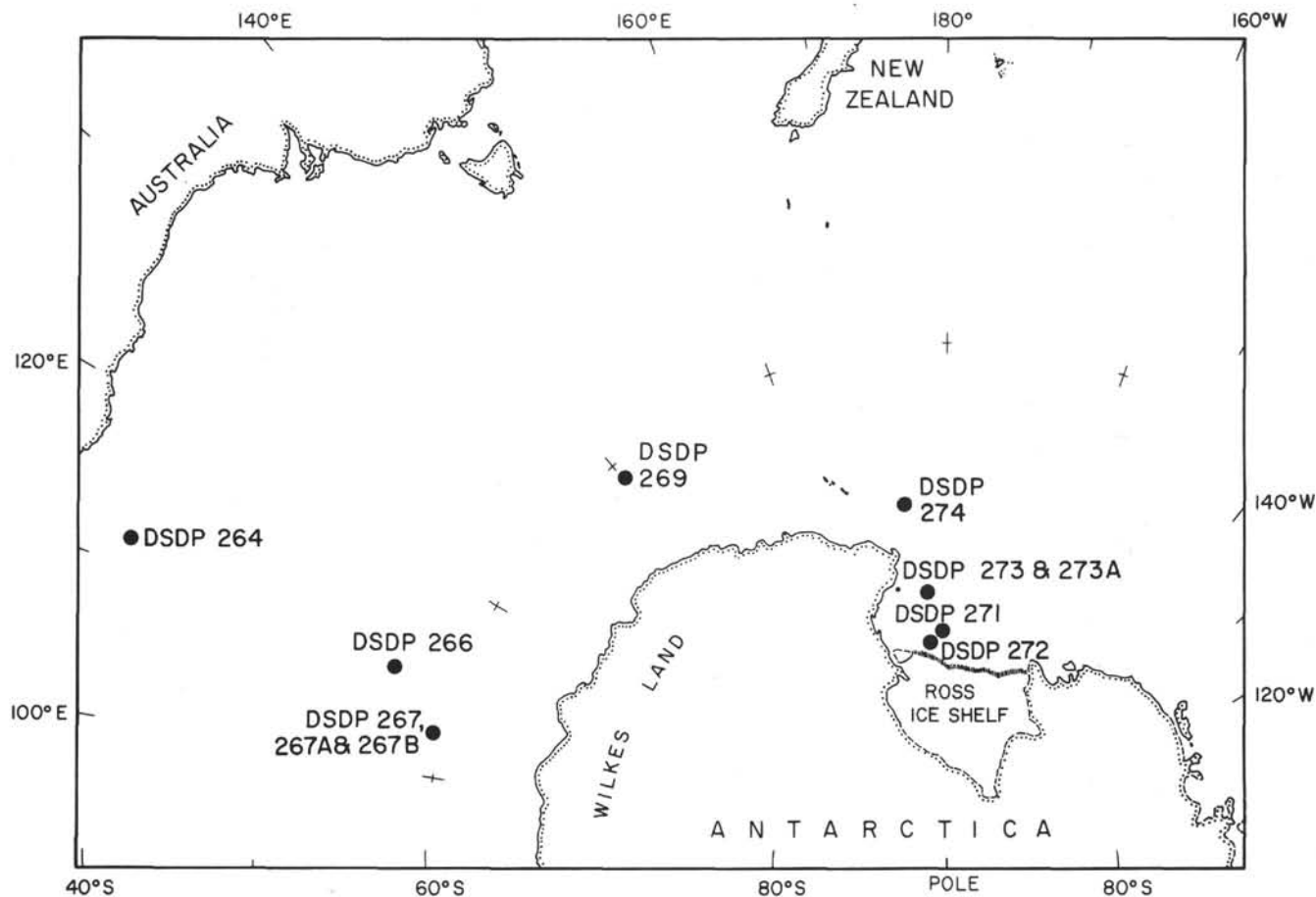


Figure 1. Locations of Deep Sea Drilling Project Leg 28 holes for which silicoflagellate assemblages are cited.

TABLE 2
Southern Ocean Paleomagnetically Dated Eltanin Piston Cores Utilized to Establish
a Silicoflagellate Biostratigraphic Zonation for the Past 4.65 m.y.B.P.

Core	Latitude	Longitude	Water Depth (Fathoms)	Paleomagnetic Age
14-8	59°40.0'S	160°17.4'W	2120	Recent-Gilbert "B"
13-17	65°41.0'S	124°06.3'W	2583	Recent-Gilbert "C"
38-7	61°49.3'S	149°53.0'E	2000	Lower Matuyama-Lower Gilbert
32-48	67°00.0'S	176°16.0'E	1928	Lower Gauss
50-28	62°54.2'S	150°41.2'E	1908	Lower Gauss-Upper Gilbert
36-33	57°46.3'S	154°55.0'E	1877	Lower Gauss-Upper Gilbert
38-8	61°48.6'S	149°54.2'E	1800	Upper Gilbert

are presented along with carbonate and quartz percentages. Detailed discussions of paleoecology, paleoclimatology, biostratigraphy, and systematic paleontology of the material recovered are presented in the following sections of this report.

PREPARATION OF SAMPLES AND METHOD OF STUDY

Samples for shore-laboratory study of silicoflagellates were taken aboard D/V *Glomar Challenger* by the shipboard diatomist Mr. David McCollum.

Eltanin samples utilized in this study were obtained at the Florida State University Antarctic Research Facility.

Some shipboard core-catcher slide preparations made by D. McCollum were utilized in this study. The shipboard processing procedure used on these core-catcher samples varied with the type of sediment and the degree of lithification. Sediments composed primarily of calcium carbonate were treated with 10% HCl and the undissolved portion centrifuged and decanted several times to concentrate the diatom and silicoflagellate

SERIES OR SUBSERIES	AGE (M. Y.)	DSDP LEG 7 Central Equatorial Pacific (Martini, 1971)	DSDP LEG 16 Panama Basin (Bukry & Foster, 1973)	DSDP 173-LEG 18 Eastern North Pacific (Bukry, 1973)	DSDP LEG 19 North Pacific (Ling, 1973)	DSDP 206-LEG 21 Tasman Sea (Dumitrica, 1973)	DSDP LEG 28 Antarctic (This Paper)
PLEISTOCENE	1	<i>M. quadrangula</i>	<i>M. epidon</i> <i>M. elliptica</i>	<i>D. octangulatus</i>	<i>D. octangulatus</i> <i>D. octonarius</i> <i>D. subarcticus</i>	<i>D. aculeata</i> "M" cf. <i>elliptica</i>	<i>D. speculum A</i>
	2		<i>D. boliviensis</i>		<i>Ammodochium rectangulare</i>		<i>D. speculum B</i>
PLIOCENE	3		<i>C. major</i>	<i>D. speculum</i>	<i>Ebriopsis antiqua</i>		<i>D. boliviensis</i>
	4				<i>C. hemisphericus</i>	<i>D. perlaevis</i>	<i>D. aspera v. pygmaea</i> <i>D. pseudofibula</i>
LATE MIOCENE	5			?			<i>M. diodon</i>
	6	<i>D. fibula</i>	<i>D. crux</i>		<i>D. speculum var. pentagonus</i>		?
	7		<i>D. fibula</i>				
	8		<i>D. aspera</i>	<i>D. pseudofibula</i>			<i>M. circulus</i>
	9				<i>M. circulus var. apiculata</i>		
	10					<i>D. fibula aspera</i>	
MIDDLE MIOCENE	11						
	12	<i>D. rhombica</i>	<i>D. longispinus</i>	<i>D. longispinus</i>	<i>D. schavinslandii</i>		
	13						
	14	<i>C. triacantha</i>	<i>C. triacantha</i> <i>D. octacanthus</i>	<i>C. triacantha</i>		<i>C. triacantha</i> <i>D. mesocephalus</i> <i>D. stauracanthus</i> lower ?	<i>Dictyocha mutabilis</i> <i>D. longispinus</i>
	15						
EARLY MIOCENE	16						<i>C. triacantha</i>
	17						
	18						<i>N. navicula</i>
	19						
	20						<i>N. regularis</i>
	21						
	22						<i>N. robusta</i>

Figure 2. Comparison of early Miocene to Pleistocene silicoflagellate zones in deep-sea sediments.

remains. This method was used primarily on samples from Sites 264, 266, and 267. When siliceous microfossil abundances were high, core-catcher samples were untreated, and slides were made of the raw sample (Sites 269 and 274). In instances where the sediment was semilithified (Sites 272 and 273) and siliceous microfossil abundances were low, the sediment was disassociated with hot 50% hydrogen peroxide. The disassociated sediment was then filtered through 25 μ , 38 μ , and 63 μ sieves. A slide was made for each fraction, including the unsieved portion.

Shore-laboratory *Eltanin* and *Glomar Challenger* samples were treated as follows: Samples of approximately 1 cc were placed in clean 200-ml beakers with 15 ml of 30% hydrogen peroxide and heated until the sediment was disassociated and activity was negligible. Fifteen ml of reagent grade HCl were then added, and heating continued until activity of the acid was reduced. Heating time for the samples varied with the sediment type and the degree of lithification. Samples

were then diluted with 50 ml of distilled water and transferred to 110-ml centrifuge tubes. This suspension was centrifuged at 2000 rpm for 3 min, decanted, and the residue diluted with distilled water. The procedure was repeated two more times. The residue was then added to 50 ml of 0.5% sodium pyrophosphate solution and centrifuged again. This step was repeated two additional times. After the last centrifugation and decanting, 50 ml of distilled water were added to the residue and the suspension placed in labeled plastic bottles. Each sample was shaken thoroughly and a small amount of suspension pipetted from the middle of the bottle. Two drops of the pipette suspension were placed on a 22 mm \times 22 mm cover slip and dried on a slide warmer. When dry, two drops of Hyrax were added and heated until the volatile components evaporated. The cover slip was taken upon a heated slide and then allowed to cool.

Slide examinations were made with a Zeiss Photomicroscope II. Specimen counts were done in bright-field illumination at magnifications of 250 \times and 650 \times .

All specimens, whole or consisting of more than half a skeleton, were counted. All slides were systematically scanned in their entirety by consecutive traverses using a mechanical stage. Counts of two slides were made at some sample intervals in sections of particular stratigraphic significance where less than 100 specimen counts were obtained from the first slide. Sections where this procedure was followed include: Site 274, lower Oligocene; Site 267, upper Oligocene; and Site 266, lower Miocene.

ZONAL CHARACTERISTICS

Distephanus speculum Zone A

Top: Not defined, but the zone includes all floras above the initial consistently common occurrence of long-spined *Distephanus speculum* morphotypes.

Base: First consistently common occurrence of long-spined *Distephanus speculum* in the absence of *Distephanus boliviensis*.

Age: Early Pleistocene-Recent: Matuyama and Brunhes paleomagnetic epochs.

Important characteristics of the zonal assemblage: This zone is characterized by the consistently common occurrence of long- and short-spined morphotypes of *Distephanus speculum*. Other species present sporadically through the zone are *Distephanus speculum* var. *pentagonus*, *D. speculum* var. *septenarius*, *Dictyocha fibula*, and *Dictyocha aspera*. Common to abundant *Distephanus polyactis* are found only in the lower portion of the zone which is within the Matuyama paleomagnetic epoch.

Reference section: Site 269: 61°40.57'S, 140°04.21'E and E14-8: 59°0.0'S, 160°17.4'W.

Occurrence of zone: Continuously cored at Site 274 and discontinuously cored at Sites 269 and 266.

Correlation: In paleomagnetically dated *Eltanin* piston cores the lower boundary of this zone is approximately correlative with the Gauss-Matuyama magnetic epoch boundary (2.43 m.y.B.P.).

Distephanus speculum Zone B

Top: First consistently common occurrence of long-spined *Distephanus speculum* in the absence of *Distephanus boliviensis*.

Base: Last consistently common occurrence of *Distephanus boliviensis* in the presence of a *Distephanus speculum* group dominated by short-spined morphotypes.

Age: Late Pliocene: within Gauss paleomagnetic epoch.

Important characteristics of the zonal assemblage: The zone is characterized by the consistently common to abundant occurrence of short-spined *Distephanus speculum* and rare to few long-spined *Distephanus speculum*. Short-spined *D. speculum* are consistently more abundant than long-spined *D. speculum*. Species present sporadically through the zone are *Dictyocha pseudofibula*, *D. aspera*, *D. fibula*, *Distephanus boliviensis*, *D. sp. cf. boliviensis*, and *Distephanus speculum* var. *pentagonus*. Abundant *Distephanus speculum* var. *pentagonus* forma *armatus*, observed at the base of this

zone, at Site 266, may provide a useful datum within the lower portion of this zone.

Reference section: Site 266: 56°24.13'S, 104°29.30'E and E14-8: 59°40.0'S, 160°17.4'W.

Occurrence of zone: Continuously cored at Site 274 and intermittently cored at Sites 266, 267, and 269.

Correlation: In paleomagnetically dated *Eltanin* piston cores this zone is present throughout the Gauss magnetic epoch between the Gauss-Matuyama boundary (2.43 m.y.B.P.) and the base of the Mammoth event (3.085 m.y.B.P.)

Distephanus boliviensis Zone

Top: Last consistently common occurrence of *Distephanus boliviensis* in the presence of a *Distephanus speculum* group dominated by short-spined morphotypes.

Base: Last common occurrence of *Dictyocha aspera* var. *pygmaea* and *Dictyocha fibula* var. *pumila*.

Age: Middle Pliocene: lower Gauss-upper Gilbert paleomagnetic epochs.

Important characteristics of the zonal assemblage: This zone is characterized by the consistent occurrence of common to abundant *Distephanus boliviensis*, *D. sp. cf. boliviensis*, and *D. speculum s.l.* Species occurring more sporadically but with a similar abundance include *Distephanus speculum* var. *pentagonus*, *D. boliviensis* var. *major*, *D. boliviensis* var. *binoculus*, and *Dictyocha pentagona*. The lower portion of the zone, within the upper Gilbert, contains a significant warm-water assemblage component which includes *Dictyocha aspera*, *D. fibula*, and *D. perlaevis*.

Reference section: *Eltanin* piston core 50-28: 62°54.2'S, 150°41.2'E.

Occurrence of zone: Continuously cored at Site 274 and discontinuously cored at Site 266.

Correlation: In *Eltanin* cores from this region of the Southern Ocean this zone occurs within the lower Gauss and upper Gilbert magnetic epochs, between 3.085 and 3.82 m.y.B.P.

Dictyocha aspera var. *pygmaea*- *Dictyocha fibula* var. *pumila* Zone

Top: Last common occurrence of *D. aspera* var. *pygmaea* and *D. fibula* var. *pumila*.

Base: First common occurrence of *D. aspera* var. *pygmaea* and *D. fibula* var. *pumila*.

Age: Early Pliocene: Gilbert paleomagnetic epoch.

Important characteristics of the zonal assemblage: This zone is characterized by common to abundant occurrence of *Dictyocha aspera* var. *pygmaea*, *D. fibula* var. *pumila*, *D. aspera*, *D. fibula*, *Distephanus boliviensis*, and *D. sp. cf. boliviensis*; and few to common *Dictyocha perlaevis*. Other species occurring sporadically include *Distephanus boliviensis* var. *major*, *D. boliviensis* var. *binoculus*, *D. crux*, *D. speculum* var. *pentagonus*, *Dictyocha pentagona*, and *Mesocena cf. elliptica*.

Reference section: *Eltanin* piston core 38-8: 61°48.6'S, 149°54.2'E.

Occurrence of zone: Discontinuously cored at Sites 266 and 267.

Correlation: In three *Eltanin* piston cores off Wilkes Land, Antarctica, E 38-8, E 50-28, and E 36-33, this zone occurs in the Gilbert magnetic epoch between events "a" and "b" (3.82-3.97 m.y.B.P.). In E 14-8, off West Antarctica, this zone is confined to sediments within the Gilbert event "a" (3.72-3.82 m.y.B.P.).

Dictyocha pseudofibula Zone

Top: The first common occurrence of *Dictyocha aspera* var. *pygmaea* and *Dictyocha fibula* var. *pumila*.

Base: First common occurrence of *Dictyocha pseudofibula*.

Age: Middle early Pliocene; Mid-Gilbert paleomagnetic epoch.

Important characteristics of the zonal assemblage: The zone is characterized by common to abundant *Dictyocha pseudofibula*, *D. aspera*, *D. fibula*, *Distephanus boliviensis*, and *D. boliviensis* sp. cf. *boliviensis*. Less common species occurring sporadically include: *Distephanus crux*, *D. speculum* var. *pentagonus*, *D. boliviensis* var. *major*, *D. boliviensis* var. *binoculus*, and *Dictyocha pentagona*.

Reference sections: *Eltanin* piston core 38-8: 61°48.6'S, 149°54.2'E; and E 14-8: 59°40.0'S, 160°17.4'W.

Occurrence of zone: Continuously cored at Site 274 and discontinuously cored at Sites 267 and 269.

Correlation: In *Eltanin* piston cores E 38-8 and E 14-8 the top of this zone occurs between Gilbert magnetic events "a" and "b" (3.82-3.97 m.y.B.P.) and in E 14-8 the bottom of this zone occurs between Gilbert magnetic events "b" and "c" (4.14-4.33 m.y.B.P.).

Mesocena diodon Zone

Top: The first common occurrence of *Dictyocha pseudofibula*.

Base: The first consistent occurrence of *Mesocena diodon*. Last consistent occurrence of *M. circulus*.

Age: Late Miocene-early Pliocene.

Important characteristics of the zonal assemblage: This zone is characterized by a low-diversity assemblage dominantly comprised of *Distephanus speculum* s.l., *D. crux*, and *Mesocena diodon*. Minor constituents of the zonal assemblage which occur sporadically include *Distephanus speculum* var. *pentagonus*, *D. boliviensis*, *D. sp. cf. boliviensis*, *Dictyocha pseudofibula*, *D. aspera*, *D. aspera* var. *pygmaea*, and *D. fibula* var. *pumila*.

Reference section: *Eltanin* piston core E 13-17: 65°41.0'S, 124°06.3'W.

Occurrence of zone: Discontinuously cored at Sites 266, 267, and 269.

Correlation: In *Eltanin* piston core 13-17 the *Mesocena diodon* Zone is present throughout the Gilbert magnetic epoch below the base of event "c" (4.41 m.y.B.P.) and in the normally magnetized basal 2 meters of the core which is probably equivalent to the late Miocene Epoch 5 magnetic epoch (5.10 m.y.B.P.). The base of the zone is unrepresented in the present study.

Mesocena circulus Zone

Top: First consistent occurrence of *Mesocena diodon*. Last consistent occurrence of *Mesocena circulus*.

Base: First consistent occurrence of *Mesocena circulus*. Last consistent occurrence of *D. mutabilis*.

Age: Late Miocene.

Important characteristics of the zonal assemblage: This zone is characterized by the consistent meager to common occurrence of the named taxon in conjunction with rare to few *Dictyocha aspera*, *Mesocena diodon*, *Distephanus speculum* var. *pentagonus*, and *D. speculum* s.l.

Reference section: Site 274: 68°59.81'S, 173°25.64'E.

Occurrence of zone: Continuously cored at Sites 266 and 274 and possibly represented at Site 267.

Correlation: Broadly equivalent to the *Mesocena circulus* var. *apiculata* Zone of Ling (1973) and includes part of the calcareous nannofossil *Discoaster quinquarum* (NN11) and *Ceratolithus tricorniculatus* (NN12) zones of Worsley (1973).

Remarks: The assemblages of this zone are of particularly low abundance and diversity. The poor preservation of the assemblage suggests that some abundance and diversity diminution may be partially the result of dissolution.

Dictyocha mutabilis Zone

Top: Last occurrence of *Dictyocha mutabilis*.

Base: First occurrence of *Dictyocha mutabilis*.

Age: Early middle Miocene.

Important characteristics of the zonal assemblage: The silicoflagellate assemblage of this zone is particularly sparse with only rare occurrences of *Distephanus longispinus*, *D. cf. longispinus*, and *D. boliviensis* var. *major*.

Reference section: Site 266: 56°24.13'S, 110°06.70'E.

Occurrence of zone: Site 266, Sections 4-6. The base of this zone may not be present at the base of Core 13 but, instead, in the uncored interval between Cores 13 and 14.

Correlation: At Site 266 this zone is broadly equivalent to the calcareous nannofossil *Discoaster exilis* (NN6) Zone of Martini (1971). The occurrence of the present species in the middle Miocene (Helvetian) of San Pedro, California (Deflandre, 1950c) may also be correlative.

Distephanus longispinus Zone

Top: First occurrence of *Dictyocha mutabilis*.

Base: Last consistent occurrence of *Corbisema triacantha*.

Age: Early middle Miocene-middle middle Miocene.

Important characteristics of the zonal assemblage: Silicoflagellate abundance and diversity are particularly low throughout the entire zone. The most consistently occurring species are *Distephanus longispinus*, *D. cf. longispinus*, *D. crux*, and *D. speculum* s.l. Rarer occurrences of *Distephanus speculum* var. *pentagonus*, *Dictyocha aspera*, *D. fibula*, and *Cannopilus hemisphericus* were noted.

Reference section: Site 266: 56°24.13'S, 110°06.70'E.

Occurrence of zone: Intermittently cored at Site 266 from Core 14 through Core 17, Section 3.

Correlation: At Site 266, the lower portion of this zone (Cores 16 and 17) is equivalent to the calcareous

nannofossil *Sphenolithus heteromorphus* (NN5) Zone of Burns (this volume). The upper portion of the zone, in Cores 14 and 15, cannot be correlated to the standard nannoplankton zonation due to the paucity of calcareous nannofossils; however, this interval can be no older than the portion of the *Discoaster exilis* (NN6) Zone of Burns, which is present in Core 13.

Corbisema triacantha Zone

Top: The last consistent occurrence of *Corbisema triacantha*.

Base: The last occurrence of *Naviculopsis navicula* and *N. regularis*.

Age: Late early Miocene-Early middle Miocene.

Important characteristics of the zonal assemblage: This zone is characterized by the consistently meager to abundant occurrence of *Corbisema triacantha* in addition to lesser amounts of *Distephanus longispinus*, *Cannopilus hemisphaericus*, and *C. sphaericus*. *Mesocena apiculata* and *D. cf. longispinus* are present only in the lower portion of the zone. The sole stratigraphic appearance of *Cannopilus antarcticus* and an acme of *Distephanus boliviensis* var. *major* provide useful datums in the upper portion of the zone.

Reference section: Site 266: 59°24.13'S, 110°06.70'E.

Occurrence of zone: Intermittently cored at Site 266, represented in Cores 17 and 18.

Correlation: The top of this zone has been previously described as occurring in the lower (?) to middle Miocene in the equatorial Pacific (Martini, 1971), in the calcareous nannofossil *Discoaster exilis* Zone (NN6) of the eastern equatorial Pacific (Bukry and Foster, 1973), and corresponding to the top of the calcareous nannofossil *Sphenolithus heteromorphus* (NN5) Zone in the eastern North Pacific (Bukry, 1973). In Italy and Majorca the *C. triacantha* Zone is broadly equivalent to the radiolarian *Calocyclus costata* Zone or *Dorcadospyrus alata* Zone and the calcareous nannofossil *Sphenolithus heteromorphus* (NN5) Zone (Sanfilippo et al., 1973).

Naviculopsis navicula Zone

Top: Last occurrence of *Naviculopsis navicula* and *Naviculopsis regularis*.

Base: First consistent occurrence of *Naviculopsis navicula*.

Age: Late early Miocene.

Important characteristics of the zonal assemblage: This zone is characterized by the consistently common occurrence of *Naviculopsis navicula*, *Distephanus cf. longispinus*, *D. crux*, *D. speculum*, and *Mesocena apiculata*. Species found sporadically through the zone include: meager to common *Corbisema triacantha* and *Naviculopsis regularis* and meager *Distephanus longispinus*, *Cannopilus hemisphaericus*, and *C. sphaericus*.

Reference section: Site 266: 56°24.13'S, 110°06.70'E.

Occurrence of zone: Discontinuously cored at Site 266.

Correlation: At Site 266 this zone is equivalent to the calcareous nannofossil *Sphenolithus belemnoides* (NN3) Zone of Burns (this volume). The only other occurrences of this zone are in Monte Calvo, Italy (Martini, 1972);

Casalino, Italy (Sanfilippo et al., 1973); and Ernstbrunn, Trafoestation, Austria (Bachmann, 1970). Sanfilippo et al. (1973) suggest that the *N. navicula* Zone is correlative to the calcareous nannofossil *Sphenolithus belemnoides* (NN3) Zone and upper *Discoaster druggi* (NN2) Zone and Martini (1972) also correlates this zone to the lower *Calocyclus costata* and upper *Calocyclus virginis* zones of the radiolarian zonation.

Naviculopsis regularis Zone

Top: First consistent occurrence of *Naviculopsis navicula*.

Base: Last common occurrence of *Naviculopsis robusta*.

Age: Middle early Miocene.

Important characteristics of the zonal assemblage: This zone is characterized by the consistently common to abundant occurrence of *Naviculopsis regularis*, *Distephanus speculum s.l.*, *D. cf. longispinus*, and *Mesocena apiculata*. Other species occurring through the zone in meager to common quantities are *Cannopilus hemisphaericus*, *Corbisema triacantha*, *Dictyocha fibula*, *D. staurodon*, *Distephanus crux*, *D. cf. longispinus*, *Mesocena oamaruensis*, and *Naviculopsis navicula* var. *naviculopsis*. A few *Naviculopsis navicula* found only at the base of the zone represent the initial appearance of this species.

Reference section: Site 266: 56°24.13'S, 110°06.70'E.

Occurrence of zone: Discontinuously cored at Site 266.

Correlation: Equivalent to the calcareous nannofossil *Discoaster druggi* (NN2) Zone of Burns (this volume) at Site 266.

Naviculopsis robusta Zone

Top: Last consistent occurrence of *Naviculopsis robusta*.

Base: First consistent occurrence of *Naviculopsis robusta*.

Age: Early early Miocene.

Important characteristics of the zonal assemblage: This zone is characterized by consistent meager to abundant *Naviculopsis robusta* and *N. regularis*, meager *Distephanus longispinus* and meager to common *Distephanus speculum*. Species which occur sporadically through the zone include: meager *Cannopilus hemisphaericus* and *Distephanus boliviensis*; and meager to common *Distephanus crux* and *D. cf. longispinus*.

Reference section: Site 266: 56°24.13'S, 110°06.70'E.

Occurrence of zone: Discontinuously cored at Site 266, Cores 22 and 23.

Correlation: Studies of Site 266 calcareous nannofossils (Burns, this volume) indicate that this zone is below the *Discoaster druggi* (NN2) Zone and still within the Miocene; thus the *Naviculopsis robusta* Zone appears to be equivalent to the *Triquetrorhabdulus carinatus* (NN1) Zone.

Naviculopsis biapiculata Zone

Top: Undefined.

Base: Last consistent common occurrence of *Dictyocha deflandrei*.

Age: Late Oligocene.

Important characteristics of the zonal assemblage: This zone is characterized by the consistent common to abundant occurrence of *Naviculopsis biapiculata* and *Distephanus crux*. Other floral elements occurring less frequently include: *Cannopilus sphericus*, *Corbisema archangelskiana*, *Dictyocha deflandrei*, *D. frenguelli*, *D. pentagona*, *Distephanus speculum* s.l., *D. speculum* var. *pentagonus*, *Mesocena apiculata*, *M. oamaruensis*, *Naviculopsis regularis*, and *N. trispinosa*.

Reference section: Site 267: 59°15.74'S, 104°29.30'E.

Occurrence of zone: Site 267.

Dictyocha deflandrei Zone

Top: Last consistent occurrence of *Dictyocha deflandrei*.

Base: The first consistent common occurrence of *Dictyocha deflandrei* above the last common occurrence of *Dictyocha hexacantha*.

Age: Early Oligocene.

Important characteristics of the zonal assemblage: This zone is characterized by the consistently common to abundant occurrence of *Mesocena apiculata*, *Dictyocha deflandrei* s.l., *Distephanus* cf. *D. boliviensis*, *D. crux* s.l., and *Corbisema apiculata*. Other species occurring sporadically and in meager to common quantities are *Corbisema hastata*, *C. triacantha*, *Dictyocha variabilis*, *Distephanus* cf. *D. speculum* var. *pentagonus*, and *Mesocena oamaruensis*. *Dictyocha frenguelli* occurs abundantly throughout the upper portion of the zone and its evolutionary appearance has been utilized in establishing two subzones. The lower portion of the *Dictyocha deflandrei* Zone which contains common *Mesocena apiculata* and lacks *Dictyocha frenguelli* is designated as the *Mesocena apiculata* Subzone, and the portion of the zone that is characterized by the consistent common to abundant occurrence of *Dictyocha frenguelli* is designated as the *D. frenguelli* Subzone.

Reference section: Site 274: 68°59.81'S, 173°25.64'E.

Occurrence of zone: Continuously cored at Site 274.

SILICOFAGELLATES AT EACH SITE

Silicoflagellate abundances and diversities were extremely low at Sites 264, 271, 272, and 273; information on their occurrence is contained in the site summaries. The occurrences of silicoflagellates, zonal subdivisions, and geologic ages are tabulated for Sites 266, 267, 269, and 274. All tables (Tables 3-6) contain the following information about each sample studied: (1) core number, section number, interval (cm), and depth below sea floor (m) in columns on the left; (2) an alphabetically arranged list of silicoflagellates with quantitative representation of abundances; (3) zones and geological ages at the right of each table. Diagonal lines in a zonal column indicate stratigraphic sections where zonation was impossible due to the lack of diagnostic silicoflagellates or unrecovered sediment. When zonal boundaries occur in coring gaps, they are positioned midway between recovered sections.

Site 264

(34°58.13'S, 112°02.68'E, water depth 2876 m)

Site 264 is located near the central-southern edge of the Naturaliste Plateau, about 125 km southwest of Leg 26 Site 258. Two holes were drilled at the site which penetrated a 167-meter (14 core) sedimentary sequence composed entirely of pelagic carbonate sediment.

Core-catcher samples from all 14 recovered cores were examined for silicoflagellates and all were found to be barren, with the exception of Core 2, obtained from 25.5 to 35 meters. Examination of several Core 2 core-catcher slide preparations yielded specimen counts of not more than five per slide. Silicoflagellates identified include: *Naviculopsis biapiculata*, *Naviculopsis constricta*, *Corbisema archangelskiana*, and *Mesocena oamaruensis* var. *quadrangula*. These species can occur concurrently in either the upper Oligocene or the upper Eocene, but a late Eocene age for Sample 2, CC is favored on the basis of calcareous nannoplankton and foraminiferal biostratigraphic evidence.

Site 266

(56°24.13'S, 110°06.70'E, water depth 4173 m)

Site 266 is located on the southern flank of the Southeast Indian Ridge about 800 km from the ridge crest. Intermittent coring of 370 meters of sediment was accomplished before basement was encountered. The sediment sequence is comprised of three main units: an upper unit, from 0 to 148 meters, composed of diatom ooze and clay diatom ooze; a middle unit, at 148 to 253 meters, composed of mixed nanno ooze and clay and diatom ooze and clay; and a lower unit, from 253 to 370 meters, predominantly composed of nanno clay.

Many of the middle and early Miocene silicoflagellate zones at this site have been related to previously described calcareous nannofossil zones. For this reason, early and middle Miocene silicoflagellate zones have had their reference sections established at this site.

Sample 1, 110-112 cm, at 1 meter, through Sample 4-3, 100-102 cm, at 67 meters, contain an abundant, well-preserved silicoflagellate assemblage of limited diversity. The floral assemblage is characterized by the consistently common occurrence of long- and short-spined *Distephanus speculum* and is therefore conformable with the *D. speculum* Zone A. Species occurring sporadically and in meager amounts include *D. speculum* var. *pentagonus*, *D. sp. cf. boliviensis*, *Dictyocha pseudofibula*, *D. medusa*, *D. aspera*, and *D. fibula*. In Sample 4-2, 60-62 cm, at 68 meters, the acme of *Distephanus polyactis* provides a usable datum within the lower portion of the *Distephanus speculum* Zone A.

Thirteen samples examined between Sample 4-4, 120-122 cm and Sample 6-6, 120-122 cm, obtained from 68 to 110 meters, contain abundant silicoflagellates and are assigned to the *D. speculum* Zone B. The samples are characterized by the consistent occurrence of abundant short-spined *D. speculum* and the sporadic, meager to common occurrence of long-spined *D. speculum*. Species occurring sporadically through this interval include those previously described in the *D. speculum* Zone A, as


TABLE 3A
Distribution of Silicoflagellates at Site 266

Site 266		Taxa																							Total Specimens	Zone	Series or Subseries						
Sample (Interval in cm)	Depth (in m)	<i>Cannopilus hemisphaericus</i>	<i>Dictyocha aspera</i>	<i>D. aspera</i> var. <i>pygmaea</i>	<i>D. fibula</i>	<i>D. fibula</i> var. <i>pumila</i>	<i>D. medusa</i>	<i>D. pentagona</i>	<i>D. perlaevis</i>	<i>D. pseudofibula</i>	<i>D. variabilis</i>	<i>Distephanus boliviensis</i>	<i>D. sp. cf. boliviensis</i>	<i>D. boliviensis</i> var. <i>binoculus</i>	<i>D. boliviensis</i> var. <i>major</i>	<i>D. crux</i>	<i>D. cf. longispinus</i>	<i>D. polyactis</i>	<i>D. speculum</i> (long-spined)	<i>D. speculum</i> (short-spined)	<i>D. speculum</i> var. <i>pentagonus</i>	<i>D. speculum</i> var. <i>pentagonus</i> f. <i>armata</i>	<i>D. speculum</i> var. <i>pentagonus</i> f. <i>geminus</i>	<i>D. speculum</i> var. <i>septenarius</i>				<i>Mesocena circulus</i>	<i>M. diodon</i>	<i>M. elliptica</i>	<i>M. cf. elliptica</i>	<i>Naviculopsis</i> sp.	
1-1, 110-112	1																		2	11	28	5									53	<i>Distephanus speculum</i> A	Pleistocene
1-2, 80-82	2																		1	39	51										100		
1-3, 70-72	4																			10	88	2									100		
1-4, 100-102	5.5																			17	79	3			2						102		
2-2, 120-122	28		4		6															31	57	1									100		
2-3, 30-32	28		3		8		2													13	74										100		
4-2, 60-62	65																		28	25	47										100		
4-3, 100-102	67																		4	24	72										100		
4-4, 120-122	68																		2		20										22		
5-1, 120-122	83																			3	30	1			1						36		
5-2, 130-132	85		1																	3	19										23		
5-3, 130-132	86																			2	4										7		
5-4, 130-132	88																			1	6	1									9		
5-5, 130-132	89		2		1									2	4	1	1			3	28										42		
5-6, 130-132	91																			40											40		
6-1, 120-122	102																			20	80										100		
6-2, 110-112	104				1									3	4					4	88				1						101		
6-3, 120-122	105		1								2		1	2						1	90	3									100		
6-4, 120-122	107													1						10	89										100		
6-5, 110-112	108												2	3	2					1	92										100		
6-6, 120-122	110					1	2						1		1	3				2	47	20	28								105		
7-1, 125-127	121									1			7	6						3	83										100		
7-2, 45-47	122												4	4							71	1									80		
7-2, 120-122	123			1					2	1			8	5						25	57	1									100		
7-3, 50-52	123.5												3	4						2	89	6									104		
7-3, 125-127	124		1							2			1	2						6	85	2									99		
7-4, 45-47	125										1		15	6							65	1					1				100		
7-4, 120-122	126		3										10	6						5		2									26		
7-5, 45-47	126.5		2							1		6	33	1							55		1				1				100		
7-5, 117-119	127		1										10	15							74										100		
8-1, 55-57	130		1										7					1		5	8			2				1			25		
8-1, 130-132	131		4		3						1		10	6							15			2				1			42		
8-2, 45-47	131.5		14	3	1					1		32	17				1				30	1									100		
8-2, 120-122	132		1	8	1	3				1		26	5					1			51	1						2			100		
8-3, 45-47	133			15	3	6					1		31				1			4	37										100		
8-3, 120-122	134		23		2							25	9								40							1	1		101		
8-4, 45-47	134.5		26	3	3		1			2		24	13								23							5			100		
8-4, 120-122	135			11	29	4						28	18	2							2	3		3							100		
8-5, 45-47	136			14	38		5					23	7								10			3							100		
8-5, 120-122	137			13	41					1		25	10								10										100		
8-6, 50-52	137.5			7	7			6	2			16	6	2							13	1									60		
8-6, 125-127	138			7	4			1	10			13	8	1							15	1									60		
9-1, 89-91	140											6	6				2				10	1			1	4					30		
9-2, 30-32	141				3					1		9	10				1				9					1	1				35		
9-3, 30-32	143			3	1					1		6	6				2				7					1					27		
9-4, 99-101	144.5		1		4												17				20	2				2					46		

TABLE 3B
Distribution of Silicoflagellates at Site 266

Site 266		Taxa																				Total Specimens	Zone	Subseries								
Sample Interval (in cm)	Depth (m)	<i>Cannopilus antarcticus</i>	<i>C. hemisphaericus</i>	<i>C. sphaericus</i>	<i>C. sp.</i>	<i>C. triacantha</i>	<i>C. triacantha</i> var. <i>flexuosa</i>	<i>Dictyocha aspera</i>	<i>D. aspera</i> var. <i>pygmaea</i>	<i>D. deflandrei</i>	<i>D. fibula</i>	<i>D. fibula</i> var. <i>pumila</i>	<i>D. mutabilis</i>	<i>D. pentagona</i>	<i>D. pseudofibula</i>	<i>D. variabilis</i>	<i>Distephanus boliviensis</i>	<i>D. boliviensis</i> var. <i>binoculus</i>	<i>D. boliviensis</i> var. <i>major</i>	<i>D. erix</i>	<i>D. longispinus</i>				<i>D. cf. longispinus</i>	<i>D. speculum</i> s.l.	<i>D. speculum</i> var. <i>pentagonus</i>	<i>D. speculum</i> var. <i>pentagonus</i> f. <i>geminus</i>	<i>Mesocena apiculata</i>	<i>M. circulus</i>	<i>Naviculopsis navicula</i>	<i>N. regularis</i>
10-1, 90-92	149													1					2					7						10	Upper Miocene	
10-2, 40-42	150							1				1													1					2		
10-4, 40-42	153																													1		
10-5, 30-32	155																													0		
10-6, 80-82	157																													0		
11-1, 60-62	159																										25			25		
11-2, 60-62	160																										37			37		
11-3, 90-92	162							1																			16			17		
11-4, 40-42	163																													0		
11-5, 30-32	164																													0		
11-6, 70-72	166																							1						1		
12-1, 30-32	177																													0		
12-2, 120-122	180																													0		
12-3, 110-112	181																													0		
13-1, 60-62	197																													0		
13-2, 70-72	198					1		1																1						3		
13-3, 60-62	200					2							5																	7		
13-4, 60-62	201												20																	20		
13-5, 60-62	203												24						2						2					28		
13-6, 60-62	204									1		10																1		12		
14-1, 80-82	216		2																2					2				2		8		
14-2, 60-62	217																						1							1		
14-3, 60-62	219																				16	4		2						22		
14-4, 60-62	220																				2	1	1							4		
15-1, 60-62	235																							3		1				4		
15-2, 60-62	236												1																	1		
15-3, 60-62	238																													0		
16-1, 92-94	244																													0		
16-2, 60-62	246																													0		
17-1, 140-142	254					2		3						2		2				5					2					15		
17-2, 60-62	255					6					3							3					6							18		
17-3, 60-62	257					2															2									4		
17-4, 60-62	258					42		27									14	4	7				4			2				100		
17-5, 63-65	260	10	4			55											7	4	13				9	1						103		
18-1, 63-65	273				12												1				3		6			1				26		
18-2, 60-62	274			4			2										2				14	2		4		2				30		
18-3, 60-62	276									3	3										6		6							18		
18-4, 60-62	277					1																		2						3		
18-5, 60-62	279																													0		
19-1, 60-62	292						1															1		1		1	2			6		
19-2, 60-62	293					2															2		2		4		8			18		
19-3, 60-62	295						2		5												5	1	5	5	1	5	2			31		
19-4, 60-62	296								1												4		6	2	3		8			24		
19-5, 60-62	298								1														5	4	2	3		3		15		
19-6, 60-62	299						2	15	3											3		7	10		9	2	9			60		

TABLE 3C
Distribution of Silicoflagellates at Site 266

Site 266		Taxa															Total Specimens	Zone	Subseries	
Sample (Interval in cm)	Depth (m)	<i>Cannopilus hemisphaericus</i> <i>C. sphaericus</i>	<i>Corbisema triacantha</i>	<i>Dictyocha fibula</i>	<i>D. staurodon</i>	<i>Distephanus boliviensis</i>	<i>D. crux</i>	<i>D. longispinus</i>	<i>D. cf. longispinus</i>	<i>D. speculum s.l.</i>	<i>Mesocena oamaruensis</i>	<i>M. apiculata</i>	<i>Naviculopsis navicula</i>	<i>N. navicula</i> var. <i>naviculopsis</i>	<i>N. regularis</i>	<i>N. robusta</i>				
20-1, 60-62	311	3	2					2	3		4		4			11	29	<i>Naviculopsis regularis</i>		Lower Miocene
20-2, 60-62	312					2	7			5						8	22			
20-3, 60-62	314	1		4		2	3		15	10		16				9	60			
20-4, 62-64	315			3			10	1	21	18	1	15	4			5	73			
21-1, 61-63	330				1				9	4	3		8	13	3		40			
21-2, 62-64	331																0			
21-3, 60-62	333								1		3						4			
21-4, 60-62	334								2		4						6			
21-5, 60-62	336									4							4			
21-6, 60-62	337									3		1					4			
22-1, 60-62	338	7					29	8	15	6					24	21	110	<i>Naviculopsis robusta</i>		
22-2, 60-62	360	2					12	2	1	12					13	12	54			
22-3, 60-62	361						6	1	1	8					10	7	33			
22-4, 60-62	363					2			4	1					6	11	24			
23-1, 33-35	370	2							2	1					6	4	15			

well as meager *D. boliviensis* and *D. boliviensis* var. *major*. The acme of *Distephanus speculum* var. *pentagonus* and *D. speculum* var. *pentagonus* forma *armatus*, at 108 meters, provides an easily recognizable datum within the lower *D. speculum* Zone B.

Sample 7-1, 125-127 cm through Sample 8-1, 130-132 cm, from 121 to 131 meters, is characterized by the consistently common occurrence of *Distephanus boliviensis* and therefore conforms to the zone bearing the same name. The portion of this interval below Sample 7-3, 125-127 cm, contains the uppermost range of consistently occurring *Dictyocha aspera* and is correlated to the Gilbert magnetic epoch above Gilbert "a" (3.72-3.32 m.y.B.P.).

Sample 8-2, 45-47 cm through Sample 9-4, 99-101 cm, from 131.5 to 144.5 meters, contains an almost temperate assemblage of silicoflagellates which includes the following warm-water species: *Dictyocha aspera*, *D. aspera* var. *pygmaea*, *D. fibula*, *D. fibula* var. *pumila*, *D. pentagona*, *D. perlaevis*, and *D. pseudofibula*.

Of five samples examined from Core 10, from 149 to 157 meters, only one sample (10-1, 90-92 cm) contained silicoflagellates. No zonal assignment was possible.

Core 11, Sections 1-3, from 159 to 163 meters, contains common to abundant *Mesocena circulus* and is referred to the zone bearing the same name. A barren interval is present throughout the remainder of Core 11, in all of Core 12 and in Core 13 above Section 2, 70-72 cm. This interval contains only fragments of unidentifiable silicoflagellates. The significance of this and other barren intervals is discussed in the paleoenvironmental portion of the text.

The *Dictyocha mutabilis* Zone occurs in Core 13, between Section 3, 60-62 cm and Section 6, 60-62 cm, at 198 to 204 meters. Cores 14, 15, 16 and Core 17 above Section 4, 60-62 cm, are referred to the *Distephanus longispinus* Zone of the middle Miocene. The interval between Sample 17-4, 60-62 cm and Sample 18-5, 60-62 cm, from 258 to 279 meters, conforms to the *Corbisema triacantha* Zone. Core 19, from 292 to 299 meters, and Core 20, at 311 to 315 meters, are referred to the *Naviculopsis navicula* and *N. regularis* zones, respectively. Core 21, obtained from 330 to 337 meters, contains insufficient age-diagnostic silicoflagellates for a zonal designation. Core 21 through Sample 23-1, 33-35 cm, at 338 to 370 meters, is referred to the *N. robusta* Zone.

Site 267

(Holes 267, 267A: 59°15.74'S, 104°29.30'E, water depth 4564 m;

Hole 267B: 29°14.55'S, 104°29.94'E, water depth 4539 m)

Site 267 is located in the deep basin south of the Southeast Indian Ridge and about 600 km north of the Wilkes Land continental shelf. Three holes (267, 267A, and 267B) were discontinuously cored at two locations 2.6 km apart. The sedimentary sequence in Holes 267 and 267A is comprised of two units; an upper unit of clay, silty clay, and clay diatom ooze which is approximately 110 meters thick; and a lower, 97-meter-thick unit of nanno ooze, chalk, and micritic limestone. The sedimentary sequence at Hole 267B is also comprised of two lithologic units; an upper unit similar to that of the

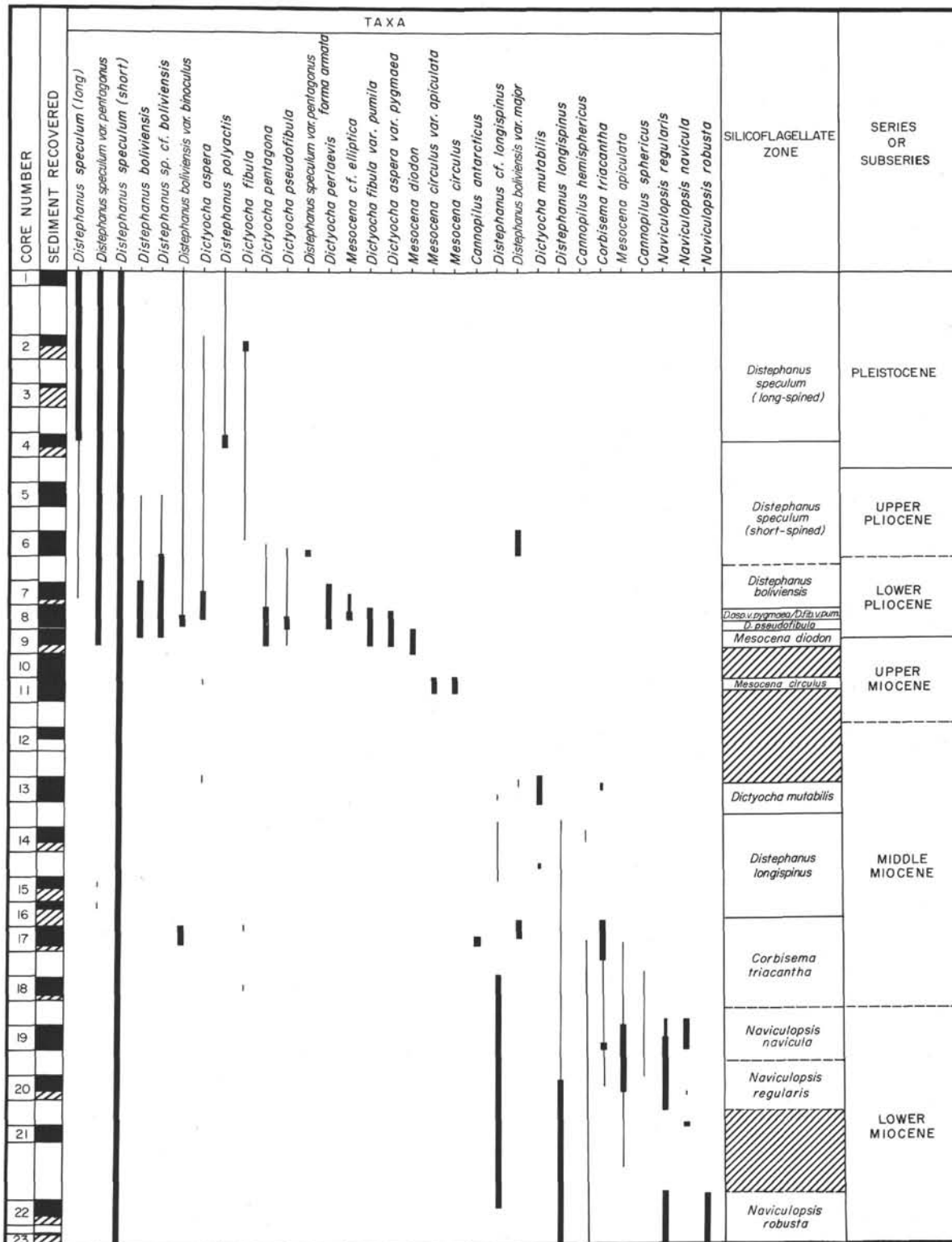


Figure 3. Ranges of selected silicoflagellates at Site 266 with zones and site geologic series and subseries.

other two holes, but 310 meters thick and a lower, 10-meter-thick nanno chalk.

Sample 1A-6, 0-2 cm, obtained at 11.5 meters, contains abundant, well-preserved silicoflagellates which conform to the *Distephanus speculum* Zone A. A meager

number of reworked specimens were observed from the older *D. speculum* Zone B or *D. boliviensis* Zone.

Sample 1A-6, 120-122 cm through Sample 1A, CC, at 13 to 13.5 meters, contain a mixed assemblage of Pleistocene and Pliocene silicoflagellates. A large

TABLE 4
Distribution of Silicoflagellates at Site 267

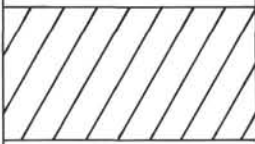
Holes 267, 267A, and 267B		Taxa																				Total Specimens	Zone	Series or Subseries												
Sample (Interval in cm)	Depth (m)	<i>Cannopilus hemisphaericus</i>	<i>Corbisema archangeliskiana</i>	<i>Dictyocha aspera</i>	<i>D. aspera</i> var. <i>pygmaea</i>	<i>D. deflandrei</i>	<i>D. fibula</i>	<i>D. fibula</i> var. <i>pumila</i>	<i>D. frenguelli</i>	<i>D. medusa</i>	<i>D. pseudofibula</i>	<i>D. sp.</i>	<i>D. variabilis</i>	<i>Distephanus boliviensis</i>	<i>D. cf. D. boliviensis</i>	<i>D. cf. D. boliviensis</i> var. <i>major</i>	<i>D. crux</i>	<i>D. octacanthus</i>	<i>D. polyactis</i>	<i>D. speculum</i>	<i>D. speculum</i> var. <i>pentagonus</i>				<i>Mesocena apiculata</i>	<i>M. circulus</i>	<i>M. diodon</i>	<i>M. oamaruensis</i>	<i>M. oamaruensis</i> var. <i>quadrangula</i>	<i>Naviculopsis biapiculata</i>	<i>N. constricta</i>	<i>N. lata</i>	<i>N. regularis</i>	<i>N. trispinosa</i>		
267-1-6, 0-2	11.5													6	2	1				72	10												91	<i>Distephanus speculum</i> A	Pleistocene	
267A-1-6, 120-122	13.0												1	8	3					93	2												107			
267A-1, CC	13.5			4	2		1	3						20	25		14			15													84	<i>Dictyocha pseudofibula</i>	Lower Pliocene	
267B-1, CC	114.5			10		27				1	52			5	1					10													106			
267B-2, CC	143.5										1									1				8									10	<i>Mesocena diodon</i>	Upper Miocene?	
267-3-1, 130-132	144.5																			2				2									4			
267B-3, CC	152.5										1													23										24		Middle Miocene
267B-4, CC	171.5																		1	3			1										5			
267B-5, CC	190.5																																	0		
267B-6, CC	219.0																	1																1		
267-2, CC	51.5																																	0	<i>Naviculopsis biapiculata</i>	Upper Oligocene
267A-3, CC	70.5	1																																1		
267-4-3, 120-122	131.5		2																		3	2					3			4	2			16		
267-4-4, 120-122	133.0		20											2		8			8	2	1			5	107	1	2	93	5					254		
267-4-6, 52-54	135.5								2							3				3				4	1	3		10	6					32		
267-4-6, 120-122	136.5															1					1					2		1						5		
267-5-2, 60-62	167.5	12	1	5							2					12	48					2		3		7		3	4					99		

TABLE 5
Distribution of Silicoflagellates at Site 269

Site 269		Taxa													Total Specimens	Zone	Series or Subseries	
Sample (Interval in cm)	Depth (m)	<i>Dictyocha aspera</i>	<i>D. fibula</i>	<i>D. pseudofibula</i>	<i>D. boliviensis</i>	<i>D. sp. cf. boliviensis</i>	<i>D. boliviensis</i> var. <i>binoculus</i>	<i>D. boliviensis</i> var. <i>major</i>	<i>D. crux</i>	<i>D. polyactis</i>	<i>D. speculum</i> var. <i>pentagonus</i>	<i>D. speculum</i> (short-spined)	<i>D. speculum</i> (long-spined)	<i>D. speculum</i> var. <i>septenarius</i>				<i>Mesocena diodon</i>
1-1, 90-92	1						1				1	17	78	3	100	<i>Distephanus speculum</i> A	Pleistocene	
1-1, 145-147	1.5											20	48		68			
1-2, 20-22	2						1					62	37		100			
1-2, 90-92	2.5											53	47		100			
1-3, 30-32	3.5										2	64	34		100			
1-3, 133-135	4.5							1		2	1	69	27		100			
1-4, 30-32	5						2					2	42	54	100			
1-4, 130-132	6										1	45	54		100			
1-5, 20-22	6									3		55	42		100			
1-5, 80-82	7									1		46	53		100			
1-6, 20-22	7.5										4	27	14		45			
1-6, 120-122	8.5										5	24	70	1	100			
2-1, 123-125	47											1			1	<i>Distephanus speculum</i> B	Upper Pliocene	
2-2, 30-32	48				1							9	7	1	18			
2-2, 80-82	48.5			1	1		1					2	10		15			
2-2, 130-132	49				10				3						13			
2-3, 20-22	49			2		1									3			
2-3, 67-69	49.5				2								2		4	<i>Dictyocha pseudofibula</i>	Lower Pliocene	
2-3, 120-122	50				2							1	2	1	6			
3-1, 60-62	94	2		7	3							2	1		15			
3-1, 120-122	95			2											2			
3-2, 40-42	95.5	1													1			
3-2, 90-92	96	1		2											3	<i>Mesocena diodon</i>	Middle Miocene	
3-2, 137-139	96.5			2											2			
3-3, 30-32	97			1	2										3			
3-3, 80-82	97.5			4	12										16			
3-3, 130-132	98			1										3	1			5
4-1, 80-82	142															0		
4-1, 130-132	142.5															0		
5-1, 131-133	190				1											1		
6-1, 90-92	199				2											2		
6-3, 140-142	202.5			1												1		
7-1, 80-82	232															0		

percentage of long-spined *D. speculum* is the sole criterion for assignment of this interval to the *D. speculum* Zone A.

Samples 1A, CC and 2, CC are barren of silicoflagellates.

Sample 1B, CC, at 114.5 meters, contains an abundant and moderately diverse assemblage. The abundant occurrence of *Dictyocha fibula*, *D. aspera*, and *D. pseudofibula* indicates, with a high degree of reliability, that the assemblage conforms to the early Pliocene *Dictyocha pseudofibula* Zone. Approximately 90% of the assemblage is comprised of warm-water *Dictyocha* species, thereby indicating early Pliocene surface water temperatures in excess of 12°C (see text on early Pliocene paleotemperatures).

The interval between the Samples 2B, CC and 3B, CC, from 143 to 152.5 meters, contains a meager but well-preserved assemblage of rare *Dictyocha pseudofibula*, *Distephanus* cf. *D. boliviensis*, and common *Mesocena diodon*. The assemblage conforms to the *M. diodon* Zone.

Sample 4B, CC at 171.5 meters, yielded only three specimens of *Distephanus speculum* and one specimen of *D. polyactis* and *Mesocena circulus*. Insufficient information exists for zonal designation; however, the restriction of *Mesocena circulus* to the upper Miocene in the Southern Ocean suggests a late Miocene age for this sample.

Sample 5B, CC is barren of silicoflagellates, and Sample 6B, CC contains only a single specimen of

TABLE 6A
Distribution of Silicoflagellates at Site 274

Site 274		Taxa										Total Specimens	Zone	Series or Subseries
Sample (Interval in cm)	Depth (m)	<i>Corbisema hexacantha</i>	<i>C. triacantha</i>	<i>Dictyocha pseudofibula</i>	<i>Distephanus boliviensis</i>	<i>D. sp. cf. boliviensis</i>	<i>D. crux</i>	<i>D. speculum</i> var. <i>pentagonus</i>	<i>D. speculum</i> (long-spined)	<i>D. speculum</i> (short-spined)	<i>D. speculum</i> var. <i>septenarius</i>	<i>Mesocena apiculata</i>		
1-2, 60-62	2.0	1	2					6	1		2	12	<i>Distephanus speculum</i> A	Pleistocene
1-2, 95-97	2.5				1	2		3	1			7		
1-2, 130-132	3.0				4	3		9				16		
1-3, 30-32	3.5			2				6	1			9		
1-3, 70-72	4.0				2			9	3			14		
1-3, 130-132	4.5				3			5				8		
1-4, 30-32	5.0				4	1		2				7		
1-4, 80-82	5.5							1				1		
1-4, 130-132	6.0		1									1		
1-5, 30-32	6.5							1				1		
1-5, 130-132	7.5							1				1		
1-6, 30-32	8.0											0		
2-2, 30-32	11.5											0		
2-3, 30-32	13.0							1				1		
2-4, 80-82	15.0						1	1				2		
2-5, 30-32	16.0			1	1			5				7		
2-6, 30-32	17.5							5	1			6		
3-1, 40-42	19.5											0		
3-2, 40-42	21.0							3				3		
3-3, 30-32	22.5			3				3	1			7		
3-4, 30-32	24.0							1				1		
3-5, 30-32	25.5					1						1		
3-6, 89-91	27.5											0		
4-1, 40-42	29.0							1				1		
4-2, 30-32	30.5											0		
5-1, 120-122	39.0			1					4			5	<i>Distephanus speculum</i> B	Upper Pliocene
5-2, 40-42	40.0					1		1				2		
5-2, 90-92	40.5							2				2		
5-2, 140-142	41.0			2				2				4		
5-3, 40-42	41.5											0		
5-3, 90-92	42.0								1			1		
5-3, 138-140	42.5											0		
6-1, 40-42	48.0											0		
6-1, 140-142	49.0				2			3	12			17		
6-2, 40-42	49.5							1	4			5		
6-2, 90-92	50.0											0		
6-2, 140-142	50.5											0		
6-3, 40-42	51.0									3		3		
6-3, 90-92	51.5			2	2			1	8			13		
6-3, 140-142	52.0			1	3		1	3	4			12		
6-4, 40-42	52.5				1				5			6		
6-4, 90-92	53.0				1				3			4		
6-4, 140-142	53.5				2			1	2			5		
6-5, 40-42	54.0				1				11			12		
6-5, 90-92	54.5								2	1		3		
6-5, 140-142	55.0											0		

TABLE 6B
 Distribution of Silicoflagellates at Site 274

Site 274		Taxa													Total Specimens	Zone	Subseries		
		<i>Dictyocha aspera</i> <i>D. fibula</i>	<i>D. pentagona</i>	<i>D. pseudofibula</i>	<i>D. variabilis</i>	<i>Distephanus boliviensis</i>	<i>D. sp. cf. boliviensis</i>	<i>D. boliviensis</i> var. <i>binocularis</i>	<i>D. boliviensis</i> var. <i>major</i>	<i>D. crux</i>	<i>D. speculum</i> var. <i>pentagonus</i>	<i>D. speculum</i> (short-spined)	<i>D. speculum</i> (long-spined)	<i>D. speculum</i> var. <i>septenarius</i>				<i>Mesocena diodon</i>	<i>Naviculopsis regularis</i>
6-6, 40-42	55.5																0	Upper Pliocene	— ? —
6-6, 90-92	56.0																0		
6-6, 140-142	56.5					1					2						3		
7-1, 40-42	57.5										3						3		
7-1, 90-92	58.0					1					3	1					5		
7-1, 140-142	58.5					1	1				1						3		
7-2, 40-42	59.0					1					13	3					17		
7-2, 90-92	59.5					1					3						4		
9-1, 40-42	76.5			2							11	2					15		
9-1, 92-94	77.0					4	2		1	3	10	3					23		
9-1, 140-142	77.5							2	1		8	0					11		
9-2, 40-42	78.0					1					14	2	2				19		
9-2, 90-92	78.5										3			1			4		
9-2, 140-142	79.0					2											2		
9-3, 40-42	79.5					1					2						3		
9-3, 80-82	80.0										7	1	2				10		
9-3, 110-112	80.0					1					3						4		
9-4, 40-42	81.0					2					2						4		
9-4, 140-142	82.0			3	3						8	2	1				17		
9-5, 40-42	82.5			4	3						9	1	1				18		
9-5, 90-92	83.0										6						6		
9-5, 140-142	83.5					1					6						7		
9-6, 40-42	84.0					1					7	1	1				10		
9-6, 90-92	84.5					1					12		2				15		
9-6, 140-142	85.0					2					14		1				17		
10-1, 90-92	86.5			4	40	19				8	20	6	3				100		
10-1, 140-142	87.0				4	2				1	6						13		
10-2, 40-42	87.5				10	4											14		
10-2, 90-92	88.0	1		1	17	6	1	1		1							28		
10-2, 140-142	88.5				13	5	1	1		1							21		
10-3, 40-42	89.0	2		1	30	5		1		1							40		
10-3, 93-95	89.5			1	23	15	2			1							42		
10-3, 140-142	90.0	1			11	3											15		
10-4, 40-42	90.5				1	12	4										17		
10-4, 90-92	91.0					15	5	1	1								22		
10-4, 140-142	91.5					5	2			1							8		
10-5, 40-42	92.0		1		4					1							6		
10-5, 90-92	92.5	5		2						2							9		
10-5, 140-142	93.0	1		1		2	2		1								7		
10-6, 40-42	93.5				9	5				8				1			23		
10-6, 90-92	94.0				6	13	3			7							29		
10-6, 140-142	94.5				12	5	3										20		
11-1, 140-142	96.5		1		9	2	10	2		3							27		
11-2, 40-42	97.0				39	2	3				2						46		
11-2, 90-92	97.5				19	2	1				1						23		
11-2, 130-132	98.0				38	2	1		1	1	2		1				46		

TABLE 6C
Distribution of Silicoflagellates at Site 274

Site 274		Taxa															Total Specimens	Zone	Subseries			
Sample (Interval in cm)	Depth (m)	<i>Dictyocha aspera</i>	<i>D. deflandrei</i>	<i>D. fibula</i>	<i>D. pentagona</i>	<i>D. pseudofibula</i>	<i>D. variabilis</i>	<i>Distephanus boliviensis</i>	<i>D. boliviensis</i> var. <i>binoculus</i>	<i>D. sp. cf. boliviensis</i>	<i>D. crux</i>	<i>D. speculum</i>	<i>D. speculum</i> var. <i>binoculus</i>	<i>D. speculum</i> var. <i>pentagonus</i>	<i>D. speculum</i> var. <i>pentagonus f. geninus</i>	<i>Mesocena circulus</i>				<i>M. diodon</i>	<i>M. cf. elliptica</i>	<i>M. apiculata</i>
11-3, 40-42	98.5	1			11			12	2	3	1	1		3						35	<i>Dictyocha pseudofibula</i>	Lower Pliocene
11-3, 82-84	99.0	1			1			6		1	6	1		1						17		
11-3, 134-136	99.5				2			10		6	1									19		
11-4, 40-42	100.0	1			23			48	6	11		2		6	1					98		
11-4, 90-92	100.5				1	18		1		3		1								24		
11-4, 140-142	101.0					15		9	1	6		4								35		
12-1, 92-94	105.5							4	1	5			1	1				1		13	<div></div>	
12-1, 140-142	106.0													2						2	<div></div>	
12-2, 90-92	107.0				1					1						2				4	<i>Mesocena circulus</i>	Upper Miocene
12-2, 140-142	107.5									1						1				2		
12-3, 40-42	108.0				1					1										2		
12-3, 90-92	108.5			1					1	3			1							6		
12-3, 140-142	109.0															4				4		
12-4, 40-42	109.5																1			1		
12-4, 90-92	110.0															4	1			5		
12-4, 140-142	110.5				1					1						8				10		
12-5, 40-42	111.0											1	2			8		2		13		
12-5, 90-92	111.5									1						2				3		
12-5, 140-142	112.0															2				2		
12-6, 40-42	112.5											1								1	<div></div>	Middle Miocene
12-6, 90-92	113.0																			0		
12-6, 140-142	113.5																			0		
13-1, 40-42	114.5												2							2		
13-2, 40-42	116.0												2							2		
13-3, 40-42	117.5																			0		
13-4, 40-42	119.0																			0		
13-5, 40-42	120.5			1																1		
13-6, 40-42	122.5																			3		
14-1, 40-42	124.0																			0		
14-2, 40-42	125.5											2								2		
14-3, 40-42	127.0											1								1		
14-4, 40-42	128.5					1						6								7		
14-5, 40-42	130.0																			0		
14-6, 40-42	131.5											2								2		
15-1, 40-42	133.5							1												1		
15-2, 40-42	135.0																			0		
15-3, 40-42	136.5											3								3		
15-4, 31-33	138.0											2								2		
15-5, 30-32	139.5							1												1		
15-6, 30-32	141.0																			0		
16-1, 30-32	143.0																			0		
16-2, 30-32	144.5											2								2		
16-3, 23-25	145.5																			0		
17-1, 140-142	153.5											2								2		
17-2, 30-32	154.0											3								3		
17-3, 30-32	155.5											2								2		

TABLE 6D
 Distribution of Silicoflagellates at Site 274


Site 274		Taxa																				Total Specimens	Zone	Subzone	Subseries																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
Sample (Interval in cm)	Depth (m)	<i>Cannopilus hemisphaericus</i>	<i>Corbisema apiculata</i>	<i>C. archangeliskiana</i>	<i>C. hastata</i>	<i>C. triacantha</i>	<i>C. triacantha</i> var. <i>flexuosa</i>	<i>C. spinosa</i>	<i>Dictyocha deflandrei</i> s.l.	<i>D. fibula</i>	<i>D. frenguelli</i> s.l.	<i>D. hexacantha</i>	<i>D. cf. D. pentagonus</i>	<i>D. variabilis</i>	<i>Distephanus</i> cf. <i>D. boliviensis</i>	<i>D. cf. D. boliviensis</i> major	<i>D. crux</i> s.l.	<i>D. speculum</i>	<i>D. cf. D. speculum pentagonus</i>	<i>Mesocena apiculata</i>	<i>M. oamaruensis</i>					<i>Naviculopsis biapiculata</i>	<i>N. constricta</i>	<i>N. trispinosa</i>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
18-1, 100-102	162.5																	3								3			Lower Miocene																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

TABLE 6E
Distribution of Silicoflagellates at Site 274

Site 274		Taxa																				Total Specimens	Zone	Subzone	Subseries			
Sample (Interval in cm)	Depth (m)	<i>Corbisema apiculata</i>	<i>C. hastata</i>	<i>C. triacantha</i>	<i>C. triacantha</i> var. <i>flexuosa</i>	<i>C. spinosa</i>	<i>C. ? sp.</i>	<i>Dictyocha deflandrei</i> s.l.	<i>D. fibula</i>	<i>D. frenguelli</i> s.l.	<i>D. hexacantha</i>	<i>D. variabilis</i>	<i>D. sp.</i>	<i>Distephanus</i> cf. <i>D. boliviensis</i>	<i>D. cf. D. boliviensis</i> var. <i>binoculus</i>	<i>D. cf. D. boliviensis</i> var. <i>major</i>	<i>D. crux</i>	<i>D. speculum</i> var. <i>pentagonus</i>	<i>D. cf. D. speculum</i> var. <i>pentagonus</i>	<i>M. apiculata</i>	<i>M. oamaruensis</i>	<i>Naviculopsis biapiculata</i>	<i>N. trispinosa</i>					
26-2, 30-32	239.5	2	2					11	11					67	2		32		7	2				136	<i>Dictyocha frenguelli</i>	<i>Dictyocha deflandrei</i>	<i>Mesocena apiculata</i>	Lower Oligocene
26-3, 30-32	241.0							10	4					16	2		40		2	6				80				
26-4, 35-37	242.5	6						5	8					20		1	19			6				65				
26-5, 30-32	244.0							4	6					25			28		6	4	1			74				
26-6, 30-32	245.5	6	2			2		5	12					18			27		2	9				83				
27-1, 30-32	247.5	2						6	8					2			16			5				39				
27-2, 130-132	250.0							4	5	1				11			14		4	2			3	44				
27-3, 30-32	250.5	5	1		2			3	26						3		23		1	4			2	70				
27-4, 30-32	252.0	2		2				10	27					8			12			3			5	69				
28-1, 30-32	257.0		1					2	14					29			91			14		1	4	156				
28-2, 30-32	258.5			9				12	20					22	2		78		5			1	10	159				
28-3, 30-32	260.0		2					5	32	1		1	28	105	3					8			5	190				
28-4, 30-32	261.5								11		2		17				38			4	3	1	6	82				
28-5, 30-32	263.0	6	2	4				2	22	1	1		46	4			93		4	4	1	2	1	193				
28-6, 30-32	264.5								18				52				34			5	1		13	123				
29-1, 90-92	267.0			1				8	27				11				15			10	1		4	77				
29-2, 30-32	268.5			3				9	40				4	1			16			4	3		5	85				
29-3, 30-32	270.0							6	31	2							5							44				
30-1, 30-32	276.0			4			1	3	56		2		1				6			9	3			85				
30-2, 30-32	277.5							2	61								1			6	2	1		73				
30-3, 30-32	279.0	4						4	52				4	1			8		1	6	5			85				
30-4, 30-32	280.5	1		3				17	37											6	4			68				
30-5, 30-32	282.0	2		6				8	26					2			15		2	2	1		4	68				
30-6, 30-32	283.5							7	40					2			21		1	15	7		4	97				
31-1, 30-32	285.5	12		2				2	4					10			32			2	8		5	77				
31-2, 30-32	287.0	2						4	2	3		4		27			27			4	9		6	88				
31-3, 30-32	288.5							6	4	1				16			39		2	6	5	4	6	89				
31-4, 30-32	290.0							7	4								2			6		1	4	24				
31-5, 30-32	291.5	2							3					2			3			4				14				
31-6, 30-32	293.0							2	5					4			2			3				16				
32-1, 30-32	295.0							8	3					3			4			5				23				
32-2, 30-32	296.5	1							2					2			3			2				10				
32-3, 30-32	298.0							7	4					4			5			5				25				
32-4, 30-32	299.5							9	3					6			4			5				27				
32-5, 30-32	301.0	5						7	2					2			2			23				41				
32-6, 30-32	302.5							6	1					2			3							12				
33-1, 30-32	304.5							2						1			9			2	1			15				
33-2, 30-32	306.0							8						2			2			7				19				
33-3, 30-32	307.5							18						3			8			10				39				
33-4, 30-32	309.0							11						2			14			13	8			48				
33-5, 30-32	310.5	3	1					23						4			10			22	7		4	74				
33-6, 35-37	312.0	6	2					18									17			19	2			64				
34-1, 30-32	314.0	2						4						5		1	10		1	20				43				
34-2, 30-32	315.5	3						4									11			21				39				
34-3, 15-17	317.0	6						13						4			4			14	4		4	49				
34-4, 40-42	318.5	7						14						10			21		1	18	2		3	76				
34-5, 30-32	320.0	8	5					20						2			6			15				56				
34-6, 30-32	321.5	3	10					10						5			14			14			4	60				

Distephanus octacanthus, which suggests a middle Miocene age for the sample.

Four samples examined between Sample 4-3, 120-122 cm and Sample 4-6, 52-54 cm, at 131.5 to 136.5 meters, contain a moderately well-preserved floral assemblage of modest diversity and abundance. All four samples are characterized by the presence of meager to abundant *Distephanus crux*, *Naviculopsis biapiculata*, *N. regularis*, *N. trispinosa*, and *N. cf. lata*. This first common occurrence of *N. biapiculata*, following the decline of *Dictyocha deflandrei* and *D. frenguelli*, suggests that this assemblage conforms to the upper Oligocene *N. biapiculata* Zone. The diatom *Coscinodiscus vigilans*, which has its Antarctic acme of occurrence in the early Miocene and late Oligocene (McCollum, personal communication), is abundant in these samples. Absent from the examined samples is *Rocella gemma* which has its first common occurrence in the latest Oligocene or early Miocene. The presence of *C. vigilans* in the absence of *Rocella gemma*, therefore, indicates that the present assemblage conforms to the portion of the upper Oligocene *N. biapiculata* Zone stratigraphically below the initial appearance of *Rocella gemma*.

Sample 5-2, 60-62 cm, obtained at 167.5 meters, contains abundant *Distephanus crux*, common *Cannopilus sphericus*, and meager *Mesocena apiculata*, *Naviculopsis biapiculata*, *N. trispinosa*, *N. regularis*, and *Dictyocha deflandrei*. The reduced abundance of *Naviculopsis* species and the presence of *D. deflandrei* suggests that this zone is near the boundary of the *N. biapiculata* Zone and the *D. deflandrei* Zone. A large number of skeletal aberrations and enigmatic silicoflagellates also occur in this sample and may be the product of a severe and rapid change in environmental conditions at the onset of the late Oligocene.

Site 269

(61°40.57'S, 14°04.21'E, water depth 4285 m)

Site 269 lies near the southeastern edge of the South Indian Abyssal Plain. Two holes were discontinuously cored at this site through a 1-km-thick, relatively uniform section. The entire section consists dominantly of silts and clays, with biogenic silica common in the upper half and absent in the lower half.

Core 1, obtained from 0 to 8 meters, is a siliceous ooze containing abundant and well-preserved silicoflagellates. The silicoflagellate assemblage of this core is completely dominated by *Distephanus speculum* and is correlative to the *Distephanus speculum* Zone A because of the high percentage of long-spined *Distephanus speculum*. Other less-frequent constituents of the assemblage include *Distephanus boliviensis* var. *binoculus*, *Distephanus speculum* var. *pentagonus* and *Distephanus polyactis*. Twelve samples were examined (Table 5).

Core 2, from 47 to 50 meters, contains a silicoflagellate assemblage of lower abundance than that of Core 1. A definite zonal assignment is not possible, but assemblages of similar composition and low abundance occur in early to mid-Gauss portions of the *Distephanus speculum* Zone B. If a Gauss paleomagnetic age is correct for Core 2 sediments, the lower *D. speculum* Zone A

and the upper *D. speculum* Zone B are not represented but may be present in the uncored interval between Cores 1 and 2 (8.5 to 47 m).

In Core 3, from 94 to 98 meters, silicoflagellate diversity and abundance continues to decrease. The highest sample, from Section 1 at 60-62 cm, contains only specimens of *Distephanus speculum* s.l. and *Distephanus boliviensis*. The consistent occurrences of rare to few *Dictyocha pseudofibula* and rare occurrences of *Dictyocha aspera* and *Dictyocha fibula* characterize the interval between Section 1, at 60 cm, and Section 3, at 82 cm. The assemblage of this interval is placed, with reasonable confidence, in the upper *Dictyocha pseudofibula* Zone (approximately 3.90 m.y.B.P.). The lowest sample examined in Section 3, at 130 cm, contains only one *D. pseudofibula*, three *Mesocena diodon*, and one reworked *Mesocena apiculata*. This lowermost assemblage may be correlative to the upper *Mesocena diodon* Zone.

Cores 5 and 6, 190 to 202.5 meters, contain very rare silicoflagellates which are not by themselves age diagnostic.

Cores 7 to 11, obtained from 232 to 397 meters, and all cores from Hole 269A (Cores 1-13), from 416 to 958 meters, lack silicoflagellates.

Ross Sea Sites

Ross Sea sediments generally contain low-abundance and low-diversity assemblages of silicoflagellates. Abundances and diversities are greatest in the upper few meters of sediment and in the early to mid-Pliocene sediments at Site 271. All silicoflagellates found in Ross Sea Miocene to Holocene sediments exhibit a high degree of intraspecific skeletal variability. This skeletal variability is usually manifested in the form of excessive ornamentation or incomplete skeletal formation. The skeletal variability makes taxonomic placement difficult, therefore, specific assignments must be considered as *sensu lato*.

Site 271

(76°43.27'S, 175°02.86'W, water depth 562 m)

Site 271 is one of two sites in the southeastern portion of the Ross Sea. A 265-meter (24 core) sequence of sediment with apparent lithological uniformity was drilled, with only 15.3 meters of core recovery. The entire sediment sequence consists of soft to semilithified, silty clays or clayey silts with granules and larger clasts.

Silicoflagellates are rare from 21 to 30.5 meters (Core 1), absent at 40 to 175 meters (Core 2A to Core 15), few to absent with varying degrees of preservation from 175 to 251 meters (Core 16 to Core 23), and common, diverse, and well preserved from 255 to 265 meters (Core 24).

Rare specimens of *Distephanus speculum* with wide apical rings were found in Sample 1-1, 10-12 cm. This particular morphotype of *Distephanus speculum* is often found in Matuyama sediments; however, no age designation is made due to the lack of other diagnostic Matuyama silicoflagellates. Sample 1, CC contains a few specimens of *Naviculopsis biapiculata* which may have been winnowed from an Eocene or Oligocene source elsewhere in the Ross Sea.

The remainder of the site samples examined were barren with the exception of Cores 16, 19, and 24. Core 16 and 19 core-catcher samples yielded only several morphotypes of *Distephanus speculum* of an indeterminate age. Silicoflagellates were surprisingly common and diverse in Sample 24, CC. This core catcher contains *Dictyocha pseudofibula*, *Distephanus boliviensis* var. *binoculus*, *Distephanus boliviensis*, *D. speculum* s.l., and *D. speculum* var. *pentagonus*. This assemblage is somewhat similar to that of the *Distephanus boliviensis* Zone or upper *Dictyocha pseudofibula* Zone, thereby indicating a sediment age of approximately 3.0 to 3.7 m.y.

Site 272

(77°07.62'S, 176°45.61'W, water depth 629 m)

Site 272 is located in the southeastern portion of the Ross Sea. The sedimentary sequence is comprised of two general units: a thin, diatomaceous silty clay (0-23.5 m) and a thick sequence of diatomaceous silty claystone (23.5-434 m).

Sediments at this site are either barren or contain very low abundances of silicoflagellates. Most of the specimens examined are well preserved and exhibit the same high degree of intraspecific skeletal variability characteristic of most silicoflagellates found in the sediments of the Ross Sea.

Sample 1-1, 80-132 cm, contains *Distephanus speculum* var. *pentagonus* and highly ornamented specimens of *Distephanus speculum* with a wide apical apparatus. Although the present morphotype of *D. speculum* is common in Matuyama sediments, no age designation is possible due to the lack of assemblage diversity.

Distephanus speculum s.l. is also present in sediments from Samples 14, CC, 18, CC, and 25, CC.

Sieved Core 35 core-catcher samples yielded common to abundant amounts of silicoflagellates of limited diversity. The assemblage at this interval is dominated by *Distephanus speculum* s.l., but contains one specimen of *Mesocena* cf. *pappi* which may indicate an early Miocene age because of its correlative occurrence in the lower Miocene at Site 266.

Sites 273 and 273A

(74°32.29'S, 174°37.57'E, water depth 495 m)

Site 273 is located in the west-central portion of the Ross Sea on the flank of an apparent erosional valley which borders the western edge of Pennell Bank. At Site 273, 346.5 meters (29 cores) of sediments were cored in two holes, with a recovery of only 83.4 meters. The sedimentary sequence in the upper 42.5 meters (Cores 1-5) is comprised of a soft to stiff, diatomaceous silty clay, and the sequence from 42.5 to 346.5 meters (Cores 6-29) is a semilithified, pebbly, silty clay.

Sediments at this site generally contain low-abundance and low-diversity assemblages of silicoflagellates. The silicoflagellates from this site are well preserved and usually highly ornamented.

Core 1 contains many skeletal morphotypes of *Distephanus speculum* which have varying apical ring widths and spine lengths. No age assignment for the sediment of Core 1 is possible.

Samples 2, CC, 3, CC, and 6, CC, between 14 and 52 meters, are barren of silicoflagellates. Sample 5, CC, at 42 meters, contains rare specimens of *Distephanus speculum* s.l. Silicoflagellates are fairly common in Sample 6A-1, 120-122 cm. This core contains the following silicoflagellate assemblage which is suggestive of a Miocene age: *Distephanus speculum* var. *pentagonus*, *D. cf. crux*, *D. cf. boliviensis*, *D. speculum*, and *D. cf. longispinus*. This assemblage also contains a variety of specific morphotypes and a number of aberrant forms with incomplete skeletons.

Cores 8A through 28A, obtained between 166 and 337 meters, contain low abundances of *Distephanus speculum* s.l. No age assignment is possible for this interval of sediment.

Site 274

(68°59.81'S, 173°25.64'E, water depth 3326 m)

Site 274 lies on the Antarctic lower continental rise about 250 km north northeast of Cape Adare. This site was originally designated as a contingency site but was occupied when severe ice and weather conditions prevented occupation of the originally designated site. Objectives at this site were to sample and date the basement horizon which was thought to be as old as Eocene (as inferred from the regional studies of Weissel and Hayes [1973]) to investigate the nature and cause of the thin sediment cover, to study the effects of glaciation at a site distal to the Ross ice shelf, and to retrieve a continuously cored section for biostratigraphic study.

At Site 274, a largely terrigenous, clay-rich sedimentary sequence of about 415 meters was recovered above basalt basement. The 34 cores of the upper 328 meter Pleistocene-Oligocene sequence generally contain abundant diatoms and/or silicoflagellates. From 328 meters to basement, a semilithified to lithified silty claystone with interbedded chert was encountered with only a trace of diatoms and no silicoflagellates present.

Cores 1 through 4, obtained between 0 and 30.5 meters below the sea floor, contain generally scarce quantities of poorly preserved silicoflagellates. The assemblage of this interval conforms to the Pleistocene *Distephanus speculum* A Zone, which according to its occurrence in paleomagnetically dated *Eltanin* cores, spans the last 700,000 years.

The highest sample studied (1-2, 60 cm) 2 meters below the sea floor, contains lower Oligocene or Eocene reworked *Dictyocha hexacantha*, *Distephanus crux*, *Mesocena apiculata*, and *Corbisema triacantha*. Underlying the highest sample, at 2 meters, younger Pliocene reworked *Distephanus boliviensis*, *D. sp. cf. boliviensis*, and *Dictyocha pseudofibula* are found throughout the remaining 24 samples of the *D. speculum* Zone A. The location of Site 274 on the continental rise distal to the Ross Sea suggests that the source of reworking was the nearby Ross Sea. The presence of Eocene or lower Oligocene specimens indicates that reworked silicoflagellates have either been transported to Site 274 from different source areas of different ages, or they have come from a single source area that has undergone erosion of continuously older sediments, thereby depositing older sediments upon younger.

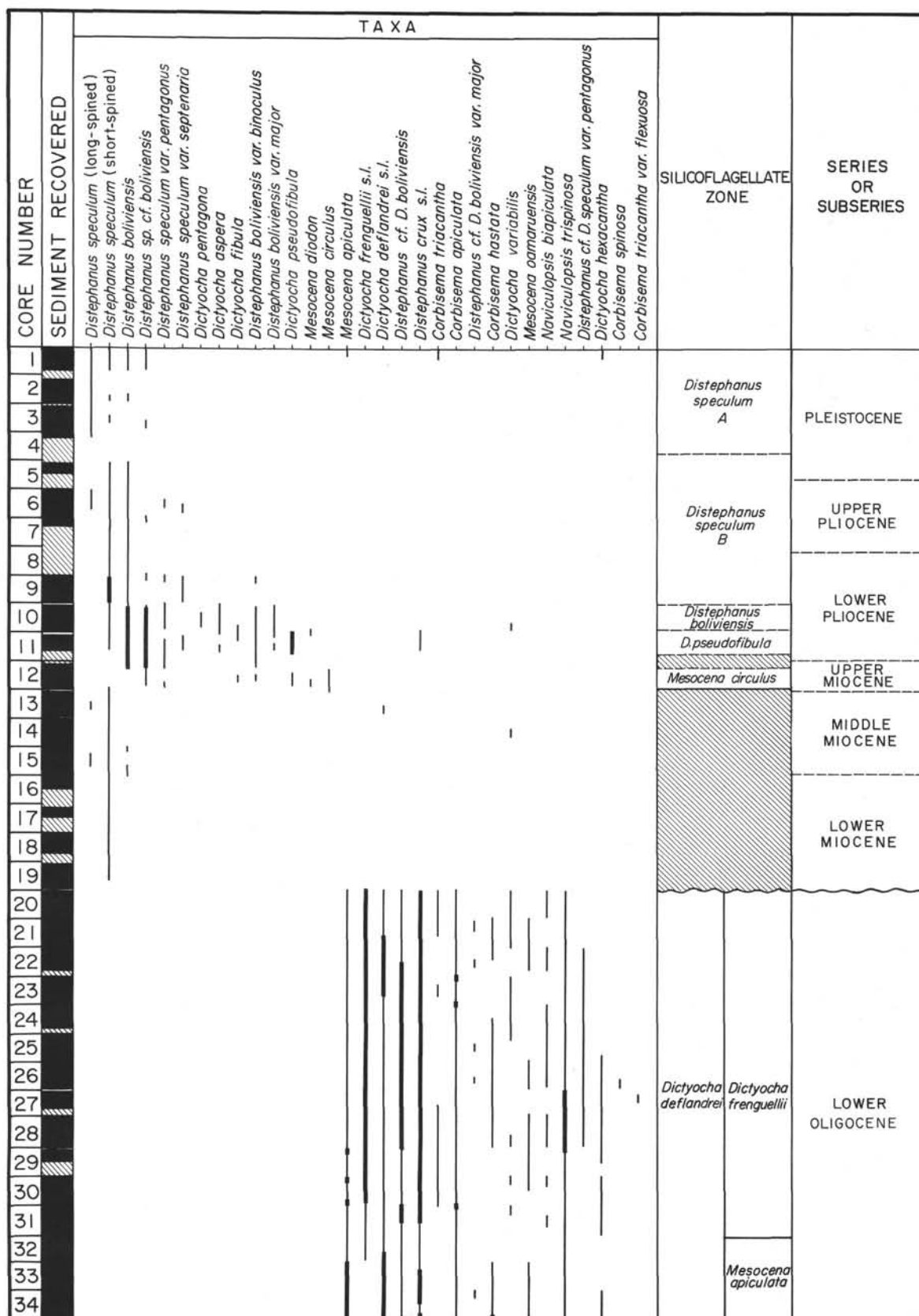


Figure 4. Ranges of selected silicoflagellates at Site 274 with zones and geologic series and subseries.

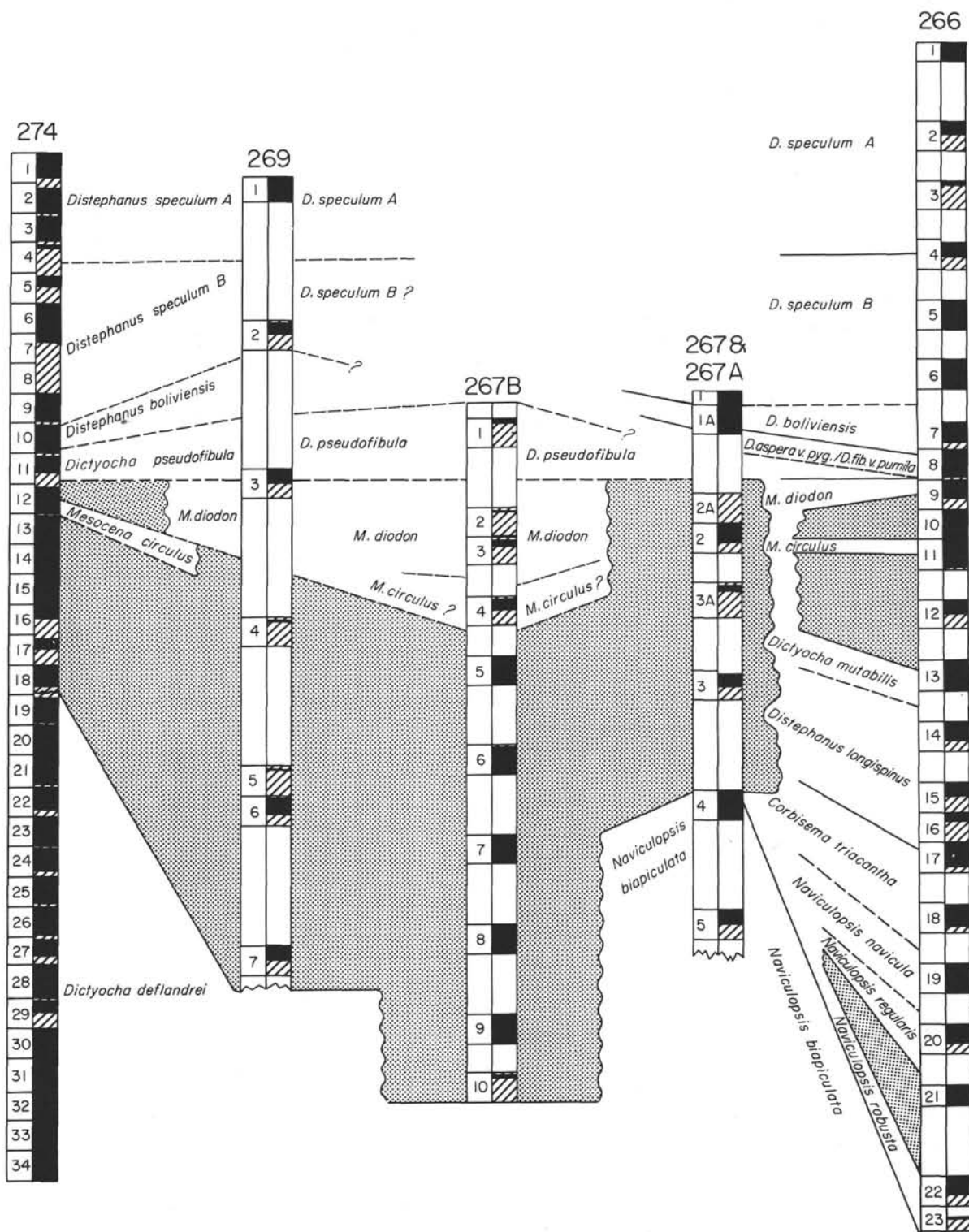


Figure 5. Correlation of silicoflagellate zones in Leg 28 Sites. Shaded areas represent intervals with insufficient floral diversity or abundance for zonal determinations.

Twenty-nine samples examined in Cores 5, 6, and 7, at 39 to 59.5 meters, are referable to the *Distephanus speculum* B Zone. The assemblage is characterized by a higher proportion of short-spined than long-spined *D. speculum*, and the rare, but consistent, occurrence of *D.*

boliviensis. One reworked *Distephanus crux* occurs in Section 2 of Core 5, at 40 cm. Core 8, from 66.5 to 76 meters, was retrieved empty.

Core 9, at 76.5 to 85 meters, is also assignable to the *Distephanus speculum* B Zone. A few specimens of

reworked *Distephanus crux* and *Naviculopsis regularis* were recorded in Sections 1 and 2, respectively.

Core 10, from 86.5 to 93.5 meters, contains commonly well-preserved silicoflagellates. *Distephanus boliviensis* occurs commonly between Section 1 at 90 cm and Section 6 at 42 cm, thus suggesting that this interval conforms to the *Distephanus boliviensis* Zone. Other taxa found in this core include *Dictyocha fibula*, *Dictyocha aspera*, *Dictyocha pseudofibula*, *Distephanus boliviensis* var. *major*, *D. boliviensis* var. *binoculus*, and *Distephanus speculum* var. *pentagonus*.

The two lowermost samples (Sample 10-6, 90-142 cm) differ from the remainder of the Core 10 assemblage by the additional common occurrence of *Dictyocha pseudofibula*. The uppermost range of *D. pseudofibula* in these samples represents the upper portion of the *D. pseudofibula* Zone which has its upper boundary with the *D. boliviensis* Zone between 42 and 90 cm in Section 6. At more northerly latitudes, the *Distephanus boliviensis* Zone lies conformably above the *Dictyocha aspera* var. *pumila*-*Dictyocha fibula* var. *pygmaea* Zone and not above the *Dictyocha pseudofibula* Zone. An ecologic restriction of the *D. aspera* var. *pumila*-*D. fibula* var. *pygmaea* Zone to latitudes north of Site 274 (69°S) results in this conformable position of the *D. pseudofibula* Zones at this site.

Ten samples from Core 11, at 96.5 to 101 meters, yielded common to abundant *Dictyocha pseudofibula* and are thus placed in the *Dictyocha pseudofibula* Zone of the early Pliocene. A significant number of warm-water species in this core, such as *Dictyocha pseudofibula*, *Dictyocha aspera*, and *D. fibula*, suggest warmer climatic conditions in the early Pliocene than today (see paleoenvironmental interpretations).

Core 12, from 105.5 to 113.5 meters, contains a relatively meager but moderately well-preserved silicoflagellate assemblage. The upper seven samples from Section 1 through Section 3, at 90 cm, contain no age-diagnostic species. The remaining Core 12 samples examined, from Section 3 at 140 cm to the basal 10 cm of the core, conform to the *Mesocena circulus* Zone.

Cores 13 through 19, from 114 to 179 meters, contain a floral assemblage of extremely low diversity and abundance. Preservation is poor, and a large percentage of the specimens found were broken. The only species found with any regularity in this interval are *Distephanus speculum* and *D. boliviensis*. An insufficient occurrence of age-diagnostic silicoflagellates prevents a zonal assignment for these cores.

Cores 20 to 34, obtained from 181 to 321.5 meters, contain an unusually uniform assemblage of silicoflagellates of excellent preservation and high abundance. Species ranging throughout the 140-meter sequence include *Mesocena apiculata*, *Dictyocha deflandrei* s.l., *Distephanus* cf. *D. boliviensis*, *Distephanus crux*, *Corbisema apiculata*, and *Naviculopsis trispinosa* (Table 6). The entire section between Cores 20 and 34 is herein defined as the *Dictyocha deflandrei* Zone. This zone is subdivided into two subzones on the basis of the evolutionary appearance of *Dictyocha frenguelli*. The lower part of the section from the base of Core 34 to the

base of Core 30 (321.5 to 283.5 m), which contains common *Mesocena apiculata* and lacks *Dictyocha frenguelli*, is designated as the *Mesocena apiculata* Subzone. The upper portion of the *Dictyocha deflandrei* Zone from Core 30, at 283.5 meters, to Core 20, at 181 meters, that is characterized by the common occurrence of *Dictyocha frenguelli*, is designated as the *Dictyocha frenguelli* Subzone.

PALEOENVIRONMENTAL INTERPRETATIONS

Introduction

The potential of silicoflagellates as paleoecologic indicators was first demonstrated early this century with the observation of their biogeographic provinciality (Gemeinhardt, 1931, 1934; Lohmann, 1919). This biogeographic provinciality of living silicoflagellate populations has been shown to be largely a result of temperature control on taxonomic development. The influence of temperature on taxonomic composition is best reflected in a reversal in dominance between the genera *Dictyocha* and *Distephanus* in warm and cold water, respectively (Gemeinhardt, 1934). Various schemes have been proposed for using the silicoflagellate genera *Dictyocha* and/or *Distephanus* in paleotemperature determinations. A scheme proposed for determining relative paleotemperatures measures the percentage of *Dictyocha* in the silicoflagellate assemblage (Jendrzewski and Zarillo, 1971). Two schemes proposed for determining absolute paleotemperatures relate surface water temperatures to the ratio of *Dictyocha fibula* to *Distephanus speculum* (Martini, 1971), and the ratio of *Dictyocha* to *Distephanus* species (Mandra, 1958).

In the present study, both the Mandra and Martini techniques for absolute paleotemperature determination were tested on two paleomagnetically dated *Eltanin* cores, E 50-28 and E 38-8, in order to determine their accuracy for use in the Southern Ocean. Application of the Martini method resulted in entirely unreasonable temperature range fluctuations of 0°-25°C throughout sediment intervals representative of only several thousand years. Climatic fluctuations delineated from these cores by the Mandra paleotemperature method (Ciesielski and Weaver, 1973; Weaver and Ciesielski, 1973) were considered accurate; however, anomalously high paleotemperatures (in excess of 20°C) were obtained.

Techniques

Silicoflagellate Paleotemperature Technique

Because of the inaccuracy of the preexisting silicoflagellate paleotemperature techniques, an evaluation of the relationship between Southern Ocean surface water temperatures and *Dictyocha* and *Distephanus* abundances was undertaken. The technique devised to determine Southern Ocean temperature relationships to *Dictyocha*/*Distephanus* ratios is essentially to determine the ratio of these genera in recent sediments and correlate this ratio to the mean annual surface temperatures of the overlying water mass. The area selected to test the

usefulness of this technique in high latitudes against the previously established method developed at low and middle latitudes is between Australia and Wilkes Land, Antarctica, from 30° to 63°S latitude, and in close proximity to the lower Pliocene cores previously studied.

Fifty phleger and trigger core surface sediment samples from similar depths and at close latitudinal intervals (1°-2°) were studied. *Dictyocha/Distephanus* ratios within the surface sediment were plotted against the overlying mean annual surface water isotherms (from Gordon and Goldberg, 1970) and a best-fit curve was constructed from the plotted points (Ciesielski, 1974).

Paleotemperature assignments utilizing this technique are compared in Table 7 with the temperature assignments derived from Mandra's (1958) paleotemperature curve. Examination of the *Dictyocha/Distephanus* ratios of surface sediments from the Southern Ocean reveals that major changes in these ratios occur in sediments immediately across major oceanographic boundaries thereby verifying their generic sensitivity to temperature change (the temperature change across the Antarctic Convergence Zone is approximately 3°-4°C). *Dictyocha/Distephanus* ratios ≥ 1 are consistently found in the surface sediments north of the Antarctic Convergence, where mean annual surface water isotherms are $\geq 7^\circ\text{C}$; however, ratios < 0.50 are generally present in surface sediments south of the Antarctic Convergence, where mean annual surface water isotherms are $\leq 4^\circ\text{C}$.

The maximum and minimum temperatures of the paleotemperature curve are determined at latitudes where *Dictyocha* and *Distephanus* become absent or nearly absent for the first time. South of 55° to 56°S latitude *Dictyocha* is generally absent from surface sediments and north of 39° to 40°S latitude *Distephanus* occurs in diminutive quantities. Mean annual surface water isotherms are $\sim 1^\circ\text{C}$ at 57°S latitude and $\sim 13^\circ\text{C}$ at 39°S latitude; therefore, the constructed paleotemperature curve has a temperature resolvability range from 1° to 13°C.

The constructed paleotemperature technique is dependent upon the behavior of living silicoflagellate species in the assemblage; therefore, use of this technique on assemblages other than Recent is based on the assumption that the ecological response of the organisms has been similar during past geologic epochs. It is also true that the older the geologic age of the sediment, the smaller the percentage of living species in an assemblage. It is therefore desirable to limit the use of the developed paleotemperature technique to only Pleistocene and Pliocene sequences because older sequences contain a high percentage of taxa which are now extinct or without living counterparts.

Relative Silicoflagellate Paleotemperature (Td) Values

Absolute paleotemperature determinations of Leg 28 Miocene and Oligocene sequences utilizing the previously described technique are not possible because most taxa are no longer living and therefore have undetermined temperature tolerances. However, the general

TABLE 7
Comparison of Surface Water
Temperature Estimates Based on
Dictyocha/Distephanus Ratios

Ratio	Mandra and Mandra (1972)	Revised
0	4°C	1-1.5°C
0.10-0.50	4-15°C	2.5-5°C
0.50-1.0	15-21°C	5-7°C
1.0-3.5	21-25°C	7-10°C
>3.5	25°C	10°C+

warm- or cold-water tolerances of Miocene and Oligocene genera are understood on the basis of the biogeographic distribution of extinct taxa and the paleoecological requirements of their living representatives.

A method, patterned after Kanaya and Koizumi (1966), is utilized for determining relative paleotemperature (Ts) values for the Miocene and Oligocene at Sites 266 and 274. The determined Td values =

$$\frac{X_w}{X_w + X_c} \cdot 100;$$

where X_w = total specimens of warm-water genera and X_c = total specimens of cold-water genera. The resultant number can vary from 0 (when $X_w = 0$) to 100 (when $X_c = 0$). This silicoflagellate Ts value is only a relative measure between cold (0) and warm (100) temperatures. In the present scheme *Distephanus* and *Cannopilus* are considered cold-water genera whereas *Naviculopsis*, *Dictyocha*, and its ancestral genus *Corbisema* are considered as warm-water genera. *Mesocena* is considered to have intermediate temperature tolerances and is tabulated with X_w and X_c to prevent bias.

Early Pliocene Temperature Changes (Sites 266, 274, and E 50-28, E 38-8, E 36-33, E 14-8)

Sediment Sampling and Quantitative Floral Analysis

Eltanin piston cores were initially sampled at 20-cm intervals, but additional samples were taken at 10-cm intervals over those core sections where significant changes in *Dictyocha/Distephanus* ratios were noted. *Glomar Challenger* drill cores were generally sampled at 50-cm intervals. *Dictyocha* and *Distephanus* species counts of not less than 100 specimens per slide were made on all surface sediments and core samples.

Results

Calculations of silicoflagellates ratios from six piston and drill cores (Figure 6, Table 8) indicate that a minimum of seven time-correlative changes occurred in the regional oceanographic regime of the Southern Ocean during the early Pliocene (Figure 7, Table 9). Temperatures fluctuated between those now found north of the present position of the Antarctic Convergence (Gilbert climatic events II, IV, V, VII) to those restricted south of this oceanographic boundary (Gilbert I, III, and VI).

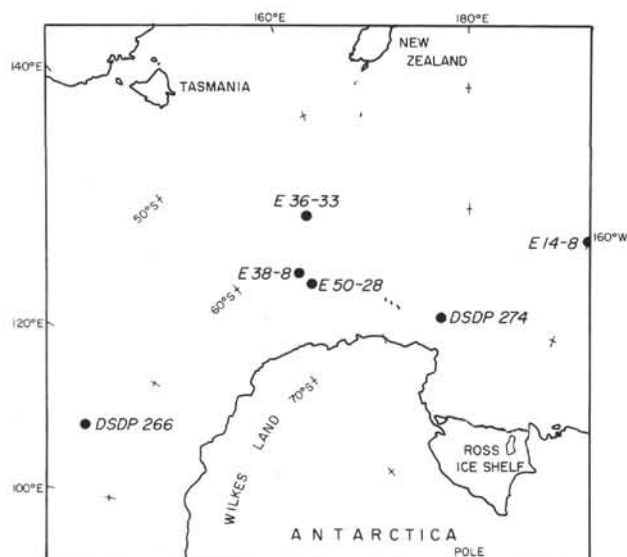


Figure 6. Location map of Eltanin piston cores and Deep Sea Drilling Project drill cores utilized in silicoflagellate paleotemperature determinations. (See Table 8 for coordinates and depths.)

The highest paleotemperatures are recorded in lower Gilbert age sediments (Gilbert V, $T = 4.00$ m.y.B.P. and Gilbert VII, $T = \sim 4.25$), where *Dictyocha*/*Distephanus* ratios are ≥ 1.0 at all sample intervals within these events. Temperatures as high as 10°C appear to have been prevalent in waters as far south as 63° and possibly 69°S latitude (Figure 7), indicating Northern Subantarctic conditions during these events. Temperatures at

TABLE 8
Location and Depths of Samples From Which
Silicoflagellate Temperatures Are Determined

Sample	Latitude	Longitude	Depth (Fathoms)
DSDP 274	$68^{\circ}59'S$	$173^{\circ}25'E$	1663
E 50-28	$62^{\circ}54'S$	$150^{\circ}41'E$	1908
E 38-8	$61^{\circ}48'S$	$149^{\circ}54'E$	1800
E 14-8	$59^{\circ}40'S$	$160^{\circ}17'W$	1830
E 36-33	$57^{\circ}46'S$	$154^{\circ}55'E$	1877
DSDP 266	$56^{\circ}24'S$	$110^{\circ}06'E$	2087

this time would have been 8° - 10°C higher than those found at similar latitudes today, suggesting that Northern Subantarctic waters were displaced significantly south of their modern position during the lower Gilbert magnetic epoch.

Antarctic temperatures, similar to and possibly lower than those of the Holocene, are indicated for Gilbert events I ($T = 3.55$ - 3.70) and III ($T = 3.80$ - 3.85). At all sample intervals within these events the *Dictyocha*/*Distephanus* ratios are 0.07, and in most sample intervals within Gilbert I (Figure 7) essentially no specimens of *Dictyocha* were counted. *Dictyocha* is only absent in modern Antarctic sediments south of $\sim 56^{\circ}\text{S}$ latitude where surface water temperatures remain throughout the year between $<0^{\circ}$ and 1.5°C . Gilbert III event spans only a short time interval, whereas Gilbert I, apparently the most severe Gilbert cooling, lasted throughout the entire upper Gilbert above event "a" with some indication of a warming prior to the Gilbert-Gauss boundary. It is important to note that these cool-

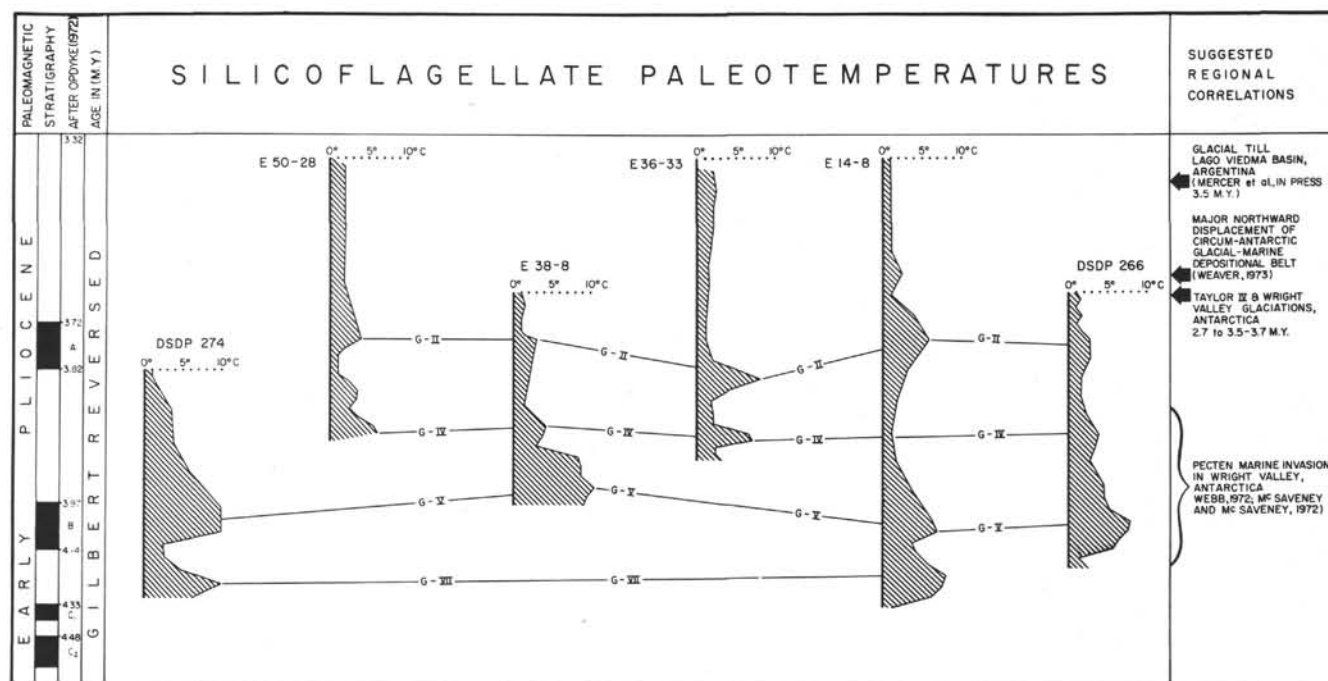


Figure 7. Early Pliocene paleotemperatures and climatic events and regional correlation of continental glacial and interglacial evidence. Core correlations based on close interval diatom, radiolarian, and silicoflagellate biostratigraphy, and Eltanin core paleomagnetic stratigraphy.

TABLE 9
Paleomagnetic Age Determinations of Early Pliocene Climatic Events
Recorded Between 69°–57° S Latitude

Event	Approximate Paleomagnetic Age (m.y. B.P.)	Calculated Temperature Range (Seasonal Average)	Climatic Regime
Holocene	—	<0–1–2°C	Antarctic
Gilbert I	3.35–3.70	<1.5–2°C	Antarctic
Gilbert II	~3.75	3–7°C	Subantarctic
Gilbert III	3.80–3.85	<1.5–2°C	Antarctic
Gilbert IV	~3.90	4–6°C	Subantarctic
Gilbert V	3.95–4.05	7–10°C	Northern Subantarctic
Gilbert VI	4.15–4.25	3–4°C	Northern Antarctic
Gilbert VII	~4.25–?	8–10°C	Northern Subantarctic

ing events recorded in Gilbert events I and III might reflect the initial establishment of true Antarctic climatic conditions within the Southern Ocean during the Pliocene, although little paleoclimatic information is available for the interval between Gilbert event “c” and the Epoch 5 boundary. Sediments of this age are found in *Eltanin* cores E 13–17 and E 34–5, and both cores contain substantial warm-water radiolarians and diatoms not endemic to Antarctic waters today.

Dictyocha/Distephanus ratios recorded at Gilbert events II, IV, and VI are similar in that they reflect a temperature range indicative of Subantarctic to northernmost Antarctic conditions (temperatures = 3°–7°C). Projected surface water isotherms during these climatic intervals within the study area indicate that temperatures were 3°–5°C higher than those in the region today. These paleotemperatures are comparable to present-day surface water temperatures between ~54° and 48°S latitude.

Silicoflagellate paleotemperatures delineate a major cooling trend between 4.30 and 3.70 m.y.B.P. (Table 9). This early Pliocene cooling trend records a major climatic deterioration in the Southern Ocean with surface water temperatures fluctuating from those commonly associated with waters north of the modern position of the Antarctic Convergence (7°–10°C) to those found associated with Antarctic waters (<1.5°C).

Interpretation

Mercer (1968) suggests that the West Antarctic ice sheet is a uniquely vulnerable and unstable body of ice which cannot exist unless composed of cold ice throughout. Because it is in equilibrium with the Ronne and Ross ice shelves, any changes in horizontal forces due to a climatically induced recession of these ice shelves would cause the grounded ice sheet to lift off the sea bottom. With further warming, it would revert to a single ice shelf and eventually would thin to pack ice similar to that found off the Antarctic today. Mercer estimates that destruction of the ice sheet would start if summer temperatures rose more than 4°C above present levels and would be completed if temperatures rose 10°C.

Silicoflagellate paleotemperature estimates (G-VII and G-V; $T=4.25$ – 3.95 m.y.B.P.) for middle and lower Gilbert cores taken as far south as 69°S latitude, average 8° to 10°C higher than those found in the Southern

Ocean today. These temperatures would satisfy Mercer's (1968) requirements for partial or complete absence of the west Antarctic ice sheet during this interval of time. In addition, a marginal recession of the east Antarctic ice sheet would have occurred simultaneously, because the present -10°C January isotherm lies only slightly inland along the East Antarctic coast (Tolstikov, 1966).

Continental evidence in support of early Pliocene warm conditions comes from recent research on *Pecten* deposits in Wright Valley, Antarctica. Webb (1972), Bull and Webb (1973), and others have studied the sedimentology and paleontology of these *Pecten* deposits and conclude that they were deposited in a fjord which extended a minimum of 40 km up Wright Valley from McMurdo Sound. Webb's (1972) study of benthic foraminifera within the *Pecten* deposits led him to suggest a fjord depth of approximately 100 meters and bottom water temperatures somewhere between -2° and 5°C, and perhaps as high as 10°C. Webb believes it is likely that warm interglacial conditions existed in Wright Valley during the time of *Pecten* deposition. It is the author's opinion that the *Pecten* “Interglacial” conditions in Wright Valley may be time-correlative with “warm conditions” recorded in Antarctic deep-sea sediments between 4.3 and 3.95 m.y.B.P. (Figure 7).

Previous marine evidence suggesting a warm early Pliocene in the Southern Ocean comes from documentation of subtropical collosphaerid radiolarians in Gilbert sediments from two cores taken in the South Pacific sector of the Southern Ocean (Bandy et al., 1971). These authors suggest a 15°C change in surface water temperatures during the Gilbert at event “c” or between events “c” and “a,” defined at the level of total disappearance of the collosphaerid radiolarians. Early Pliocene paleotemperatures presented here are substantially lower, but generally corroborate their earlier climatic interpretation of a very warm early to mid-Gilbert.

Between 3.95 and 3.70 m.y.B.P. (G-IV through G-I), a major cooling trend is recorded in the Southern Ocean region (Figure 7, Table 9). It is in general agreement with the earlier findings of Bandy et al. (1971) based on radiolarian data. Surface water temperatures delineated in this study indicate a decline from temperatures characteristic of northern Subantarctic waters to those associated with modern Antarctic waters, rather than a

decrease from tropical or subtropical temperatures, as suggested by Bandy et al. (1971).

Pliocene temperatures characteristic of Antarctic waters were initially established by Gilbert III (Table 9) or by Gilbert I at the latest. Silicoflagellate temperature data indicate that due to the total absence of the genus *Dictyocha* at the beginning of Gilbert I, this cooling may have been one of the most severe recorded during the Pliocene.

Further evidence to substantiate this was found in the Southern Ocean sedimentary record; Weaver (1973) recorded this same cooling event in marine sediments adjacent to the Adelie coast of East Antarctica. He noted a major northward displacement of the glacial-marine/siliceous ooze sediment boundary following Gilbert event "a," and referred to this event as Gilbert cooling I (Figure 7). After correcting the latitudinal position of his core material for southerly movement due to sea-floor spreading since the early Pliocene, he calculated that the characteristic glacial-marine/siliceous ooze boundary in the Southern Ocean must have been displaced 1° to 1-1/2° further north than its Holocene position. This displacement indicates more severe climatic conditions in the Antarctic region than at present.

This severe late Gilbert cooling event is also substantiated by continental evidence. Mercer et al. (in press) have discovered evidence for a major glaciation in Argentine Patagonia (Figure 7) which is apparently the first to affect the area and is approximately time equivalent to Gilbert I. They have documented major till deposition intercalated between lava flows with indistinguishable radiometric ages of 3.50 m.y.B.P., and have concluded that this glaciation probably resulted from a major increase in Antarctic ice cover.

In conclusion, the data imply that temperatures in the Antarctic during the early Pliocene between 4.3 and 3.95 m.y.B.P. were much higher than they are today. Surface water temperatures calculated from *Dictyocha*/*Distephanus* ratios indicate that Antarctic water temperatures may have been 10°C higher than they are today. The inferred surface water temperatures suggest the possible absence of the West Antarctic ice sheet at this time. It is further suggested that the West Antarctic ice sheet would have been established or possibly reestablished during the succeeding climatic cooling of the late Gilbert. The ice sheet could have reached its present size as early as 3.80-3.85 m.y.B.P. (Gilbert climatic event III) but was no doubt fully developed by 3.35-3.70 m.y.B.P. (late Gilbert climatic event I).

Late Miocene (Site 266)

Fifteen samples examined from the late Miocene sequence of Site 266, between Samples 10-1, 90 cm and 12-3, 112 cm, generally contain an insufficient variety and abundance of silicoflagellates for paleotemperature and Ts value determinations. Most of the stratigraphic interval is barren or nearly barren except for a bloom of *Mesocena circulus* between Samples 11-1, 60 cm and 11-3, 92 cm. The paleoecologic significance of the late Miocene occurrence of this species, at Sites 266 and 274

as well as in Falkland Plateau sediments, is relatively uncertain. The short stratigraphic range of *Mesocena circulus* in the Southern Ocean suggests that it may have been a stenothermal species whose thermal requirements were maintained only briefly during the changing climatic conditions of the late Miocene.

Middle Miocene (Site 266)

Silicoflagellate Ts values were calculated from 24 middle Miocene samples between 200 and 277 meters (Figures 8c, d). The obtained Ts values are exceptionally low or equal to zero throughout most of the middle Miocene sequence. Low Ts values and low assemblage diversities and abundances are indicative of cool middle Miocene climatic conditions. High Ts values of between 60 and 100 are recorded only in the *Dictyocha mutabilis* Zone, between 200 and 204 meters, and the lower *Distephanus longispinus* and upper *Corbisema triacantha* zones, between 254 and 260 meters. Several characteristics of the *Corbisema triacantha* Zone that are suggestive of moderate early middle Miocene conditions include: the common to abundant occurrence of the cosmopolitan species *Corbisema triacantha*; the presence of few to common warm-water *Dictyocha aspera*, *D. fibula*, and *D. variabilis*; and an assemblage of moderate diversity and abundance.

Early Miocene (Site 266)

Silicoflagellate Ts values were calculated from 22 samples obtained between 279 and 370 meters. The *Naviculopsis navicula* Zone in Core 19, between 292 and 299 meters, yields moderate Ts values varying from 30 to 60. The *Naviculopsis regularis* Zone, between 311 and 315 meters, possesses slightly lower Ts values ranging from 20 to 45. The unzoned interval of Core 21, between 330 and 337 meters, has Ts values of 0 at all sample intervals except in Section 1 where a Ts value of 50 is obtained. The *Naviculopsis robusta* Zone in Cores 22 and 23, from 338 to 370 meters, contains common to abundant silicoflagellates which yield moderate to high Ts values varying from 40 to 80.

At this site, moderate early Miocene climatic conditions are not only suggested by the obtained Ts values but also by the cosmopolitan character of the assemblage. Many of the species found in this early Miocene sequence are found, with similar abundances, in the middle latitude Mediterranean region (Sanfilippo et al., 1973). Species commonly found in the early Miocene of this site and the Mediterranean include: *Corbisema triacantha*, *Distephanus crux*, *D. speculum*, *Naviculopsis navicula*, *N. robusta* (?), and *Mesocena apiculata*.

Early Miocene (DSDP 266):

Ts values. Silicoflagellate Ts values were calculated from twenty-two samples obtained between 279 and 370 meters. The *Naviculopsis navicula* zone in Core 19, between 292 and 299 meters, yields moderate Ts values varying from 30 to 60. The *Naviculopsis regularis* Zone, between 311 and 315 meters, possesses slightly lower Ts values ranging from 20 to 45. The unzoned interval of Core 21, between 330 and 337 meters, has Ts values of 0

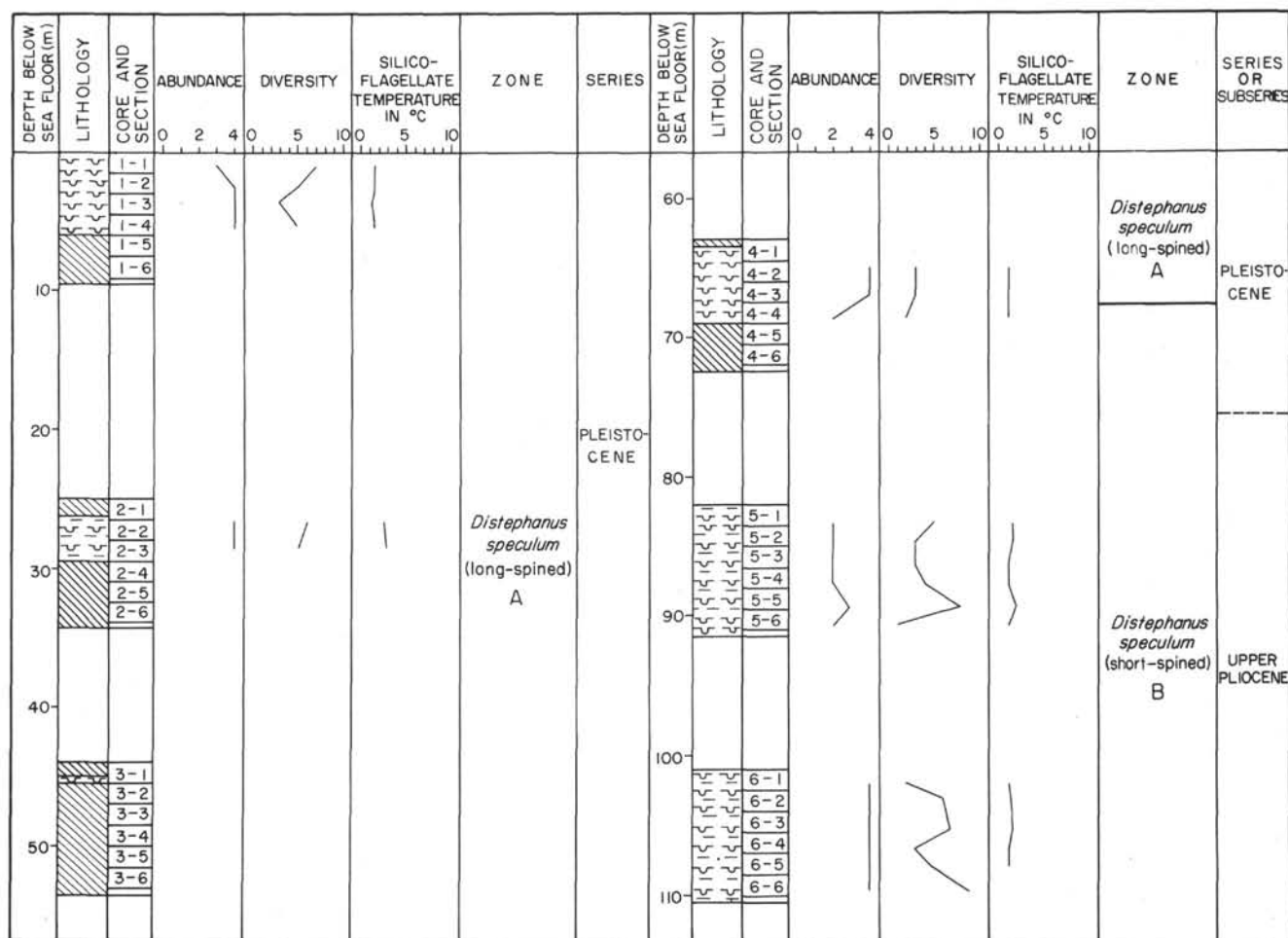


Figure 8a. Silicoflagellate abundances, diversities, and paleotemperature values for Site 266. Depths, lithologies, core and section numbers, silicoflagellate zones, and geologic series or subspecies are indicated. For a discussion of the data, see text.

at all sample intervals except in section 1 where a Ts value of 50 is obtained. The *Naviculopsis robusta* Zone in Cores 22 and 23, from 338 to 370 meters, contains common to abundant silicoflagellates which yield moderate to high Ts values varying from 40 to 80.

At this site, moderate early Miocene climatic conditions are not only suggested by the Ts values obtained but also by the cosmopolitan character of the assemblage. Many of the species found in this early Miocene sequence are found, with similar abundance, in the middle latitude Mediterranean region (Sanfilippo, et al., 1973). Species commonly found in the early Miocene of this site and the Mediterranean include—*Corbisema triacantha*, *Distephanus crux*, *D. speculum*, *Naviculopsis navicula*, *N. robusta* (?), and *Mesocena apiculata*.

Late Miocene (Site 274)

The Site 274 late Miocene sequence, between Samples 12-1, 92 cm and 12-5, 14 cm, contains insufficient silicoflagellate occurrences for Ts value determinations. Throughout the late Miocene at this site the only species occurring with any regularity is *Mesocena circulus*. A large number of fragmented forms occur throughout much of the section.

Associated with this sparse floral assemblage is a distinct and maintained late Miocene increase in coarse detritus (Figure 9b) and ferromanganese micronodule formation which is suggested by Frakes (this volume) to be the result of intensified ice rafting and bottom water activity caused by an expanding Ross ice shelf. The sparse and fragmented floral assemblage in the late Miocene sequence at this site is certainly not inconsistent with oceanographic and sedimentological conditions that would be associated with an expanding Ross ice shelf.

Middle and Late Miocene (Site 274)

The Site 274 early Miocene section, between Cores 16 and 19, and the middle Miocene sequence, between the base of Cores 1 and 16, contains insufficient silicoflagellate occurrences for Ts value determinations. All early Miocene stratigraphic intervals examined are either barren or contain a monospecific assemblage of *Distephanus speculum*. Middle Miocene sequences are similar except for the very rare occurrence of early Oligocene reworks. A large number of skeletal fragments, predominately composed of thick radial spines, are present throughout the section. A high percentage of

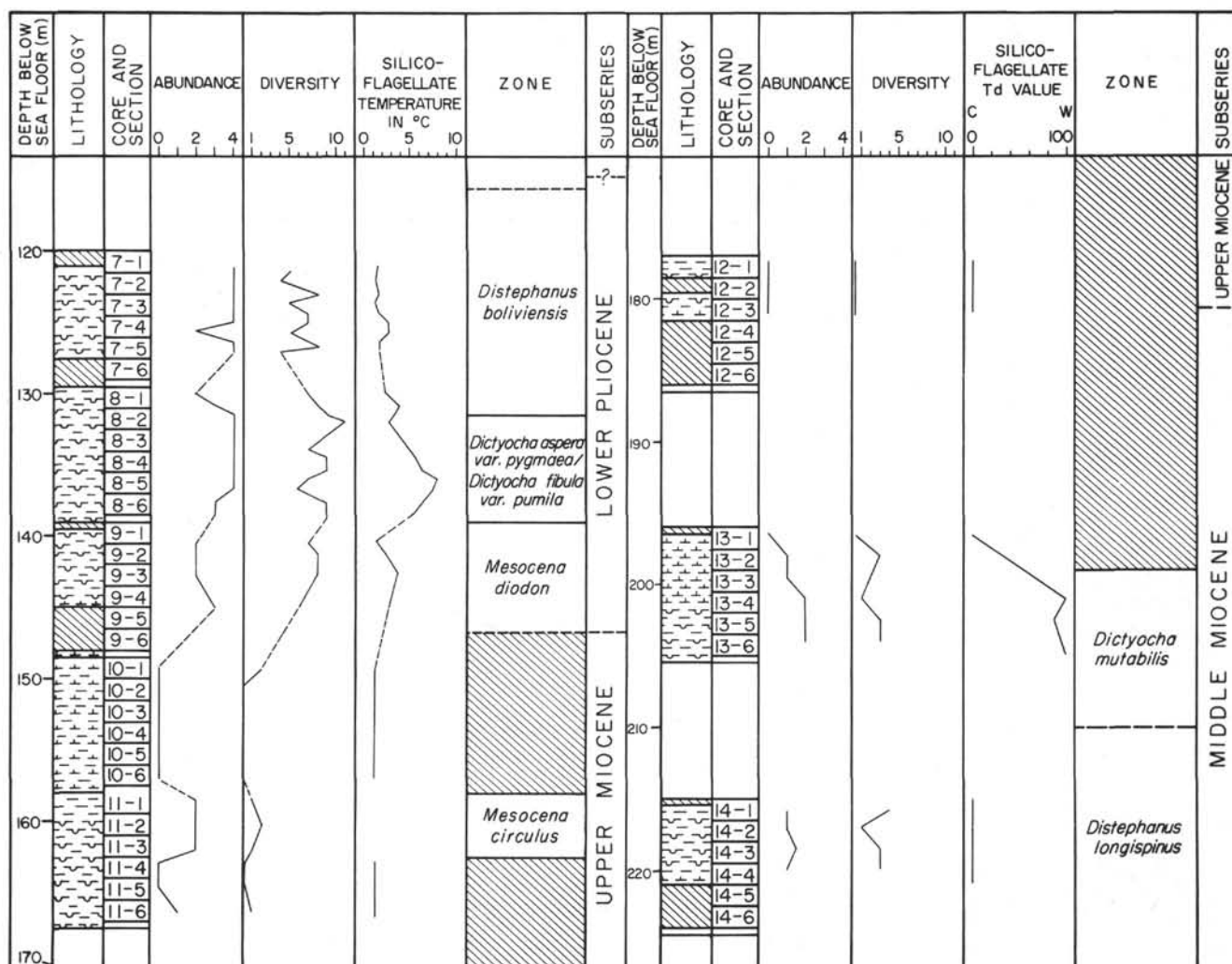


Figure 8b. Silicoflagellate abundances, diversities, paleotemperatures, and Td values for Site 266. Depths, lithologies, core and section numbers, silicoflagellate zones, and geologic subseries are indicated. For a discussion of the data, see text.

silicoflagellate fragments suggests that active cold bottom water currents, which formed the hiatus between the early Miocene (Core 19) and early Oligocene (Core 20), may have decreased in intensity but still were active during the early and middle Miocene.

Lower Oligocene (Site 274)

Ts values. Silicoflagellate Ts values were calculated from 82 samples taken in the lower Oligocene *Dictyocha deflandrei* Zone, from 181 to 321.5 meters. The obtained Td values indicate that relatively warm conditions existed throughout the interval represented. The highest Td value obtained is 80 and the lowest value 30; however, the majority of the values fall around 50. Td values in the *Mesocena apiculata* Subzone, Cores 31 to 34, range from 40 to 50. A noticeable increase in Td values is seen in the lower two cores of the *Dictyocha frenguelli* Subzone, Cores 29 and 30. The very high Td values, between 60 and 80, are the result of the near dominance of the silicoflagellate population by warm-water *Dictyocha* species. At the base of Core 28, Ts values decrease from 80 to 30, in an interval of approxi-

mately 5 meters. Ts values are generally between 20 and 40 throughout the slight cooling in Cores 26 and 28. Moderate Ts values, from 30 to 50, are maintained throughout the uppermost portion of the lower Oligocene represented in Cores 20 to 25.

Calculations of sand abundances in the lower Oligocene section, from Core 20 to Core 34, reveal that sand is not present in significant amounts at any interval of the section (Figures 9b-9d). The lack of significant sand deposition at this site, just distal to the Ross Sea, therefore seems to indicate that ice rafting did not commence before the deposition of Core 20.

SYSTEMATIC PALEONTOLOGY

Most of the silicoflagellate species encountered in the present study have recently been reviewed in detail (Loeblich et al., 1968; Ling, 1970, 1972). Silicoflagellate taxonomy is given fully in these works; therefore full synonymies are not presented here. In the following, silicoflagellate genera and species are arranged in alphabetical order and relevant comments and references describing the named taxa are presented wherever deemed appropriate.

Type specimens will be deposited in the U.S. National Museum, Washington, D.C.

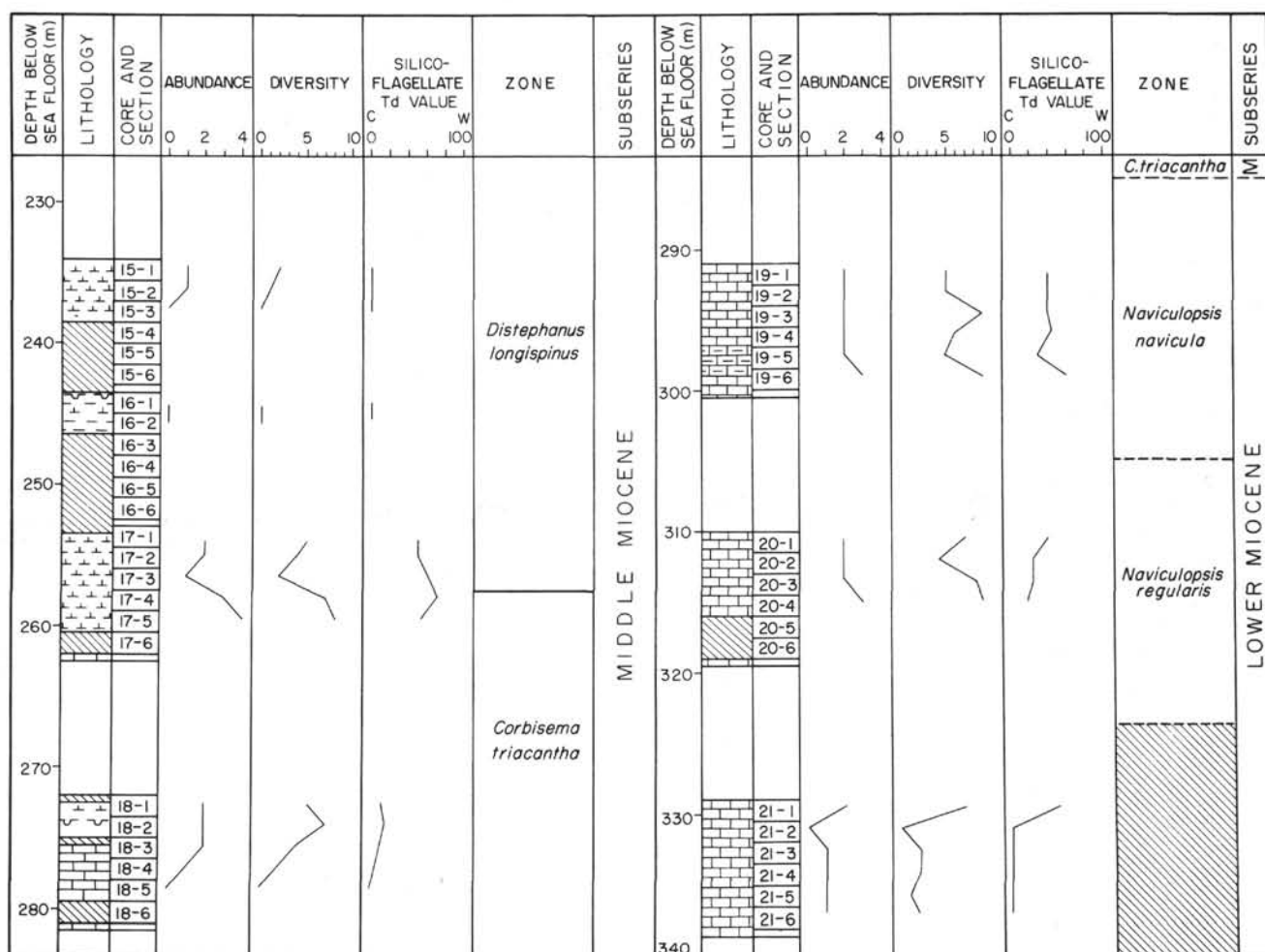


Figure 8c. Silicoflagellate abundances, diversities, and Td values for Site 266. Depths, lithologies, core and section numbers, silicoflagellate zones, and geologic subseries are indicated. For a discussion of the data, see text.

Order SIPHONOTESTALES Lemmermann, 1901

Genus CANNOPILUS Haeckel, 1887, emend. Bachmann, 1967

Cannopilus antarcticus n. sp. (Plate 1, Figures 1-9)

Description and measurements: Basal ring, 50-58 μ in diameter, and seven to nine sided with straight or convex sides, 15-25 μ long. An equal number of radial spines, 4-8 μ , on the plane of the basal ring. No accessory spines. Apical ring relatively high standing, 30-40 μ in diameter. Apical apparatus possesses 11-16 apical windows from 4 to 10 μ in diameter. Total skeletal diameter between 54 and 66 μ .

Occurrence: *Cannopilus antarcticus* only occurs in one sample (17-5, 63-65 cm) from the early Miocene *Corbisema triacantha* Zone at Site 266.

Type specimens: The holotype (Plate 1, Figures 7-9) and paratypes (Plate 1, Figures 1-6) will be deposited at the USNM. Type numbers have not been assigned but will be published in Contribution 41 of the Florida State University Sedimentological Research Laboratory.

Cannopilus hemisphaericus (Ehrenberg) (Plate 2, Figures 2, 3)

Dictyocha hemisphaerica Ehrenberg, 1844b, p. 258, 266.

Cannopilus hemisphaericus Ling, 1972, p. 147-149, pl. 23, fig. 1-5.

Remarks: The only significant occurrence of this normally rare species is in the lower middle Miocene to lower Miocene interval of Site 266, between Cores 17 and 22. Its occurrence in this section is sporadic, and its abundance in any one sample is limited to a few specimens.

Cannopilus sphaericus Gemeinhardt (Plate 2, Figure 1)

Cannopilus sphaericus Gemeinhardt, 1931, p. 104, pl. 10, fig. 3, 4.

Remarks: A few specimens of this species were observed in the lower middle to upper upper Miocene sections at Site 266, between Cores 18 and 20.

Genus CORBISEMA Hanna, 1928, emend. Frenguelli, 1940

Corbisema apiculata (Lemmermann) (Plate 2, Figures 4-11)

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

Corbisema apiculata Ling, 1972, p. 151, 152, pl. 23, fig. 13-17.

Remarks: Those specimens found in this study which are referable to the present species have a basal ring length between 30 and 65 μ .

Few to common *C. apiculata* are present throughout the entire lower Oligocene section at Site 274, from Cores 20 to 34. The species has also been found in samples from Site 6 of the radiolarian *Podocyr-tis chalara* Zone (Lutetian), in reference samples from the Bain's Farm and Totara sections of the Oamaru Diatomite, New Zealand, and in samples from the Kellogg and Sidney shales of California (Ling, 1972).

Corbisema archangelskiana (Schulz) (Plate 3, Figures 1, 2)

Dictyocha triacantha var. *archangelskiana* Schulz, 1928, p. 250, 251, fig. 33a-c; p. 281, fig. 77, 78 (?).

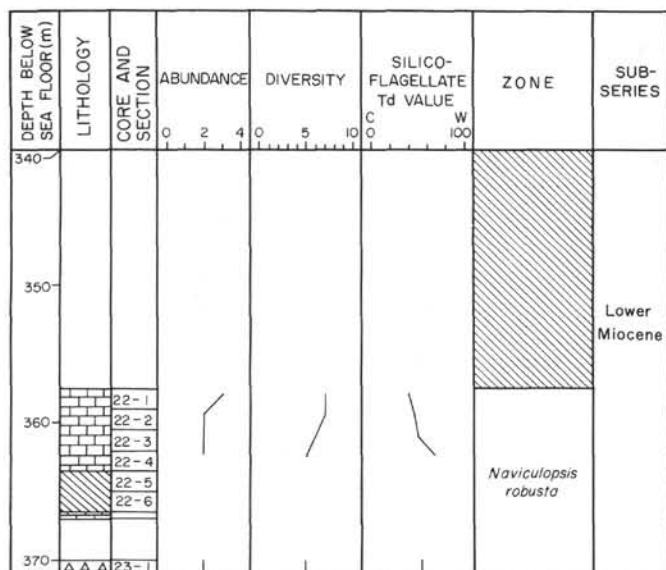


Figure 8d. Silicoflagellate abundances, diversities, and Td values for Site 266. Depths, lithologies, core and section numbers, silicoflagellate zones, and geologic subseries are indicated. For a discussion of the data, see text.

Dictyocha triacantha var. *archangelskiana* Gemeinhardt, 1930, p. 45, 46, fig. 37a, b (?).

Corbisema archangelskiana Frenguelli, 1940, fig. 12a; Stradner, 1961, p. 89, fig. 25 (only); Glezer, 1966, p. 232, 233, pl. 8, fig. 6, 7.

Remarks: This distinctive species was found only in Core 4 of the *Naviculopsis biapiculata* Zone at Site 267, where it makes up less than 10% of the total assemblage.

***Corbisema hastata* (Lemmermann)**
(Plate 2, Figures 12-15)

Dictyocha triacantha var. *hastata* Lemmermann, 1901, p. 259, pl. 10, fig. 16, 17; Schulz, 1928, p. 249, 250, fig. 31a-c, 29b (only); Gemeinhardt, 1930, p. 43, fig. 35a-c; Deflandre, 1932a, fig. 28; Frenguelli, 1940, fig. 12c (only); Glezer, 1966, p. 231, 232, pl. 6, fig. 6-8, pl. 7, fig. 1-8, pl. 31, fig. 8, 9.

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

Remarks: *Corbisema hastata* occurs sporadically throughout most of the early Oligocene *Dictyocha deflandrei* Zone at Site 274. It has also been observed in the middle Eocene (Lutetian) *Podocyrus chalaru* and *Thyrsoyrtis triacantha* radiolarian zones at Sites 13 and 6, respectively (Ling, 1972). Late Eocene and early Oligocene occurrences have also been noted in the Soviet Union (Glezer, 1966).

***Corbisema spinosa* Deflandre**
(Plate 3, Figure 9)

Corbisema spinosa Deflandre, 1950a, p. 65, fig. 178-182.

Dictyocha spinosa Glezer, 1960, fig. 31; Glezer, 1966, p. 256, pl. 10, fig. 6-8.

Remarks: Rare abundances of this species were noted in three samples of the *Dictyocha frenguelli* Subzone of the early Oligocene *Dictyocha deflandrei* Zone at Site 274.

***Corbisema* ? sp.**
(Plate 3, Figure 7)

Remarks: This species is characterized by a triangular basal ring with three radial spines and an apical apparatus consisting of three lateral rods which merge to form a triangular-shaped apical ring. The species is tentatively placed under the present genus because of its triangular basal ring and three lateral rods; however, the presence of an apical window is not in agreement with the generic definition. The existence of an apical ring is not considered sufficient reason for exclusion of this species in the assigned genus, because all occurrences are concurrent with *Corbisema triacantha*, suggesting that it may be an intraspecific variation of the latter species.

Only three specimens of *Corbisema* ? sp. were found, one from each of the early Miocene samples, 266-19-6, 60-62 cm and 266-21-2, 62-64 cm; and one from early Oligocene Sample 274-30-1, 30-32 cm.

***Corbisema triacantha* (Ehrenberg)**
(Plate 3, Figures 3-6)

Dictyocha triacantha Ehrenberg, 1844a, p. 80.

Dictyocha triacantha var. *triacantha* fa. *triacantha* Glezer, 1966, p. 226, 227, pl. 4, fig. 1-6, pl. 5, fig. 1-4.

Corbisema triacantha Ling, 1972, p. 156-157, pl. 24, fig. 8-13; Ling, 1972, p. 751, pl. 1, fig. 7, 8; Bukry and Foster, 1973, p. 826, pl. 2, fig. 3.

***Corbisema triacantha* var. *flexuosa* Stradner**
(Plate 3, Figure 8)

Corbisema triacantha var. *flexuosa* Stradner, 1961, p. 39, fig. 1-8.

Dictyocha triacantha var. *flexuosa* Glezer, 1966, p. 244, pl. 5, fig. 5, 6, 7, 10.

Remarks: Three specimens referable to Stradner's variety were only found in the Site 274 early Oligocene *Dictyocha frenguelli* Subzone of the *Dictyocha deflandrei* Zone at Site 274. This is the first recorded occurrence of this variety in the deep sea, as it has previously been recorded only in the late Eocene to late Oligocene of Central Europe and Asia.

All three specimens of this variety are approximately 20 μ in width and have a partially hollow apical plate.

Genus DICTYOCHA Ehrenberg, 1839

***Dictyocha aspera* (Lemmermann)**
(Plate 4, Figures 2, 5)

Dictyocha fibula var. *aspera* Lemmermann, 1901, p. 260, pl. 10, fig. 27, 28.

Dictyocha aspera Bukry and Foster, 1973, p. 826, pl. 2, fig. 4, 6.

Remarks: This taxa shows a high degree of intraspecific variability in basal ring size and shape and length of the apical bar. In the present study, those specimens referred to this species have an apical bar aligned with the short axis of the skeleton.

An intraspecific variation in the orientation of the apical bar has been noted by Dumitrica (1973) in his study of double skeletons from middle Miocene samples of Romania. On the basis of variations of the apical bar in double skeletons, Dumitrica has suggested taxonomic revision of the species. Several double skeletons found in this study all had apical bars in the transverse position; therefore, at this time the taxonomic revisions suggested by Dumitrica are not followed.

Dictyocha aspera is found common to abundant in most samples of the *Dictyocha pseudofibula* Zone and is found less common in the *Distephanus boliviensis* Zone.

***Dictyocha aspera* var. *pygmaea* n. v.**
(Plate 4, Figures 1, 3, 4, 6)

Description and measurements: Basal ring is square or rhombic with straight or slightly convex sides, 20-36 μ long. Two short radial spines, 8-12 μ , and two long radial spines, 20-38 μ , aligned normal to the high-standing apical bar. Radial spines taper and are usually curved abapically. Basal accessory spines, 2-4 μ , are located at the center of each basal ring side and point obliquely downward. Skeletal surface smooth.

Remarks: This variety is similar in size and ornamentation to *D. fibula* var. *pumila*, but differs in possessing an apical bar oriented normal to the axis of the long radial spines.

Occurrence: *D. aspera* var. *pygmaea* occurs abundantly in lower Pliocene sediments between Gilbert paleomagnetic events "a" and "b" (3.82-3.97 m.y. B.P.). The first and last occurrences of this variety and *D. fibula* var. *pumila* define the upper and lower limits of the *D. aspera* var. *pygmaea*-*D. fibula* var. *pumila* Zone.

Type specimens: The holotype (Plate 4, Figure 4) and paratypes (Plate 4, Figures 1, 3, 6) will be deposited at the USNM. Type numbers have not been received but will be published in Contribution 41 of the Florida State Sedimentological Reports.

***Dictyocha fibula* Ehrenberg**
(Plate 5, Figures 1-4)

Dictyocha fibula Ehrenberg, 1839, p. 129.

Remarks: This species is identified by the parallel alignment of the apical bar with the short axis. The taxonomic placement suggested by

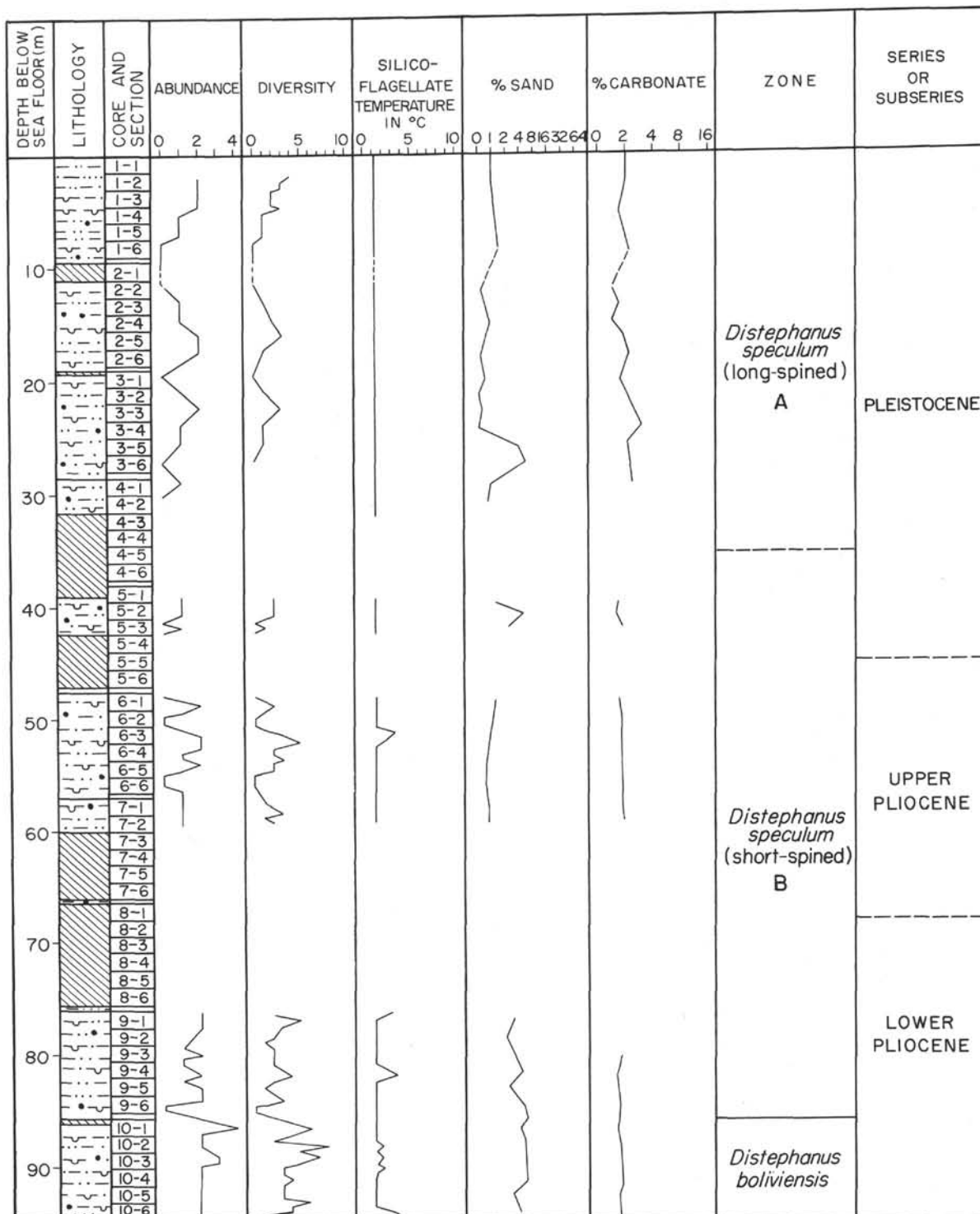


Figure 9a. Site 274 sand and carbonate percentages (Frakes, this volume) with silicoflagellate paleotemperatures, abundances, and diversities. Depths, lithologies, core and section numbers, silicoflagellate zones, and geologic series and subseries are indicated. For discussion of the data, see text.

Dumitrica (1973) is not followed at this time for similar reasons previously given in the discussion of *D. aspera*.

In the Antarctic, this species is noted to occur sporadically in the Pleistocene, Miocene, and Oligocene, but it also occurs fairly abundantly in the early Pliocene.

Dictyocha fibula var. *pumila* n.v.
(Plate 5, Figures 5-10; Plate 6, Figures 1, 2)

Description and measurements: Basal ring is square or rhombic with straight or convex sides, 22-35 μ long. Two short radial spines, 8-18 μ ,

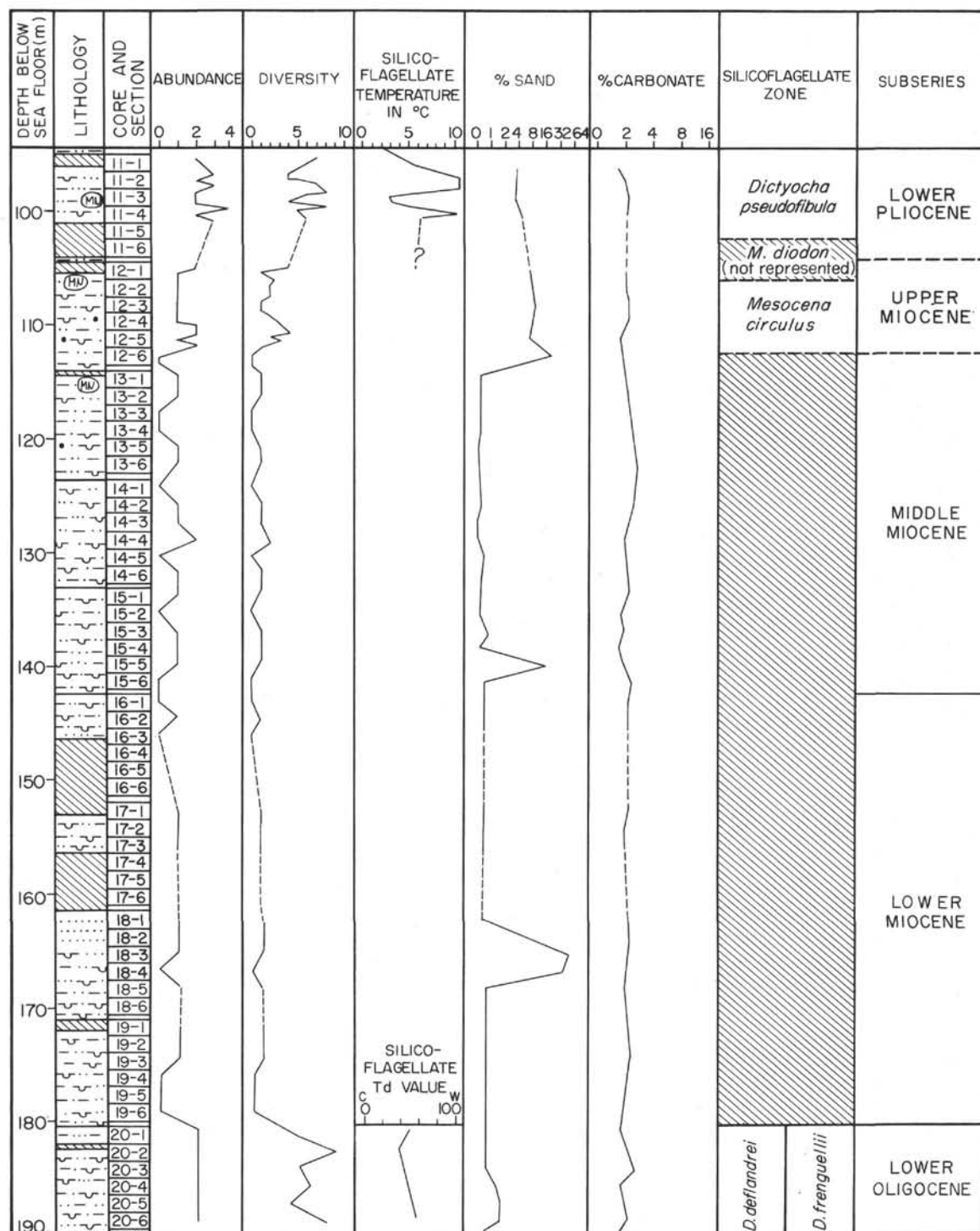


Figure 9b. Site 274 sand and carbonate percentages (Frakes, this volume) with silicoflagellate paleotemperatures, Td values, abundances, and diversities. Depths, lithologies, core and section numbers, silicoflagellate zones and subzones, and geologic subseries are indicated. For discussion of the data, see text.

and two long radial spines, 20-40 μ , aligned with the high-standing apical bar. Radial spines taper and are usually curved abapically. Basal accessory spines, 2-4 μ , located at the center of each basal ring side point obliquely downward. Skeletal surface smooth.

Remarks: Differs from *D. fibula* "var" *messenensis* by its overall smaller size and lack of an apical spine.

Occurrence: *Dictyocha fibula* var. *pumila* is a short-ranged variety that occurs abundantly in lower Pliocene sediments between Gilbert

events "a" and "b" (3.82-3.97 m.y. B.P.). Its first to last occurrence within this interval defines the *D. aspera* var. *pygmaea*-*D. fibula* var. *pumila* Zone.

Type specimens: A holotype (Plate 5, Figure 5, 6) and paratypes (Plate 5, Figures 7-10) will be deposited at the USNM. Type numbers have not yet been received but will be published in Contribution 41 of the Florida State Sedimentological Reports.

Type locality: E 50-28 (400-402), lower Antarctic Continental rise.

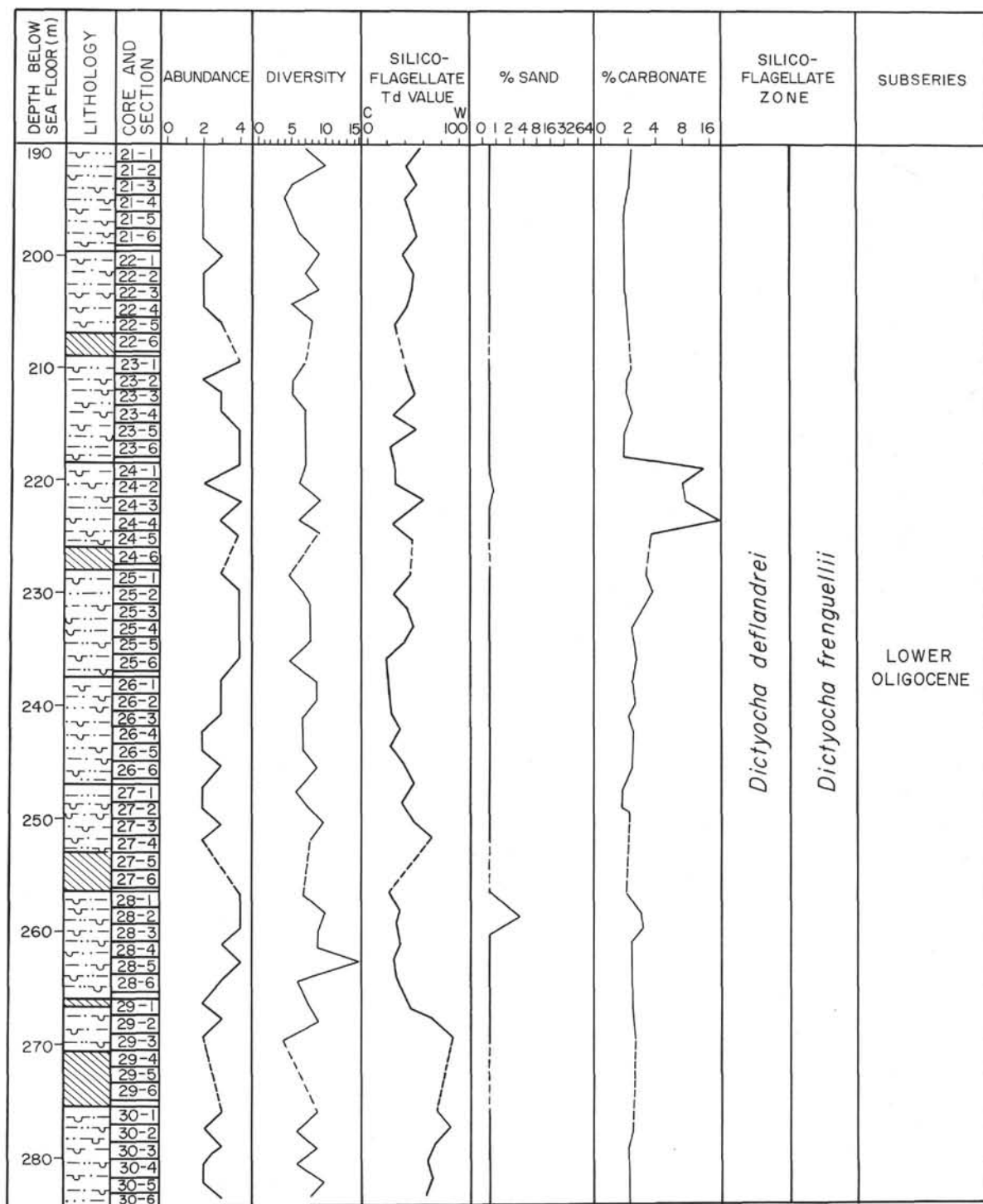


Figure 9c. Site 274 sand and carbonate percentages (Frakes, this volume) with silicoflagellate Td values, abundances, and diversities. Depths, lithologies, core and section numbers, silicoflagellate zones and subzones, and geologic subseries are indicated. For discussion of the data, see text.

Dictyochoa frenguelli Deflandre
(Plate 6, Figures 3-9)

Dictyochoa fibula Ehr. forma Deflandre, 1940, p. 598, fig. 2

Dictyochoa frenguelli Deflandre, 1950c, p. 194, fig. 188-193.

Dictyochoa frenguelli var *frenguelli* Glezer, 1966, p. 257, 258, pl. 11, fig. 9.

Remarks: Specimens of *Dictyochoa frenguelli*, from the early Oligocene *Dictyochoa deflandrei* Zone at Site 274, exhibit several intra-specific variations of the apical apparatus (Plate 6, Figures 4-9). All

variations are presently combined in occurrence tabulations as *Dictyochoa frenguelli* s.l. until further analysis of the *Dictyochoa frenguelli* group is made to determine the stratigraphic significance of the various morphotypes.

This species has previously only been reported from late Eocene or early Oligocene strata of the Soviet Union (Glezer, 1966). No specimens of *D. frenguelli* have been found in late Eocene or early Oligocene samples from Oamaru sections in New Zealand examined by the author or in Eocene deep-sea samples studied by Ling (1972).

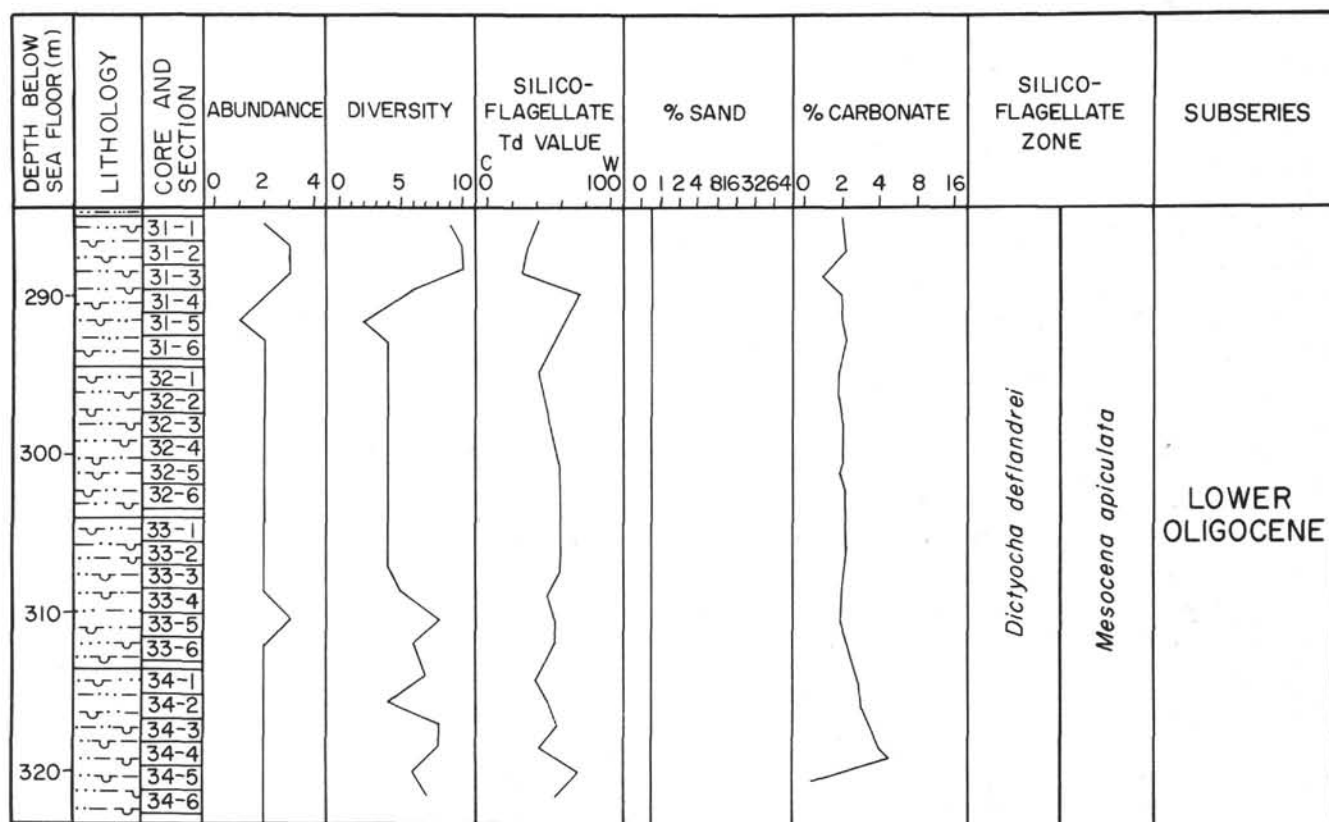


Figure 9d. Site 274 sand and carbonate percentages (Frakes, this volume) with silicoflagellate Td values, abundances, and diversities. Depths, lithologies, core and section numbers, silicoflagellate zones and subzones, and geologic subseries are indicated. For discussion of the data, see text.

Specimens have been observed in the early Oligocene section at Site 274 which have one to three apical spines and appear to be intermediary forms between *D. deflandrei* and *D. frenguelli*. The presence of such evolutionary intermediates and the younger stratigraphic position of *D. frenguelli* suggest that the species may have developed from the late Eocene-early Oligocene *D. deflandrei* stock.

Dictyocha hexacantha Schulz
(Plate 6, Figures 10, 11)

Dictyocha hexacantha Schulz, 1928, p. 255, fig. 43; Gemeinhardt; 1930, p. 55, 56, fig. 46; Hanna, 1931, p. 198, fig. 7; Glezer, 1966, p. 239, pl. 10, fig. 12; Ling, 1972, p. 162, 163, pl. 26, fig. 3.
Dictyocha deflandrei fa. *hexacantha* Frenguelli, 1940, p. 65, fig. 14g.
Corbisema hexacantha Deflandre, 1950a, p. 65-66, fig. 183-187.

Remarks: Rare occurrences of this species are noted in Cores 26 to 31 in the early Oligocene section at Site 274. It is also found reworked into Pleistocene sediments at the same site.

Dictyocha medusa Haeckle, 1887

Dictyocha medusa Haeckel, 1887, p. 1560, pl. 101, fig. 13, 14.

Remarks: This species is characterized by four lateral rods which merge at a central point. It has a four-sided basal ring and is easily differentiated from *Dictyocha deflandrei* by its larger size and conspicuous constrictions where lateral rods and basal ring merge. In the Antarctic it is only found in Pliocene aged sediments, particularly those of the *Dictyocha pseudofibula* Zone. In the Eastern Equatorial Pacific it is restricted to the Miocene (Bukry and Foster, 1973).

Dictyocha mutabilis Deflandre
(Plate 7, Figures 1-5)

Dictyocha mutabilis Deflandre, 1950c, p. 197, fig. 203-210.

Remarks: This species occurs commonly at Site 266, Core 13, and its interval of common occurrence at this site defines the *Dictyocha mutabilis* Zone. Its middle Miocene occurrence at Site 266 may be correlative with its occurrence in the middle Miocene (Helvetian) of San Pedro, California (Deflandre, 1950c).

Dictyocha pentagona (Schulz)
(Plate 7, Figures 6, 7)

Dictyocha fibula var. *pentagona* Schulz, 1928, p. 255, fig. 41a-b (fide Loeblich et al., 1968, p. 96, pl. 12, fig. 13, 14).

Dictyocha perlaevis Frenguelli

Dictyocha perlaevis Frenguelli, 1951, p. 279, fig. 4b, c (fide Loeblich et al., 1968, p. 40, 109, pl. 51, fig. 7, 8); Dumitrica, 1973, p. 848, 849, pl. 3, fig. 8-12, pl. 4, fig. 1, 2).

Remarks: The only occurrence of this species in the Antarctic is in the early Pliocene of the *Distephanus boliviensis* and *Dictyocha pseudofibula* zones.

Dictyocha pseudofibula (Schulz)
(Plate 7, Figures 8-11)

Distephanus speculum fa. *pseudofibula* Schulz, 1928, p. 262, 263, fig. 51a, b.

Dictyocha pseudofibula Tsumura, 1963, p. 55, pl. 11, fig. 1-3, pl. 24, fig. 2.

Dictyocha staurodon Ehrenberg*Dictyocha staurodon* Ehrenberg, 1844a, p. 70, 80.**Remarks:** In the present study, *Dictyocha staurodon* was only recovered from Site 266 (20-3, 60-62 cm).**Dictyocha variabilis (Hanna) n. comb.**
(Plate 7, Figures 12-15)*Dictyocha variabilis* Hanna, 1931, pl. D, fig. 8, pl. E, fig. 4-7.**Remarks:** This species is characterized by a five-sided basal ring with spines radiating from each of the five corners and by a convex apical bridge which is usually without apical windows. All specimens observed lack an apical window and a majority of those specimens examined from the type locality also lack an apical window. The predominance of specimens lacking an apical window suggests that the rarer specimens with a window may in fact be cannopilean variations. This fact, coupled with the species' presence in warm-water assemblages with a high percentage of *Dictyocha* species is considered ample reason for a generic reassessment.In the present study, *Dictyocha variabilis* is represented only rarely in the *Dictyocha frenguelli* Subzone of the early Oligocene *Dictyocha deflandrei* Zone. This species is also recorded in the late Eocene Kellogg, Kreyenhagen, and "Sidney Flat" shales (Mandra, 1968).Genus **DISTEPHANUS** Stöhr, 1880**Distephanus boliviensis (Frenguelli)**
(Plate 8, Figures 8, 9; Plate 9, Figures 1, 2)*Dictyocha boliviensis* Frenguelli, 1940, p. 44, fig. 4 (fide Loeblich et al., 1968, p. 83, pl. 9, fig. 3).*Distephanus boliviensis* Bukry and Foster, 1973, p. 827, pl. 4, fig. 1-3.**Remarks:** This particularly large species is characterized by an open apical ring, a six- or seven-sided basal ring with or without basal accessory spines, and equant radial spines. Typical forms are prominent in the early Pliocene and portions of the late Pliocene.Smaller forms, with two opposing basal ring spines longer than the other four, are referred to as *Distephanus* sp. cf. *D. boliviensis* in the occurrence charts. These forms have occurrences and abundances similar to those of *D. boliviensis*.Forms of this species from the *Dictyocha deflandrei* Zone of Site 274 are similar to Pliocene specimens of *D. boliviensis* in general skeletal form, but have a thicker skeleton which usually exhibits a more prominent microstructure of subparallel ridges. Early Oligocene forms of this species are referred to as *D. cf. D. boliviensis* in the occurrence charts.**Distephanus boliviensis var. binoculus n. comb.**
(Plate 8, Figures 6, 7)*Dictyocha boliviensis* f. *binoculus* Frenguelli, 1951, p. 276.*Cannopilus binoculus* Bukry and Foster, 1973, p. 825-826, pl. 1, fig. 1, 2.**Remarks:** This variety is characterized by equant distal spines on a six or seven-sided basal ring and by two apical windows. Basal accessory spines are usually present on each side of the basal ring. The variety differs from *Distephanus boliviensis* only by the presence of two apical windows. Abundant *D. boliviensis*, found associated with *D. boliviensis* var. *binoculus*, exhibit a high degree of skeletal variability in the apical apparatus. The skeletal variability of *D. boliviensis* and the restricted occurrence of this variety, within the geologic range of *D. boliviensis*, are, in the author's opinion, an argument in favor of considering these multiwindowed forms as varieties of *D. boliviensis*. In addition, the differences between the range of two-windowed forms and specimens with three to five windows is considered sufficient reason for maintaining separate variety names for specimens with a multiwindowed apical apparatus.**Distephanus boliviensis var. major (Frenguelli) n. comb.**
(Plate 8, Figures 1-5)*Dictyocha boliviensis* var. *major* Frenguelli, 1951, p. 277, fig. 3a-c.*Cannopilus major* Bukry and Foster, 1973, p. 826, pl. 1, fig. 4-7, pl. 7, fig. 4.**Remarks:** The present variety is characterized by equant distal spines on a six- or seven-sided basal ring and by three to five apical windows. Basal accessory spines are usually present on each side of the basal ring.**Distephanus crux (Ehrenberg)**
(Plate 9, Figures 3-9)*Distephanus crux* Ehrenberg, 1840 (fide Loeblich et al., 1968, p. 85, pl. 8, fig. 29-32); Ehrenberg, 1854, pl. 18, fig. 56, pl. 33 (XV), fig. 9.**Remarks:** Specimens of *Distephanus crux* from the early Oligocene at Site 274 exhibit a number of skeletal variations in basal ring size and shape, apical ring size, radial spine length, and ornamentation (see Plate 9, Figures 3-9). All skeletal variations are presently combined in occurrence tabulations as *D. crux* s.l. until further stratigraphic analysis of the various morphotypes is complete.In the Antarctic, rare to few *D. crux* occur in early Pliocene to late Miocene aged sediments; however, in the Oligocene it is a major component of the silicoflagellate assemblage.**Distephanus longispinus (Schulz)**
(Plate 9, Figure 10)*Distephanus crux* f. *longispina* Schulz, 1928, p. 256, fig. 44.*Distephanus longispinus* Bukry and Foster, 1973, p. 828, pl. 4, fig. 7, 8.**Distephanus polyactis (Ehrenberg)**
(Plate 10, Figures 12-17)*Dictyocha polyactis* Ehrenberg, 1839, p. 129.*Distephanus polyactis* Deflandre, 1932b, p. 501, fig. 40.*Distephanus polyactis* Dumitrica, 1973, p. 851-852, pl. 7, fig. 13, pl. 8, fig. 1-10.**Remarks:** *Distephanus polyactis* ranges from the upper *Distephanus speculum* B Zone throughout the *Distephanus speculum* A Zone. An acme of this species occurs in the upper *D. speculum* B Zone, where it becomes a dominant component of the assemblage. The number of radial spines present varies from 7 to 13, with the average number of radial spines being 8 or 9.**Distephanus speculum (Ehrenberg)**
(Plate 9, Figures 11, 12; Plate 10, Figures 1-3)*Distephanus speculum* Ehrenberg, 1839, p. 129.**Remarks:** This species exhibits a wide degree of intraspecific skeletal variability with basal ring spine lengths and apical ring diameters exhibiting the greatest and most frequent variability.**Distephanus speculum var. pentagonus Lemmermann**
(Plate 10, Figures 4-8)*Distephanus speculum* var. *pentagonus* Lemmermann, 1901, p. 264, pl. 11, fig. 19.**Remarks:** This species is found throughout the Pleistocene, Pliocene, and latest Miocene of most sites and rarely in the early Oligocene at Site 274. It is most common in intervals between the early Pliocene *Distephanus boliviensis* and *Dictyocha pseudofibula* zones.Specimens from the Site 274 early Oligocene *Dictyocha deflandrei* Zone have a similar skeletal shape but are recorded as *D. cf. D. speculum* because of their thicker and wider skeleton, wider apical ring, and usually conspicuous surface ornamentation of subparallel ridges.**Distephanus speculum var. pentagonus forma armatus Lemmermann**
(Plate 10, Figures 9, 10)*Distephanus speculum* var. *pentagonus* forma *armatus* Lemmermann, 1901, p. 264, pl. 11, fig. 20.**Remarks and measurements:** This form has a symmetric five-sided basal and apical ring and is differentiated from the type variety by the presence of one to three very prominent spines on the apical ring. Measurements are: Basal ring 20-25 μ wide, apical ring 10 μ wide and length of apical spines 5-10 μ .This species was found to occur abundantly at Site 266 between Samples 6-6, 120-122 cm and 7-3, 50-52 cm. Its acme serves as a useful datum in the late Pliocene, as it closely approximates the *Distephanus speculum* Zone B-*Distephanus boliviensis* Zone boundary.**Distephanus speculum var. pentagonus f. geminus n.f.**
(Plate 10, Figure 11)**Description and measurements:** Basal ring is pentagonal with straight sides, 15-25 μ long, which may or may not possess basal accessory spines. Two relatively low-standing apical rings are connected to the basal ring by five straight lateral rods. Five long, 10-15 μ , tapering

radial spines project on the plane of the basal ring or curve slightly abapically.

Occurrence: The stratigraphic occurrence of this new form is apparently restricted to early Pliocene sedimentary sequences, with a few specimens noted in the *Dictyocha pseudofibula* Zone at Site 274 and the *Distephanus boliviensis* and *Dictyocha aspera* var. *pygmaea*-*D. fibula* var. *pumila* zones at Site 266.

Type specimen: The holotype (Plate 10, Figure 11) will be deposited at the USNM. The type number has not yet been assigned but will be published in Contribution 41 of the Florida State University Sedimentological Research Laboratory.

***Distephanus speculum* var. *septenarius* (Ehrenberg)**

Dictyocha speculum var. *septenaria* Hovasse, 1946, p. 9.

Distephanus speculum var. *septenarius* Jorgensen, 1899, p. 50.

Genus MESOCENA Ehrenberg, 1843, emend. Deflandre, 1950

***Mesocena apiculata* (Schulz)**

(Plate 11, Figures 1-5)

Mesocena apiculata Deflandre, 1932b, p. 499, fig. 34, 35.

***Mesocena diodon* Ehrenberg**

(Plate 12, Figures 1-3)

Mesocena diodon Ehrenberg, 1844a, p. 71, 84 (*fide* Loeblich et al., 1968, p. 54, 128); Ehrenberg, 1854, pl. 33, fig. 18; Loeblich et al., 1968, pl. 27, fig. 4.

Mesocena crenulata var. *diodon* Lemmermann, 1901, p. 255, pl. 10, fig. 1, 2; Schulz, 1928, p. 236, fig. 1ab; Gemeinhardt, 1930, p. 26, fig. 10a, non lob; Deflandre, 1932a, fig. 4.

Mesocena elliptica diodon Dumitrica, 1972, p. 905, pl. 1, fig. 3.

Remarks: This circular to elongate elliptical species is usually 50-60 μ in length and has two, 2-10 μ , distal spines aligned with the major axes. The surface ornamentation is usually comprised of prominent transverse crests but may also have a pustulate appearance.

The present study agrees with Dumitrica's observation that forms meeting the present description have a short geologic range and occur independently or greatly outnumber the four-spined *Mesocena elliptica* forms. These reasons are considered to be sufficient to favor maintaining *M. diodon* as an independent taxon of specific or subspecific rank.

M. diodon has been recorded in *Eltanin* piston core stratigraphic sequences of the early Gilbert magnetic epoch, below event "c" (~4.65 m.y. B.P.) and also in a probable Epoch 5 (late Miocene) sequence. In this study *M. diodon* was only found in early Pliocene sections at Sites 266, 267B, and 269, with the exception of very rare occurrences in the late Miocene at Site 274. The general lack of late Miocene occurrences is in part due to very poor recovery of sediment of this age.

M. diodon has also been recorded from the middle and upper Miocene at Site 206 in the Tasman Basin and Site 33 in the northeastern Pacific (Dumitrica, 1973), the experimental Mohole drilling (Ling, 1972), and Sites 157-158 from the Panama Basin area (Bukry and Foster, 1973).

***Mesocena circulus* (Ehrenberg)**

(Plate 11, Figures 6, 8, 9)

Dictyocha circulus Ehrenberg, 1840, p. 208.

Mesocena circulus Ling, 1972, p. 175, 176, pl. 28, fig. 5, 6.

***Mesocena elliptica* Ehrenberg**

Remarks: *Mesocena elliptica* was rarely noted to occur in the lower Pliocene *Mesocena diodon* Zone at Site 266, the *Distephanus boliviensis* Zone of El 36-33 and 50-28, and *Dictyocha aspera* var. *pygmaea*-*D. fibula* var. *pumila* Zone of E 50-28.

Two and three-spined varieties occur abundantly in lower Pliocene *Eltanin* cores and in the *Distephanus boliviensis* and *Dictyocha aspera* var. *pygmaea*-*D. fibula* var. *pumila* zones at Site 266. These specimens are unlike *M. diodon* and are very likely two and three-spined varieties of *M. elliptica*. In the present paper such forms are considered as *Mesocena cf. elliptica*.

***Mesocena oamaruensis* Schulz**

(Plate 12, Figure 11)

Mesocena oamaruensis Schulz, 1928, p. 240, fig. 10a, b; Gemeinhardt, 1930, p. 34, fig. 20; Deflandre, 1932a, fig. 11; Tsumura, 1959, p. 56,

pl. 2, fig. 22; Ling, 1972, p. 179, 180, pl. 29, fig. 8-10; Glezer, 1966, p. 285, pl. 28, fig. 3.

Corbisema oamaruensis Frenguelli, 1940, p. 64, fig. 13c.

Not *Mesocena oamaruensis* Stradner, 1961, p. 89, fig. 30, 31; Tsumura, 1963, p. 43, pl. 7, fig. 2; pl. 21, fig. 12; Bachmann, 1964, pl. 4, fig. 37.

Remarks: Specimens assigned to this species have a smooth, roundly triangular basal ring, without basal or accessory spines. Most specimens also have a complete lumen without septa.

Rare to common abundances of this species occur throughout most of the early Oligocene at Site 274 between Cores 21 and 34. It also occurs more rarely in the late Oligocene Cores 4 and 5 at Site 267. *Mesocena oamaruensis* is known to occur elsewhere: in late Eocene samples from the Oamaru Diatomite of New Zealand, the Kellogg and Sidney shales of California (Ling, 1972), and the Oligocene of the Soviet Union (Glezer, 1966). Its total stratigraphic range as presently known is, thus, late Eocene through late Oligocene.

***Mesocena oamaruensis* var. *quadrangula* Schulz**

(Plate 12, Figure 7)

Mesocena oamaruensis var. *quadrangula* Schulz, 1928, p. 240, fig. 12.

Remarks: In the present study, only rare occurrences of the present species were observed in the late Eocene at Site 264 (2, CC) and in the late Oligocene *Naviculopsis biapiculata* Zone at Site 267 (4-4, 120-122 cm and 4-6, 120-122 cm).

***Mesocena pappi* Bachmann**

(Plate 12, Figure 8)

Mesocena pappi Bachmann, 1962, p. 380, pl. 1, fig. 1-9; Ling, 1973, p. 753, pl. 3, fig. 5, 6.

Remarks: This rather rare species was only recovered from the three following early Miocene samples, Site 266 (19-1, 60-62 cm and 20-3, 60-62 cm) and Site 272 (35, CC). This species was originally described from the Eocene Kreyenhagen Shale of California and was recorded in the early Miocene of Site 186 (Ling, 1973), which is located in the North Pacific.

Genus NAVICULOPSIS Frenguelli, 1940

***Naviculopsis biapiculata* (Lemmermann)**

(Plate 12, Figures 9-11)

Dictyocha navicula var. *biapiculata* Lemmermann, 1901, p. 258, pl. 10, fig. 14, 15.

Naviculopsis biapiculata Ling, 1972, p. 181, pl. 30, fig. 1-4.

***Naviculopsis constricta* (Schulz)**

Dictyocha navicula var. *biapiculata* fa. *constricta* Schulz, 1928, p. 246, fig. 21.

Naviculopsis biapiculata var. *constricta* Glezer, 1966, p. 257, 258, pl. 17, fig. 4.

Naviculopsis constricta Ling, 1972, p. 183-184, pl. 30, fig. 5-8.

Remarks: The present taxa was observed from a single, late Eocene sample (2, CC) from Site 264.

***Naviculopsis lata* (Deflandre)**

Dictyocha biapiculata var. *lata* Deflandre, 1932b, p. 500, fig. 300, 301. *Dictyocha lata* Bachmann, 1970, p. 278, 279, pl. 2, fig. 1-20; pl. 3, fig. 1-15; Ling, 1972, p. 185, 186, pl. 30, fig. 12-16.

***Naviculopsis navicula* (Ehrenberg)**

(Plate 13, Figure 1)

Dictyocha navicula Ehrenberg, 1839, p. 129; Ehrenberg, 1854, pl. 20, fig. 43; Haeckel, 1887, p. 1559; Lemmermann, 1901, pl. 10, fig. 12, 13; Lemmermann, 1903, p. 27, fig. 90; Schulz, 1928, p. 243, fig. 166; Gemeinhardt, 1930, p. 35, 36, fig. 22.

Dictyocha ponticuliculus Ehrenberg, 1844c, p. 267; Bailey, 1845, p. 328, pl. 4, fig. 21.

Naviculopsis navicula Deflandre, 1950a, p. 77, fig. 241, 243; Stradner, 1961, p. 89, fig. 47; Bachmann, 1970, fig. 2b; Ling, 1972, p. 186, 187, pl. 30, fig. 17-19, pl. 31, fig. 1.

Not *Dictyocha navicula* Glezer, 1966, p. 233, 235, pl. 9, fig. 4, 5.

***Naviculopsis navicula* var. *naviculopsis* (Deflandre)**

(Plate 13, Figures 2, 3)

Dictyocha navicula var. *naviculopsis* Tsumura, 1963, p. 44, pl. 7, fig. 5.

Naviculopsis regularis (Carnevale)
(Plate 13, Figures 4-7)

- Dictyocha regularis* Carnevale, 1908, p. 35, pl. 4, fig. 28.
Dictyocha ausonia var. *regularis* Deflandre, 1950a, p. 68-69, fig. 198 (only).
Naviculaopsis regularis Ling, 1972, p. 188, 189, pl. 31, fig. 3-5.

Naviculopsis robusta Deflandre
(Plate 13, Figures 8-12)

- Naviculopsis robusta* Deflandre, 1950c, p. 202, fig. 227-230; Glezer, 1966, p. 273, pl. 16, fig. 1, pl. 33, fig. 3-6.

Naviculopsis trispinosa (Schulz)
(Plate 13, Figures 13, 14)

- Dictyocha navicula* var. *trispinosa* Schulz, 1928, p. 246-247, fig. 23a,b; Gemeinhardt, 1930, p. 40, fig. 27; Deflandre, 1932a, fig., 24; Tsumura, 1963, p. 46, pl. 8, fig. 4-6.
Naviculopsis biapiculata fa. *trispinosa* Frenguelli, 1940, fig. 11e.
Naviculopsis trispinosa Glezer, 1966, p. 258, 259, pl. 17, fig. 7; Ling, 1972, p. 190, pl. 31, fig. 7, 8.

Remarks: *Naviculopsis trispinosa* was found to be rare in the late Oligocene *Naviculopsis biapiculata* Zone at Site 267 (Cores 4 and 5) and rare or abundant throughout the early Oligocene *Dictyocha deflandrei* Zone at Site 274 (Cores 20-34). An acme of this species occurs in the *Dictyocha deflandrei* Zone (Core 25) that provides a useful datum within the *Dictyocha frenguelli* Subzone.

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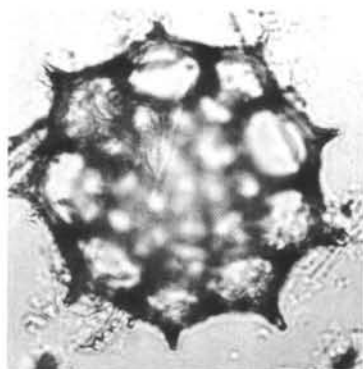
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PLATE 1

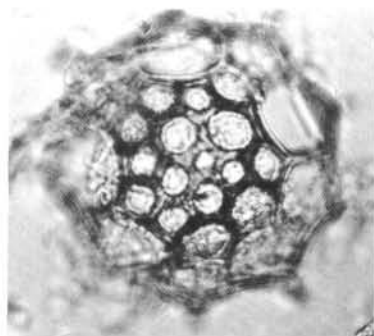
Silicoflagellate photomicrographs; 615×

- Figures 1-9 *Cannopilus antarcticus* n. sp.
1. Sample 266-17-5, 65-67 cm, low focus.
 2. Same, high focus.
 3. Sample 266-17-5, 65-67 cm, low focus.
 4. Same, high focus.
 5. Sample 266-17-5, 65-67 cm, low focus.
 6. Same, high focus.
 7. Sample 266-17-5, 65-67 cm, low focus.
Holotype.
 8. Same, intermediate focus.
 9. Same, high focus.

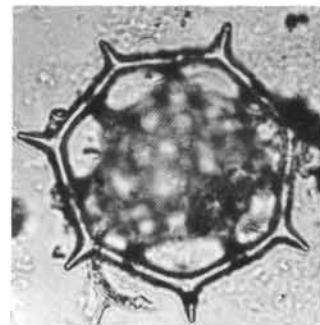
PLATE 1



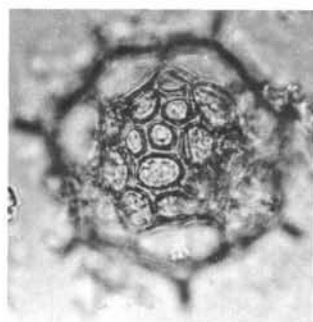
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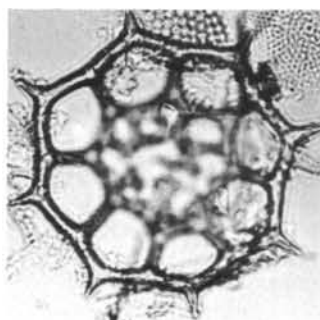
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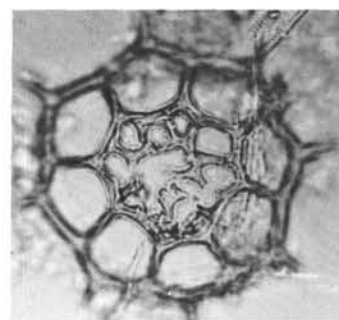
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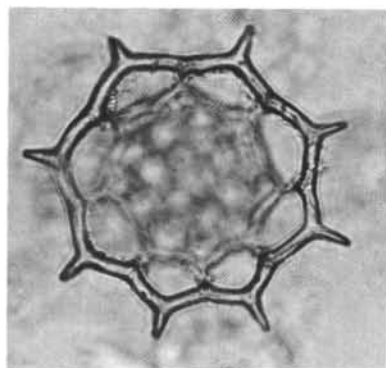
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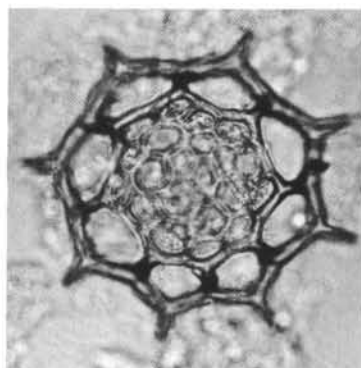
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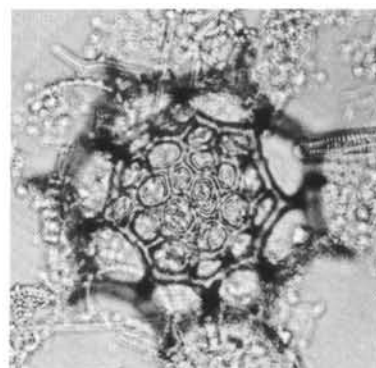
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PLATE 2

Silicoflagellate photomicrographs; 615×
(except Figure 1 which is 1395×)

Figures 1-3 *Cannopilus hemisphericus* (Ehrenberg).

1. Sample 266-8-2, 120-122 cm.
2. Sample 266-17-5, 65-67 cm.
3. Sample 266-17-5, 65-67 cm.

Figures 4-11 *Corbisema apiculata* (Lemmermann).

4. Sample 274-23-5, 80-82 cm.
5. Sample 274-23-5, 80-82 cm.
6. Sample 274-23-2, 30-32 cm.
7. Sample 274-23-5, 80-82 cm.
8. Sample 274-21-6, 30-32 cm.
9. Sample 274-23-2, 30-32 cm.
10. Sample 274-21-6, 30-32 cm.
11. Sample 274-23-5, 80-82 cm.

Figures 12-15 *Corbisema hastata* (Lemmermann).

12. Sample 274-28-1, 30-32 cm.
13. Sample 274-23-5, 80-82 cm.
14. Sample 274-20-1, 30-32 cm.
15. Sample 274-21-2, 30-32 cm.

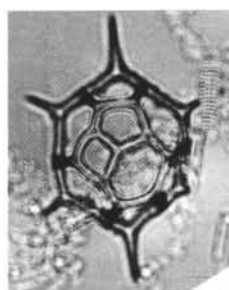
PLATE 2



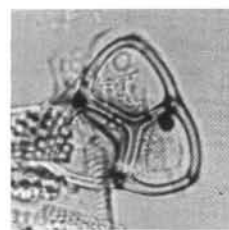
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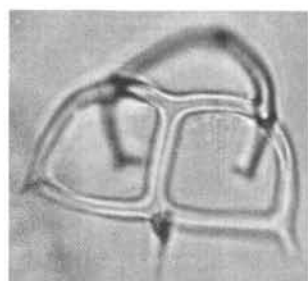
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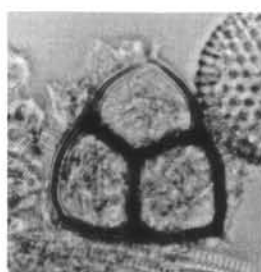
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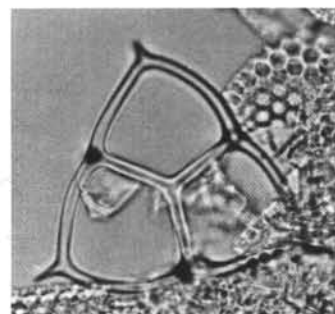
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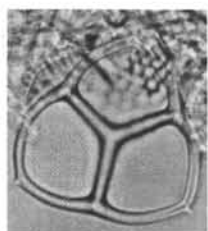
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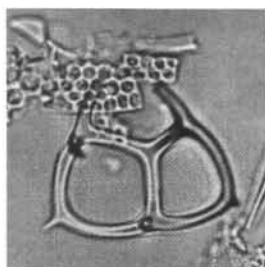
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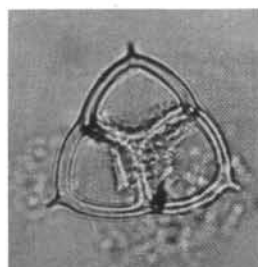
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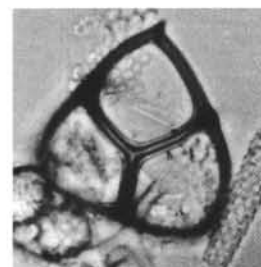
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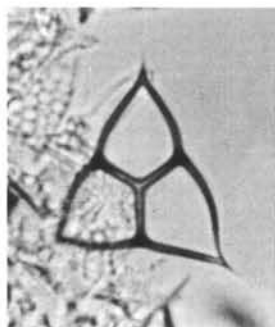
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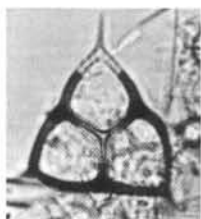
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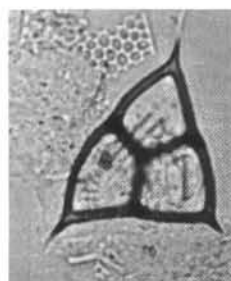
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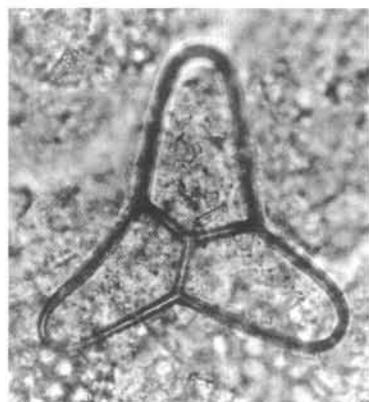
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PLATE 3

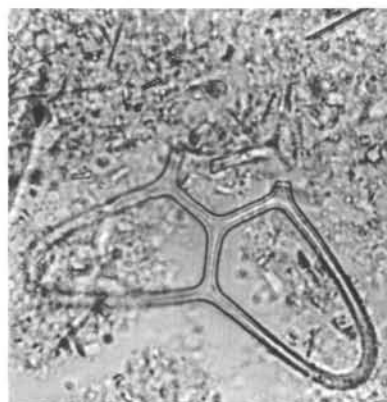
Silicoflagellate photomicrographs; 615X.

- Figures 1, 2 *Corbisema archangeliskiana* (Schulz).
1. Sample 267-4-4, 120-122 cm.
2. Sample 267-4-4, 120-122 cm.
- Figures 3-6 *Corbisema triacantha* Ehrenberg.
3. Sample 274-24-1, 58-60 cm.
4. Sample 274-23-3, 30-32 cm.
5. Sample 266-17-4, 60-62 cm.
6. Sample 266-17-5, 65-67 cm.
- Figure 7 *Corbisema* ? sp.
Sample 274-27-3, 130-132 cm.
- Figure 8 *Corbisema triacantha* var. *flexuosa* Stradner.
Sample 266-20-3, 60-62 cm.
- Figure 9 *Corbisema spinosa* Deflandre.
Sample 274-26-6, 30-32 cm.
- Figures 10, 11 *Dictyocha aspera* (Lemmermann).
10. Sample E 38-8, 480-482 cm.
11. Sample 269-8-4, 45-47 cm.

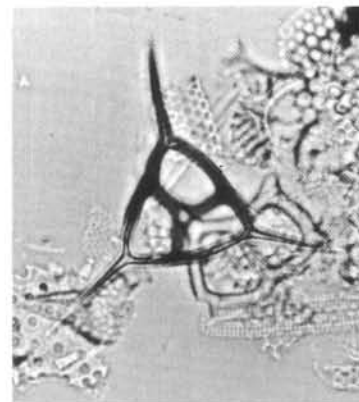
PLATE 3



1



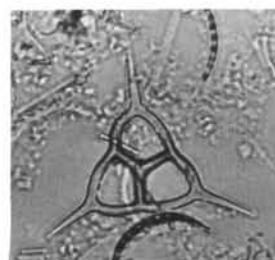
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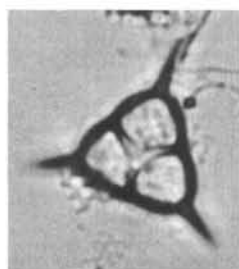
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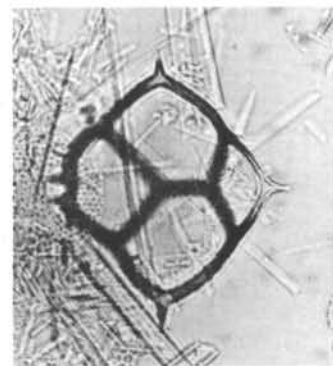
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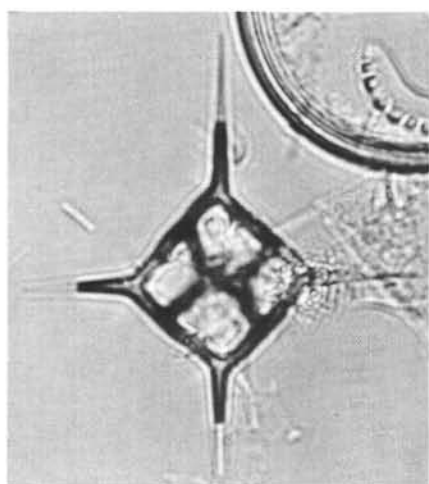
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PLATE 4

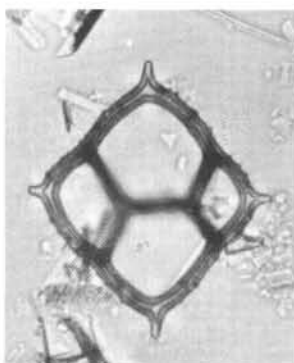
Silicoflagellate photomicrographs; 615×
(except Figures 7-9 which are 920×).

- Figures 2,5 *Dictyocha aspera* (Lemmermann).
2. Sample 269-8-3, 120-122 cm.
5. E 38-8, 400-402 cm.
- Figures 1,3,4,6 *Dictyocha aspera* var. *pygmaea* n. var.
1. E 38-8, 400-402 cm.
3. E 38-8, 440-442 cm.
4. E 50-28, 400-402 cm. Holotype.
6. E 50-28, 410-412 cm.
- Figures 7-9 *Dictyocha deflandrei* Frenguelli
7. Sample 274-25-1, 130-132 cm.
8. Sample 274-23-5, 80-82 cm.
9. Sample 274-33-3, 30-32 cm.

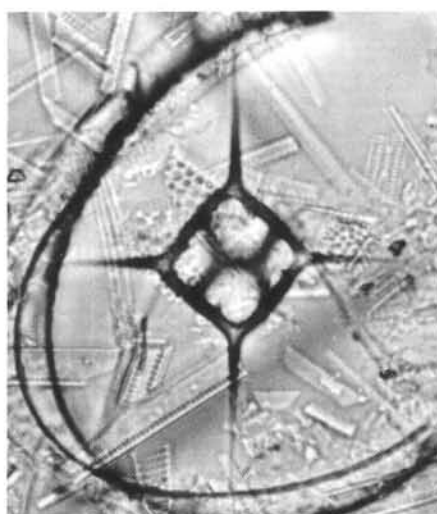
PLATE 4



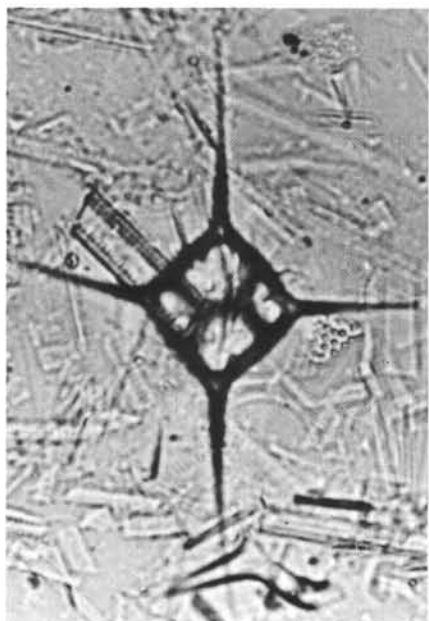
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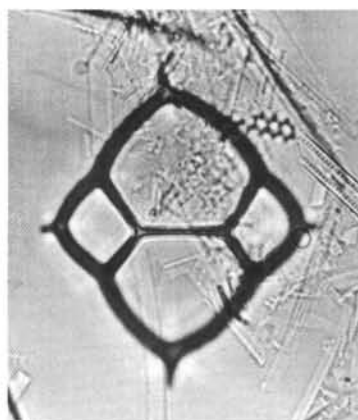
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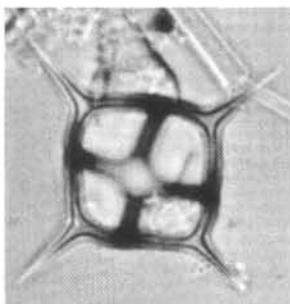
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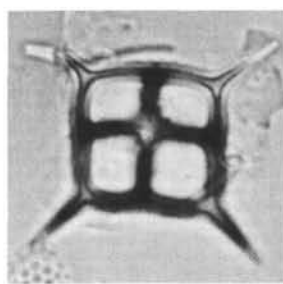
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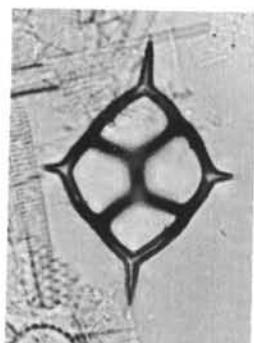
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PLATE 5

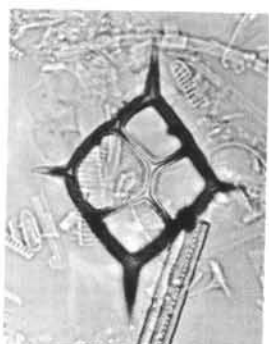
Silicoflagellate photomicrographs; 820×
(except Figures 1-4 which are 615×).

- Figures 1-4 *Dictyocha fibula* Ehrenberg.
E 38-8, 460-462 cm.
- Figures 5-10 *Dictyocha fibula* var. *pumila* n. var.
5. 50-28, 400-402 cm, low focus. Holotype.
6. Same, high focus.
7. E 50-28, 415-417 cm.
8. E 38-8, 440-442 cm, low focus.
9. Same, high focus.
10. E 50-28, 400-402 cm.

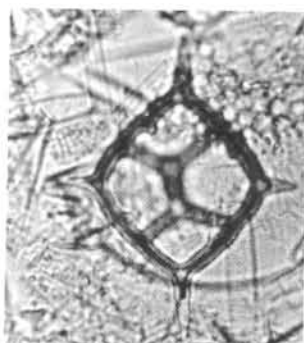
PLATE 5



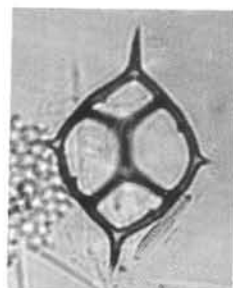
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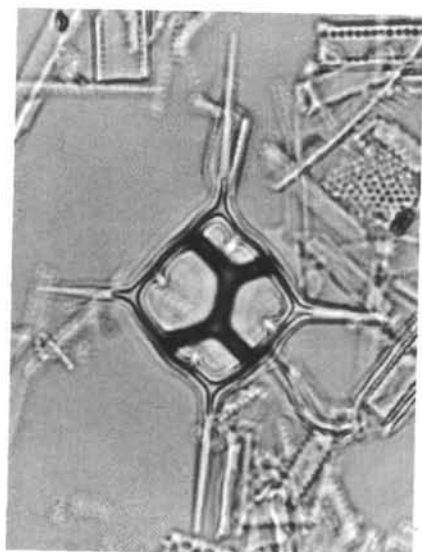
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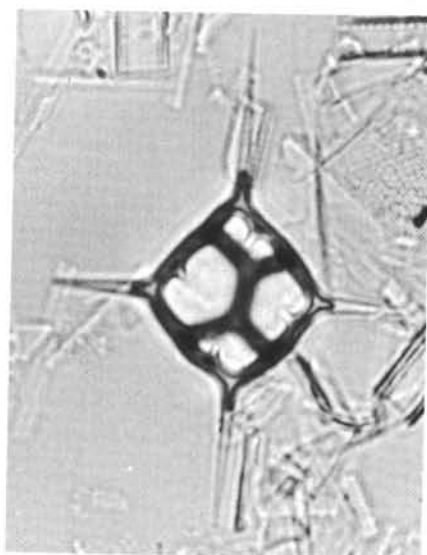
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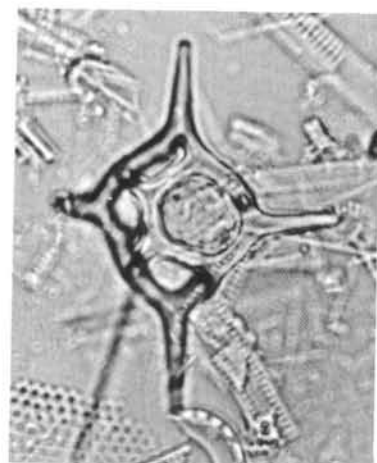
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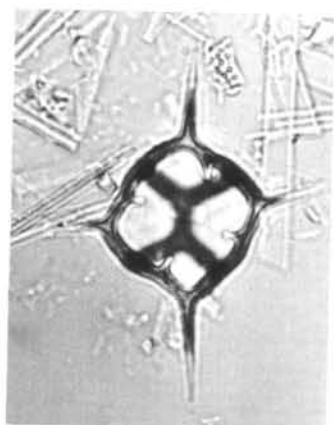
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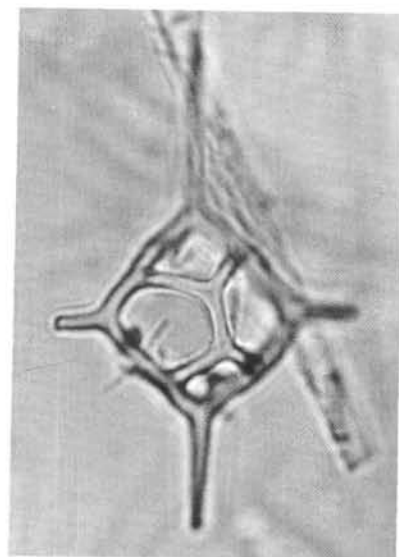
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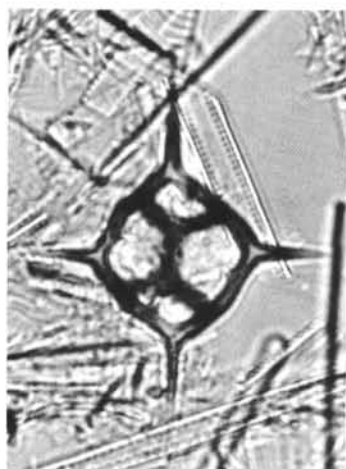
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PLATE 6

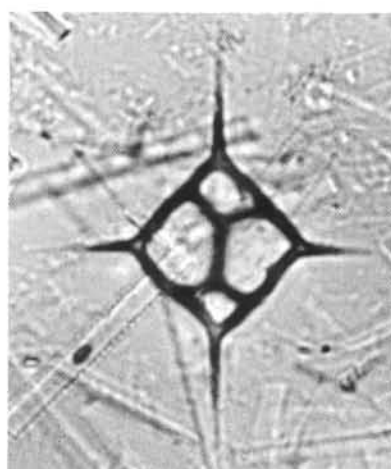
Silicoflagellate photomicrographs.

- Figures 1,2 *Dictyocha fibula* var. *pumila* n. var.
1. E 38-8, 400-402 cm, $\times 1025$.
2. E 50-28, 415-417 cm, $\times 1025$.
- Figures 3-9 *Dictyocha frenguellii* Deflandre.
3. Sample 274-21-6, 30-32 cm, $\times 820$.
4. Sample 274-21-6, 30-32 cm, $\times 820$.
5. Sample 274-20-1, 30-32 cm, $\times 1025$.
6. Sample 274-24-3, 30-32 cm, $\times 1025$.
7. Sample 274-30-6, 30-32 cm, $\times 1025$.
8. Sample 274-22-4, 30-32 cm, $\times 820$.
9. Sample 274-27-4, 30-32 cm, $\times 1025$.
- Figures 10,11 *Dictyocha hexacantha* Schulz.
10. Sample 274-28-5, 30-32 cm, $\times 1025$.
11. Sample 274-28-5, 30-32 cm, $\times 820$.

PLATE 6



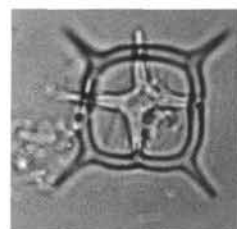
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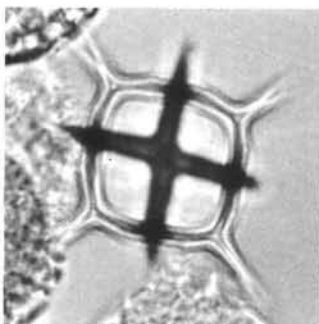
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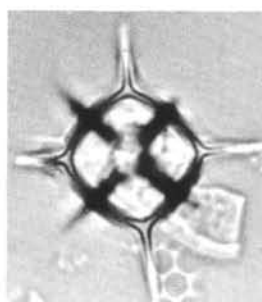
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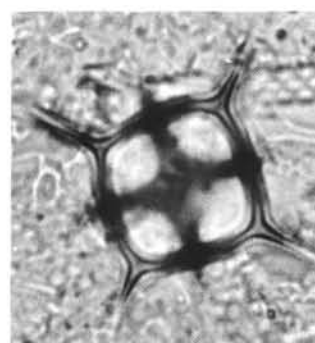
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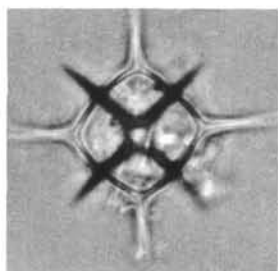
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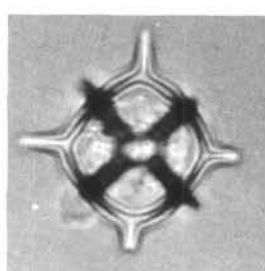
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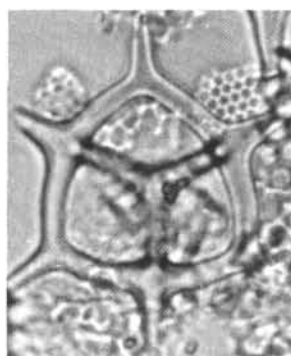
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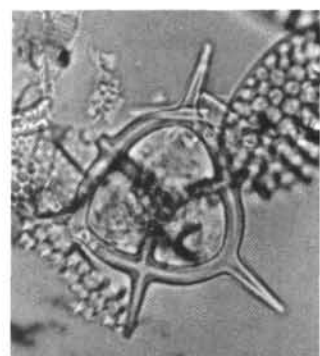
8



9



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11

PLATE 7

Silicoflagellate photomicrographs.

- Figures 1-5 *Dictyocha mutabilis* Deflandre.
Sample 266-13-5, 60-62 cm, $\times 615$.
- Figures 6,7 *Dictyocha pentagona* (Schulz).
6. Sample 266-8-5, 45-57 cm, $\times 1025$.
7. Sample 266-8-4, 120-122 cm, $\times 1025$.
- Figures 8-11 *Dictyocha pseudofibula* (Schulz).
8. Sample 266-8-6, 125-127 cm, $\times 615$.
9. Sample 274-11-4, 90-92 cm, $\times 615$.
10. Sample 266-9-2, 30-32 cm, $\times 615$.
11. Sample 274-11-2, 130-132 cm, $\times 615$.
- Figures 12-15 *Dictyocha variabilis* (Hanna).
12. Sample 274-24-3, 30-32 cm, high focus, $\times 1025$.
13. Same, low focus, $\times 1025$.
14. Sample 266-18-1, 63-65 cm, $\times 1025$.
15. Sample 274-24-1, 58-60 cm, $\times 1025$.

PLATE 7



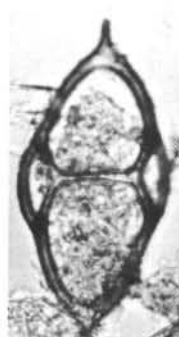
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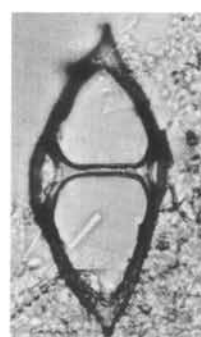
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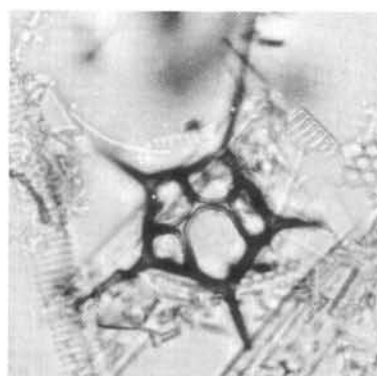
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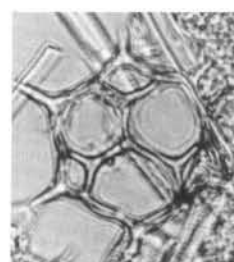
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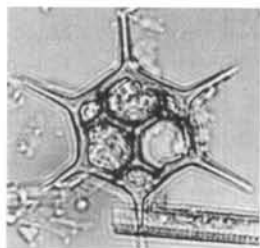
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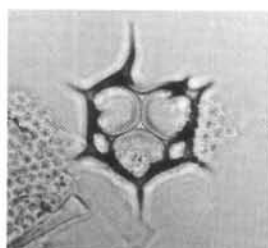
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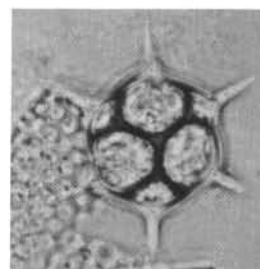
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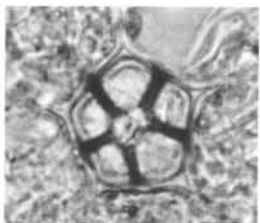
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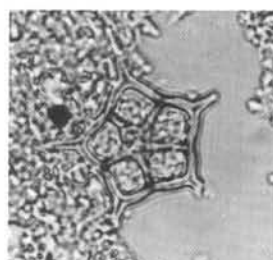
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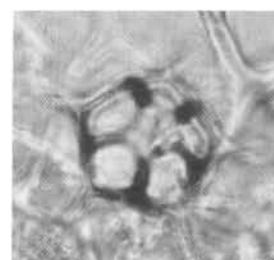
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13



14



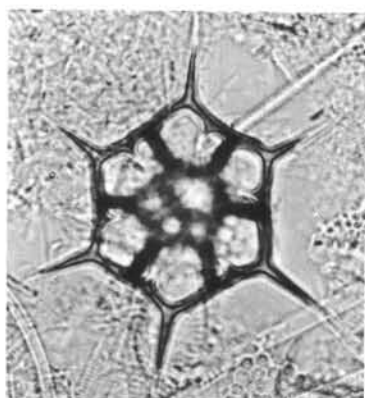
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PLATE 8

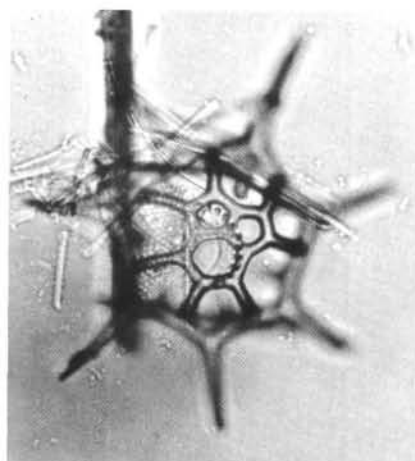
Silicoflagellate photomicrographs; 615 \times .

- Figures 1-5 *Distephanus boliviensis* var. *major* (Frenguelli).
1. E 50-28, 160-162 cm.
2. Sample 266-6-6, 120-122 cm, high focus.
3. Same, low focus.
4. E 38-7, 340-342 cm, low focus.
5. Same, high focus.
- Figures 6,7 *Distephanus boliviensis* var. *binoculus* (Frenguelli).
6. E 50-28, 160-162 cm.
7. E 38-8, 540-542 cm.
- Figure 8 *Distephanus* sp. cf. *D. boliviensis* (Frenguelli).
E 50-28, 300-302 cm.
- Figure 9 *Distephanus boliviensis* (Frenguelli).
Sample 274-11-4, 90-92 cm.

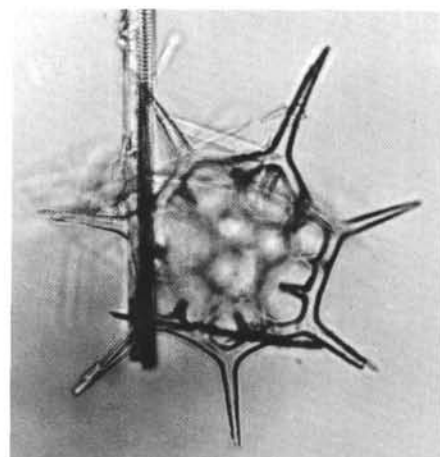
PLATE 8



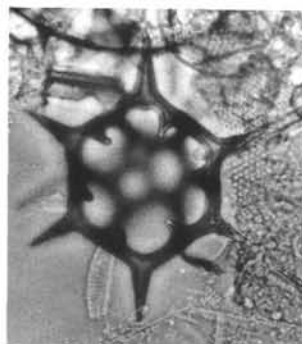
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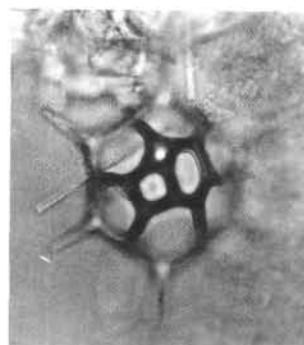
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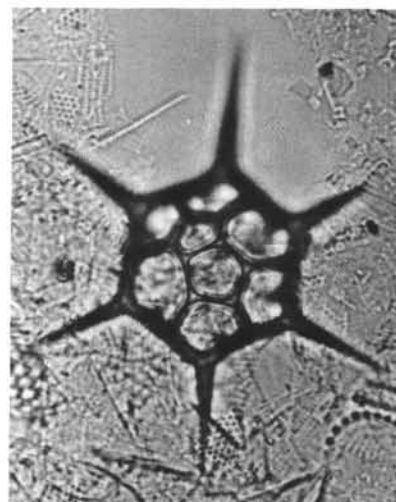
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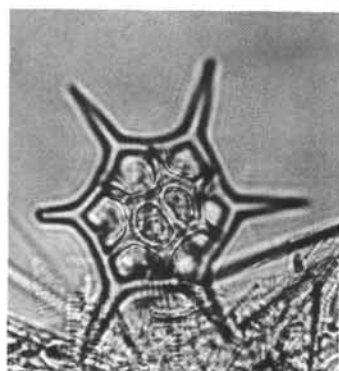
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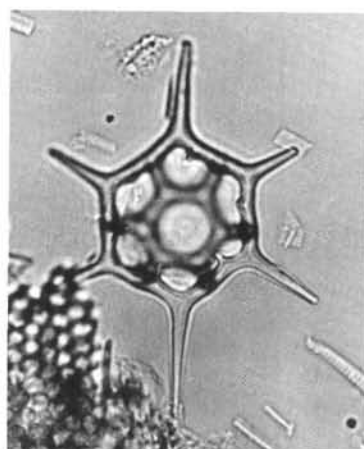
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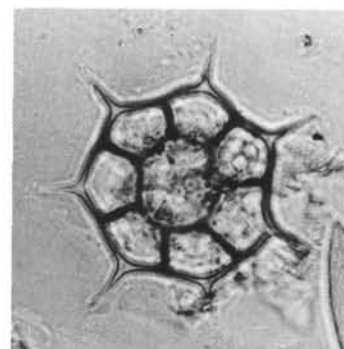
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7



8



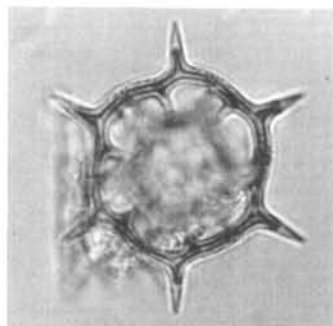
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PLATE 9

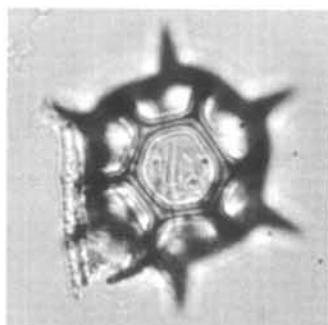
Silicoflagellate photomicrographs; 615 \times .

- Figures 1,2 *Distephanus* cf. *D. boliviensis*.
1. Sample 274-23-5, 80-82 cm, low focus.
2. Same, high focus.
- Figures 3-9 *Distephanus crux* (Ehrenberg).
3. Sample 274-20-1, 30-32 cm.
4. Sample 274-25-4, 80-82 cm.
5. Sample 274-24-1, 58-60 cm.
6. Sample 274-24-1, 58-60 cm.
7. Sample 266-22-2, 60-62 cm.
8. Sample 274-28-1, 30-32 cm.
9. Sample 266-14-3, 60-62 cm.
- Figure 10 *Distephanus longispinus* (Schulz).
Sample 266-17-1, 140-142 cm.
- Figures 11,12 *Distephanus speculum* (Ehrenberg).
11. Sample 266-4-3, 100-102 cm.
12. Sample 266-4-2, 60-62 cm.

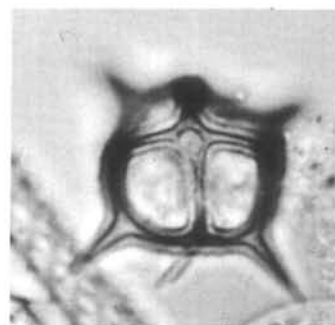
PLATE 9



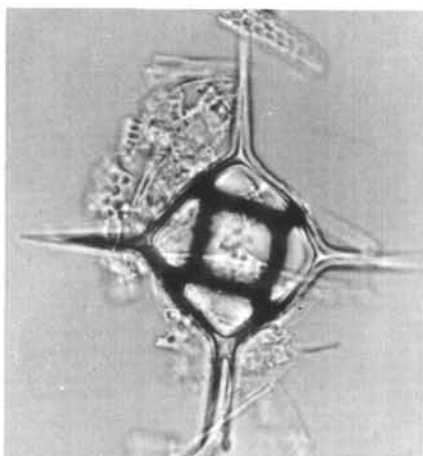
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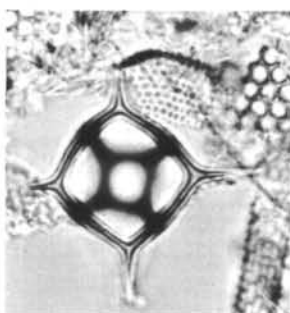
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3



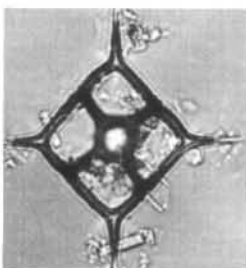
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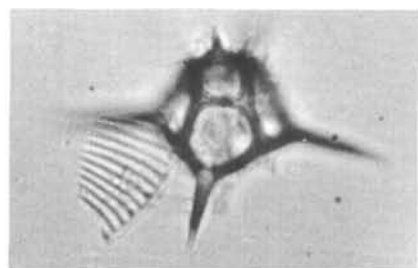
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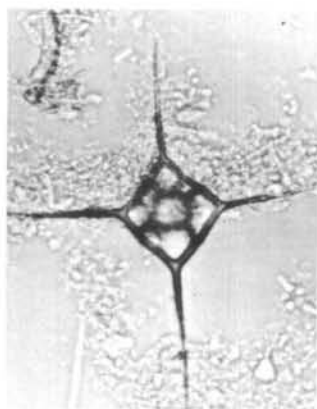
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7



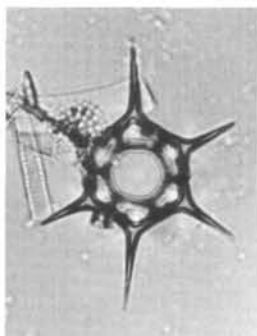
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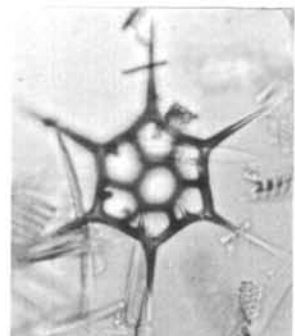
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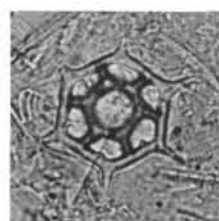
12

PLATE 10

Silicoflagellate photomicrographs; 615×
(except Figure 9 which is 920×).

- Figures 1-3 *Distephanus speculum* (short-spined) (Ehrenberg).
1. Sample 274-1-3, 30-32 cm.
2. Sample 269-1-1, 90-92 cm.
3. Sample 269-1-2, 90-92 cm.
- Figures 4-7 *Distephanus speculum* var. *pentagonus* Lemmermann.
4. Sample 266-11-3, 134-136 cm.
5. Sample 266-11-3, 134-136 cm.
6. Sample 266-13-5, 60-62 cm.
7. Sample 274-11-4, 40-42 cm.
- Figure 8 *Distephanus* cf. *D. speculum* var. *pentagonus*.
Sample 274-24-2, 30-32 cm.
- Figures 9,10 *Distephanus speculum* var. *pentagonus* f. *armata* Lemmermann.
9. Sample 266-6-6, 120-122 cm, ×920.
10. Sample 266-6-6, 120-122 cm.
- Figure 11 *Distephanus speculum* var. *pentagonus* f. *geminus*.
Sample 274-11-4, 40-42 cm. Holotype.
- Figures 12-17 *Distephanus polyactis* (Ehrenberg).
Sample 266-4-2, 60-62 cm.

PLATE 10



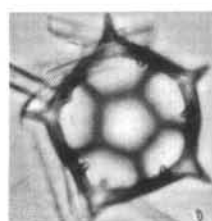
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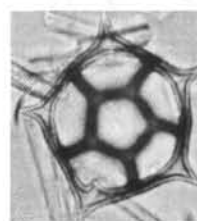
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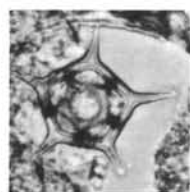
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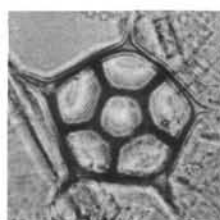
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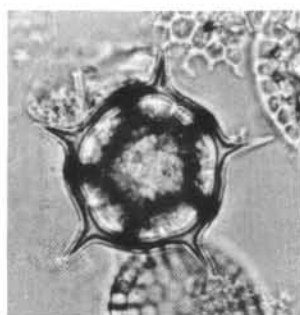
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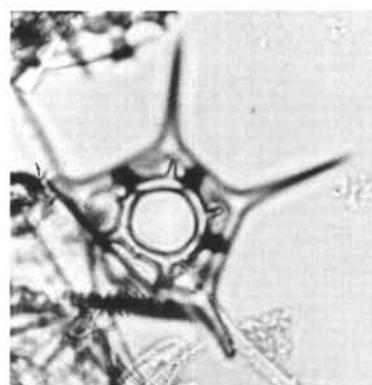
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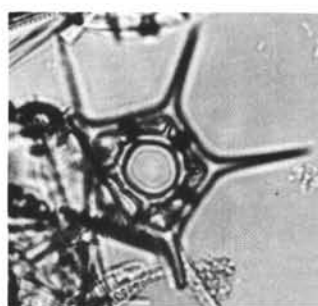
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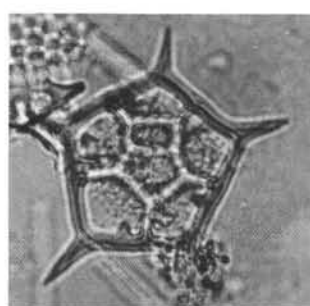
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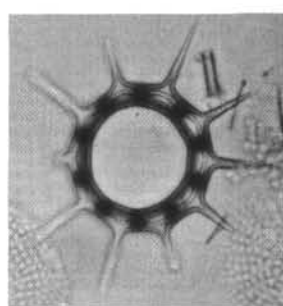
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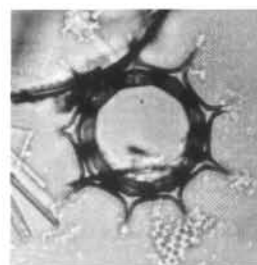
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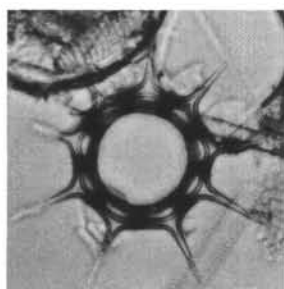
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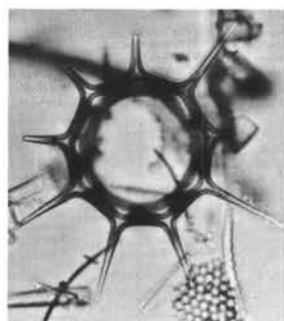
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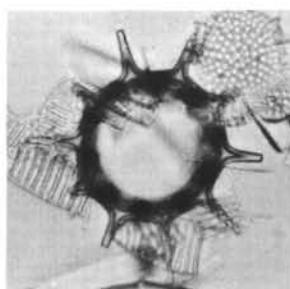
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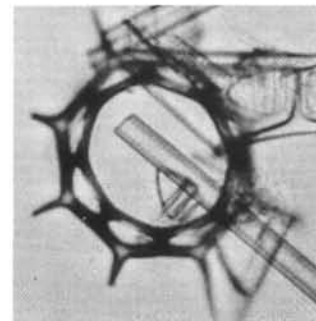
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15



16



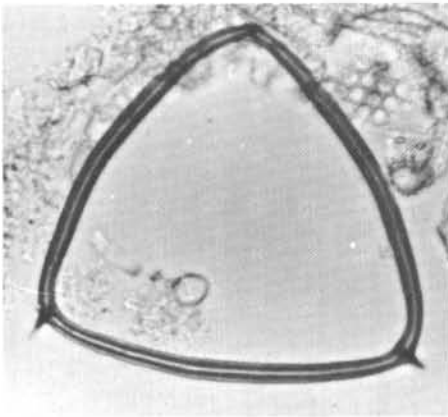
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PLATE 11

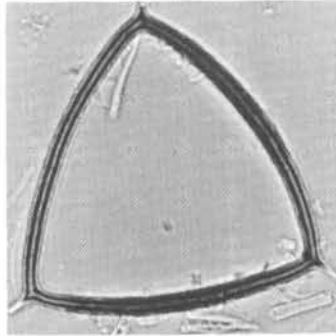
Silicoflagellate photomicrographs; 615 \times .

- Figures 1-5 *Mesocena apiculata* (Schulz).
1. Sample 274-26-1, 30-32 cm.
2. Sample 274-24-3, 30-32 cm.
3. Sample 274-24-3, 30-32 cm.
4. Sample 274-23-5, 80-82 cm.
5. Sample 274-24-3, 30-32 cm.
- Figures 6,8,9 *Mesocena circulus* Ehrenberg.
6. Sample 274-12-4, 140-142 cm.
8. Sample 266-11-2, 60-62 cm, high focus.
9. Same, low focus.
- Figure 7 *Mesocena* cf. *circulus* Ehrenberg.
Sample 266-11-2, 60-62 cm.

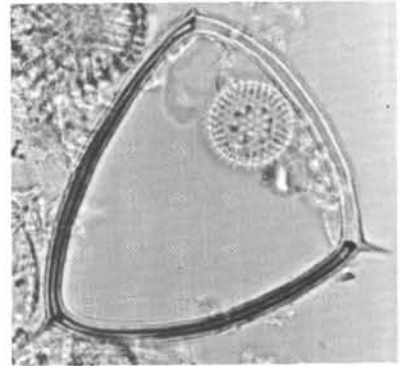
PLATE 11



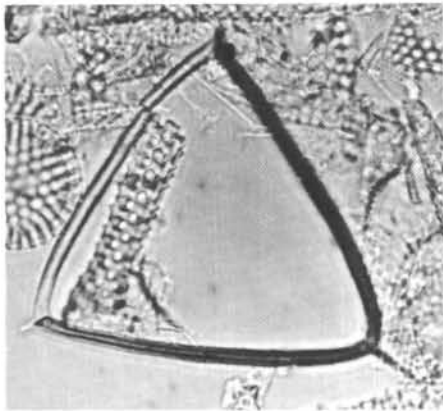
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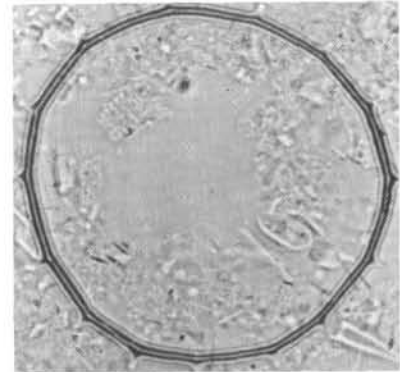
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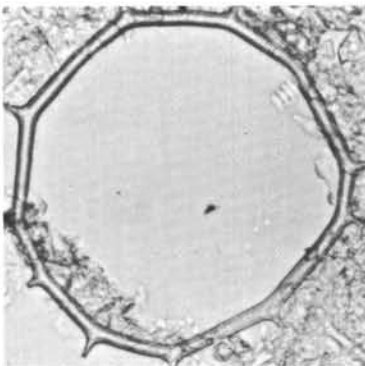
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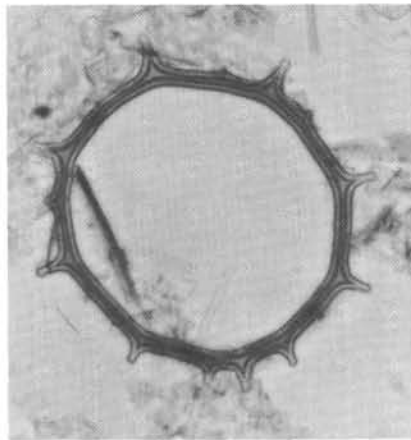
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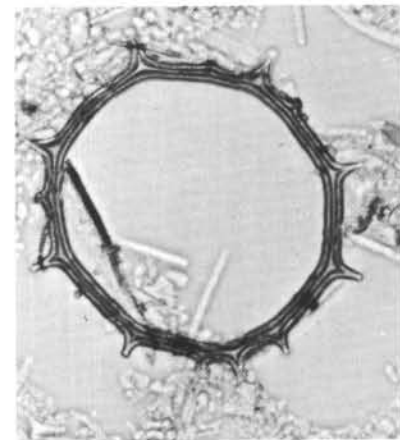
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PLATE 12

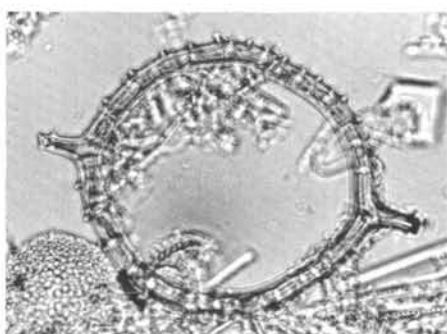
Silicoflagellate photomicrographs; 615 \times .

- Figures 1-3 *Mesocena diodon* Ehrenberg.
1. Sample 266-8-4, 120-122 cm.
2. Sample 266-9-1, 89-91 cm.
3. Sample 266-9-1, 89-91 cm.
- Figures 4, 5 *Mesocena* cf. *elliptica*.
4. Sample 266-7-5, 45-47 cm.
5. Sample 266-5-5, 130-132 cm.
- Figure 6 *Mesocena oamaruensis* Schulz.
Sample 274-22-5, 30-32 cm.
- Figure 7 *Mesocena oamaruensis* var. *quadrangula* (Schulz).
Sample 266-9-2, 30-32 cm.
- Figure 8 *Mesocena pappi* Bachmann.
Sample 266-19-2, 60-62 cm.
- Figures 9-11 *Naviculopsis biapiculata* (Lemmermann).
9. Sample 264-2, CC.
10. Sample 267-4-4, 120-122 cm, low focus.
11. Same, high focus.

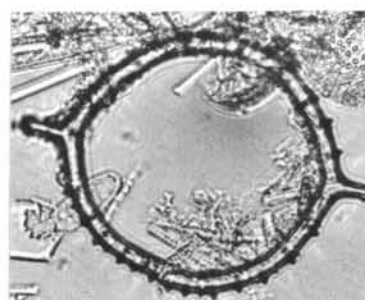
PLATE 12



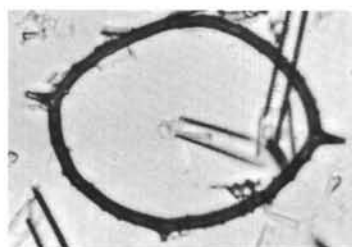
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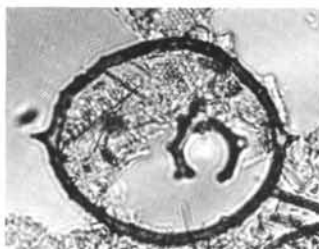
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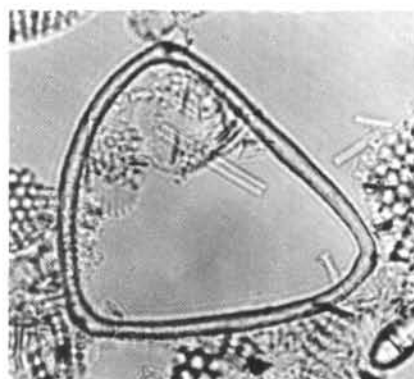
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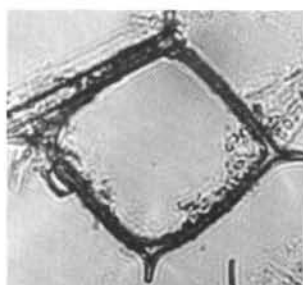
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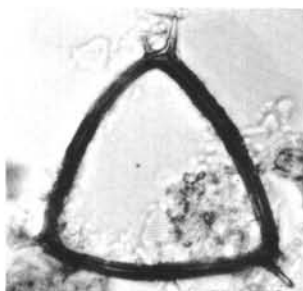
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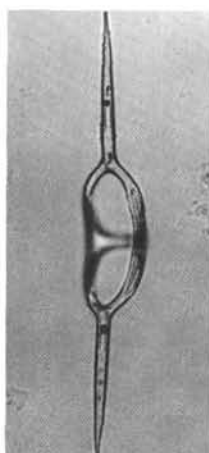
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7



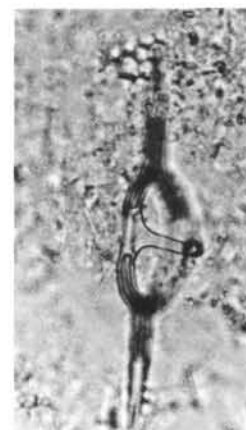
8



9



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11

PLATE 13

Silicoflagellate photomicrographs; 615 \times .

- Figure 1 *Naviculopsis navicula* (Ehrenberg).
Sample 266-21-2, 60-62 cm.
- Figures 2, 3 *Naviculopsis navicula* var. *naviculopsis* (Deflandre).
2. Sample 266-21-2, 60-62 cm.
3. Sample 266-21-2, 60-62 cm.
- Figures 4-7 *Naviculopsis regularis* (Carnevale).
4. Sample 266-22-2, 60-62 cm.
5. Sample 266-18-3, 60-62 cm.
6. Sample 266-22-2, 60-62 cm.
7. Sample 274-24-1, 58-60 cm.
- Figures 8-12 *Naviculopsis robusta* Deflandre.
8. Sample 266-22-1, 60-62 cm.
9. Sample 266-22-1, 60-62 cm.
10. Sample 266-22-1, 60-62 cm.
11. Sample 266-22-3, 60-62 cm.
12. Sample 266-22-2, 60-62 cm.
- Figures 13, 14 *Naviculopsis trispinosa* (Schulz).
13. Sample 274-25-1, 130-132 cm.
14. Sample 274-25-1, 130-132 cm.

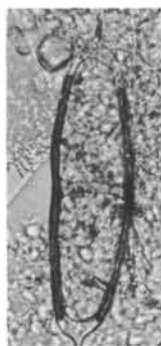
PLATE 13



1



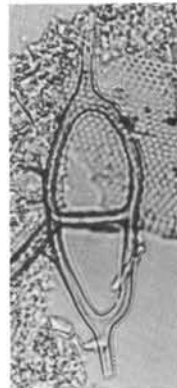
2



3



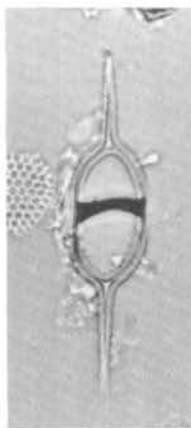
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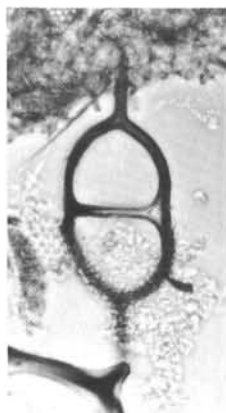
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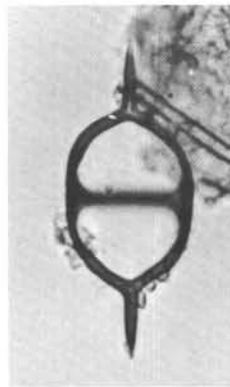
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7



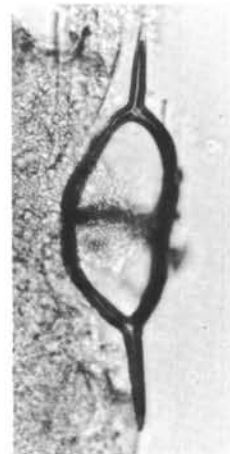
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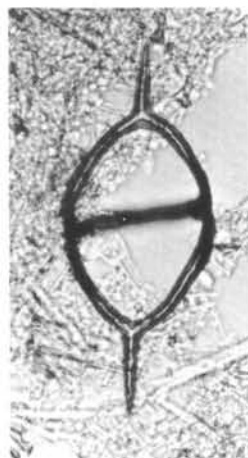
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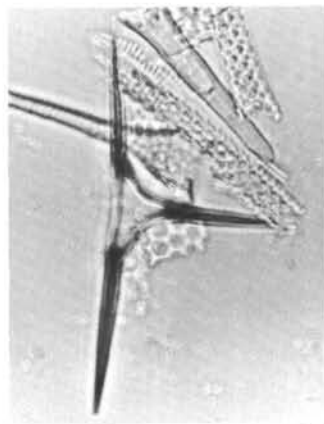
10



11



12



13



14