27. SILICOFLAGELLATES AND EBRIDIANS FROM LEG 19[1]

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INTRODUCTION

During Leg 19 of the Deep Sea Drilling Project aboard the D/V *Glomar Challenger*, eleven sites were drilled: three sites in the northeastern Pacific, two sites in the northwestern Pacific, and six sites in the Bering Sea (five in the Aleutian Basin and one in the Kamchatka Basin). These localities are shown in Figure 1 and their coordinates are listed in Table 1.

Thick sequences of Neogene sediments containing silicoflagellates and ebridians were recovered. Abundance and consistency of occurrence of these fossils were exceeded only by diatoms. Although pre-Miocene sediments were recovered from at least two sites, 183 and 192, no silicoflagellates or ebridians were found in the sediments.

Previously, similar investigations were carried out from deep-sea sediments of the mid-latitudes of the central North Pacific (Ling, 1970), and tropical and subtropical areas of the Pacific and Atlantic oceans (Ling, 1972). The present study from the high-latitude regions of the North Pacific, therefore, represents part of a continuous effort dealing with these siliceous microfossils, their taxonomy, and evaluation of their stratigraphic potential.

METHODS

After examining the core catcher samples at the first site, 183, it became apparent that diatoms were the dominant biogenic element and would provide the stratigraphic control for sediments of the region. Therefore most of the additional samples for shore laboratory study were collected immediately below the levels sampled for diatoms so that the results of these two groups of microfossils could be directly compared.

Due to limited time available for preparation and microscopic examination of each sample on shipboard, the sediments were treated almost exclusively with hydrogen peroxide followed by washing through a sieve of 63μ opening, instead of 74μ, as has been carried out previously. Consequently, a sieve of the same opening size was also used in the shore laboratory preparation.

Residue of both the greater than and less than 63μ fractions were mounted separately, with Canada balsam as the mounting medium. All the slides prepared bear a prefix of DSDP (abbreviation for the Deep Sea Drilling Project), but for convenience, it will be omitted hereafter throughout this paper. The designation of the slides are: site number-core number-section number, sampled position in centimeters from the top of the section. Note here that each core is cut into 1.5-meter sections numbered consecutively from the top. For core catcher samples, the abbreviation of CC is used in place of a section number. The position of a figured specimen in the strewn slides is indicated with England Finder coordinates (Ling and Anikouchine, 1967).

SYSTEMATIC MICROPALEONTOLOGY

Most of the silicoflagellate and ebridian species encountered during the present study have been reviewed in detail recently and their synonymy list has been presented (Ling, 1970, 1971, 1972). In the following, genera and species are arranged in alphabetical order within silicoflagellates and ebridians, and relevant comments or original references describing the named taxa are given wherever deemed appropriate.

Order SIPHONOTESTALES Lemmermann, 1901a

Genus CANNOPILUS Haeckel, 1887, emend. Bachmann, 1967

Cannopilus hemisphaericus (Ehrenberg)
(Plate 1, Figures 1-4)

Dictyocha hemisphaerica Ehrenberg, 1844b, p. 266.

Cannopilus sphaericus Gemeinhardt
(Plate 1, Figures 5, 6.)

Cannopilus sphaericus Gemeinhardt, 1931a, p. 104, pl. 10, figs. 3, 4.
Remarks: *C. sphaericus* is found from limestone pebbles of 190-16(CC) only during the present study.

Genus CORBISEMA Hanna, 1928, emend. Frenguelli, 1940

Corbisema triacantha (Ehrenberg)
(Plate 1, Figures 7, 8)

Dictyocha triacantha Ehrenberg, 1844a, p. 80.
Remarks: A few specimens of the present taxon are found in Core 20 from Site 183, and specimens replaced by pyrite were found in limestone pebbles from 192-31-1, at 88 cm.

Genus DICTYOCHA Ehrenberg, 1839

Dictyocha fibula Ehrenberg
(Plate 1, Figures 9, 10)

Dictyocha fibula Ehrenberg, 1839, p. 129.
Remarks: Except for an occurrence in 191-2-1 (52-54 cm), *D. fibula* is found in Miocene interval from Sites 183 and 192.

Dictyocha formosa Bachmann
(Plate 1, Figure 11)

Dictyocha formosa Bachmann, 1964, pp. 98, 99, pl. 1, figs. 1-8.
Remarks: Bachmann erected the present species from Hojuji diatomaceous mudstone of the Noto Peninsula, Japan, which is considered as late Miocene age according to Fuji and Bachmann (1968). This is the second recorded occurrence and the first time that *D. formosa* is found in deep-sea sediments. The specimens were recovered from limestone pebbles in the core catcher sample of Core 16, Site 190.
Measurements of figured specimen: Diameter of basal body ring, 50μ; radial spines, 9-12μ.

[1]Contribution No. 691 from the Department of Oceanography, University of Washington.

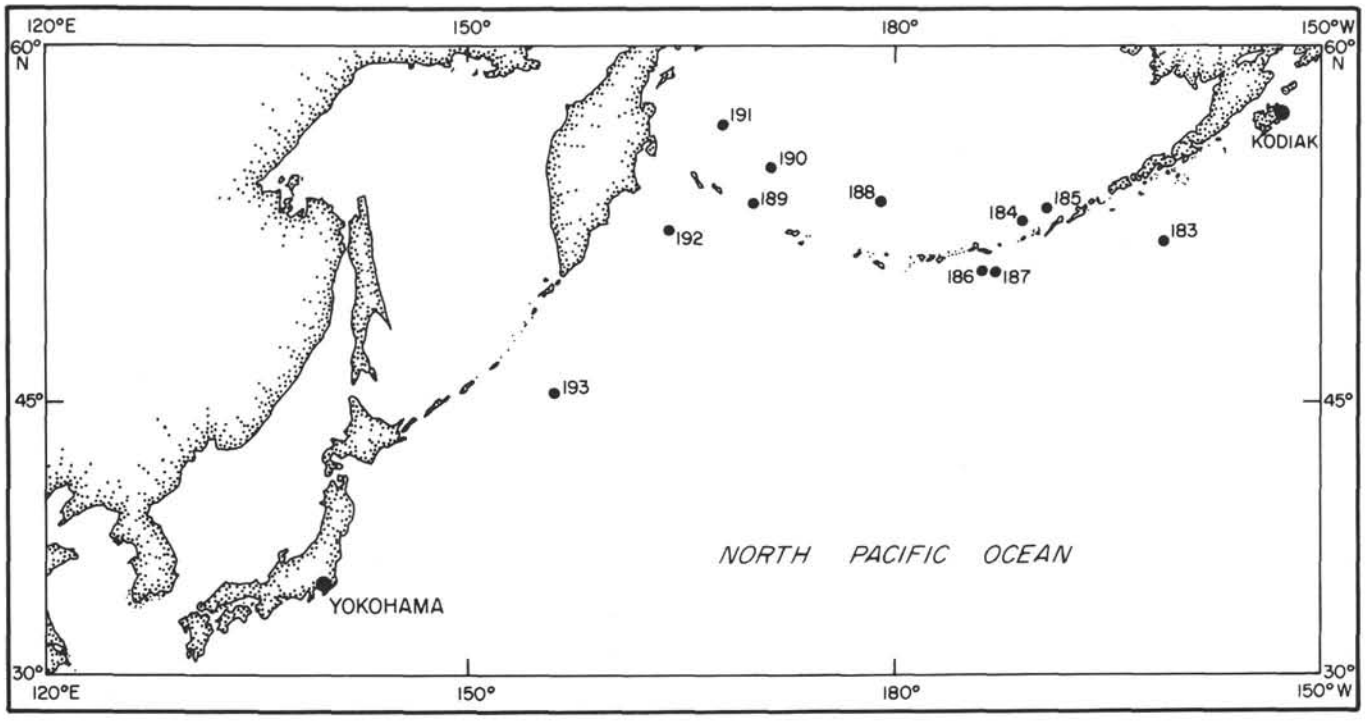

Figure 1. *Geographic location of drilling sites, Deep Sea Drilling Project, Leg 19.*

TABLE 1
Coordinates of Drilling Sites, Deep Sea Drilling Project, Leg 19

Hole	Latitude	Longitude	Water Depth (m)
183	52°34.30'N	161°12.33'W	4708
184	53°42.64'N	170°55.39'W	1910
184A	53°42.64'N	170°55.39'W	1910
184B	53°42.64'N	170°55.39'W	1910
185	54°25.73'N	169°14.59'W	2110
186	51°07.81'N	174°00.34'W	4522
187	51°06.6'N	173°57.2'W	4567
188	53°45.21'N	178°39.56'E	2649
189	54°02.14'N	170°13.38'E	3437
190	55°33.55'N	171°38.42'E	3875
191	56°56.70'N	168°10.72'E	3854
191A	56°56.70'N	168°10.72'E	3860
191B	56°56.70'N	168°10.72'E	3860
192	53°00.57'N	164°42.81'E	3014
192A	53°00.57'N	164°42.81'E	3014
193	45°48.20'N	155°52.27'E	4811

Dictyocha subarctios Ling
(Plate 1, Figures 12-16)

Dictyocha subarctios Ling, 1970, pp. 95, 96, pl. 18, figs. 16-18, pl. 19, figs. 1-4.

Remarks: The abapical view of a specimen under the scanning electron microscope is presented here (see Plate 1, Figure 16) to show the structure of the present species. Note the uniform and smooth nature of the surface of the siliceous skeleton.

Genus DISTEPHANUS Stöhr, 1880

Distephanus crux (Ehrenberg)
(Plate 1, Figures 17, 18)

Dictyocha crux Ehrenberg, 1840, pp. 207, 208.

Distephanus crux var. stauracanthus (Ehrenberg)
(Plate 1, Figures 20, 21)

Dictyocha stauracanthus Ehrenberg, 1845, p. 76.

Distephanus octangulatus Wailes
(Plate 2, Figures 1-4)

Distephanus speculum var. *octonarius* Ehrenberg forma Wailes, 1928, p. 14, pl. 12, fig. 33.
Distephanus octangulatus Wailes, 1932, p. 216, fig. 3.

Remarks: As shown in Figure 4, the present species are found in many of the surface sediments from the Bering Sea. A scanning electron micrograph (see Plate 2, Figure 4) clearly shows the definite parallel ridge pattern on the apical surface of the skeleton.

Distephanus octonarius Deflandre
(Plate 2, Figures 5, 6)

Distephanus octonarius Deflandre, 1932, p. 503, fig. 7; Glezer, 1966, p. 271.
Distephanus speculum var. *octonarius* (Ehrenberg). - Gemeinhardt, 1930, p. 69, fig. 59 a-c; Gemeinhardt, 1931b, p. 241, pl. 42, figs. 5, 6; Gemeinhardt, 1934, p. 296, fig. 21.

Remarks: Although Glezer (1966, p. 271) recognized three varieties within the present species, her var. *cyrtoides* was not found during the present study, and both var. *octonarius* and var. *polyactis* show the similar stratigraphic range, with the latter found more sporadically. Therefore, Deflandre's concept is followed in the present study. Judging from the stratigraphic position, *Distephanus octonarius* var. *polyactis* (Jorgensen) Glezer, reported by Jousé (1969, 1971) from V20-119 core, seems to correspond with present species.

Distephanus schauinslandii Lemmermann
(Plate 2, Figures 7-9)

Distephanus schauinslandii Lemmermann, 1901b, p. 262, pl. 11, figs. 4, 5.

Distephanus speculum (Ehrenberg)
(Plate 2, Figures 10-15)

Dictyocha speculum Ehrenberg, 1839, p. 129.

Remarks: From the present study, it is concluded that, at least for deep-sea sediments from this part of the Pacific, specimens with different radial spine lengths have no stratigraphic significance and therefore they are included under the present taxon. Number of radial spines observed ranges from six to nine.

Distephanus speculum var. pentagonus Lemmermann
(Plate 2, Figures 16, 17)

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

Remarks: As was also true in samples from the experimental drilling phase of the Mohole Project at Guadalupe site (Ling, 1972), the present taxon has a limited stratigraphic range both in the Pacific and the Bering Sea sediments.

Distephanus speculum var. pseudocrux Schulz
(Plate 2, Figures 18-20)

Distephanus speculum fa. *pseudocrux* Schulz, 1928, p. 263, fig. 52 a, b.

Remarks: Although it is not found in samples from Leg 19, specimens referable to this Schulz's variety were recovered from the dredged rocks of the continental margin of the Bering Sea (see below).

Distephanus speculum var. pseudofibula Schulz

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

Genus MESOCENA Ehrenberg, 1843, emend. Deflandre, 1950

Mesocena circulus var. apiculata Lemmermann
(Plate 2, Figures 21, 22)

Mesocena circulus var. *apiculata* Lemmermann, 1901b, p. 257, pl. 10, figs. 9, 10.

Mesocena cf. elliptica Ehrenberg
(Plate 3, Figures 1-4)

Remarks: As in previous studies (Ling, 1970, 1971, 1972), both *"M. diodon"* and *"M. elliptica"* described by various authors are considered under the present taxon; however, in the tables reporting the occurrence from each site, they are listed separately. Through communication with Dr. Sigurd Locker of Paläontologisches Museum of Natural History at the Humboldt University, Berlin, it is learned that Ehrenberg's original collection has been kept safely and is available for reexamination, and Dr. Locker is now working on a revision of silicoflagellates including drawings and a short index. It is hoped that the exact nature of *M. triangula* Ehrenberg (1839) will be defined in the future.

Mesocena pappi Bachmann
(Plate 3, Figures 5, 6)

Mesocena pappi Bachmann, 1962, p. 380, pl. 1, figs. 1-9.

Remarks: *M. pappi* is found from sample 186-23-3(52-54 cm) only. Originally Bachmann described this species from the Kreyenhagen Shale (Eocene) of California and this is the first record from such high latitudes of the North Pacific.

Mesocena ? sp.
(Plate 3, Figures 7, 8)

Remarks: Limestone pebbles from sample 192-31-3(88-90 cm) contained this triangular-shaped silicoflagellate whose basal body ring was filled with or replaced by pyrite, thus obscuring the detailed structure, particularly at the three apices. They are tentatively placed under the present genus.

Genus NAVICULOPSIS Frenguelli, 1940

Naviculopsis lata (Deflandre)
(Plate 3, Figures 9, 10)

Dictyocha biapiculata var. *lata* Deflandre, 1932, p. 500, figs. 300, 301.

Remarks: In the present study, *N. lata* was recovered only from Sample 186-23-3(52-54 cm).

Genus SEPTAMESOCENA Bachmann, 1970

Septamesocena apiculata Bachmann
(Plate 3, Figures 11, 12)

Mesocena apiculata (Schulz), Deflandre, 1932, p. 499, figs. 34(?), 35.

Remarks: Although *S. apiculata* was not found in Leg 19 samples, occurrence of the species is noticed in a dredge sample from the continental margin of the Bering Sea (see below).

Order STEREOTESTALES Lemmermann, 1901a

Genus AMMODOCHIUM Hovasse

Ammodochium rectangulare (Schulz)
(Plate 3, Figures 13-16)

Ebria antiqua var. *rectangularis* Schulz, 1928, p. 274, fig. 72 a-d.

Genus EBRIOPSIS Hovasse, 1932a

Ebriopsis antiqua (Schulz)
(Plate 3, Figures 17-21)

Ebria antiqua Schulz, 1928, pp. 273, 274, fig. 69 a-f.

Remarks: As in previous works (Ling, 1971; 1972), two forms, with and without anterior and posterior axial spines, are recognized in the present study. It now seems apparent that specimens without these spines have a longer stratigraphic range than those with spines. Furthermore, it is also noticed that these spines are less developed among specimens from this region than those from Japan or California (compare with Ling, 1970, Pl. 1, fig. 20, or Ling, 1972).

Genus PARATHRANIUM Hovasse, 1932b

Parathranium californicum Deflandre
(Plate 3, Figures 22-25)

Parathranium californicum Deflandre, 1951, pp. 49-51, 77, figs. 168-171.

SILICOFLAGELLATES AND EBRIDIANS AT EACH SITE

In the following Tables 2-12, occurrence of silicoflagellates and ebridians from each site is presented. Abundance of species in one strewn slide is indicated as: "+" (single specimen), "R" (rare, 2-5 specimens), "F"(few, 6-10 specimens), "C" (common, 11-25 specimens), and "A" (abundant, over 26 specimens). Although samples from the lower part of each site were also examined, they are barren of these microfossils, and the samples are not listed in the tables.

SILICOFLAGELLATE AND EBRIDIAN ZONATION

Introductory Remarks

As already mentioned, the thick Neogene marine sediments recovered during Leg 19 provide a unique opportunity to observe the geologic occurrence of silicoflagellates and ebridians from the high-latitude North Pacific and the Bering Sea. With the assistance of diatom microflora, a biostratigraphic zonation from the area by means of these fossils is now possible.

TABLE 2
Silicoflagellates and Ebridians from Site 183

Sample	*Distephanus speculum*	*Distephanus octangulatus*	*Dist. crux* var. *stauracanthus*	*Distephanus octonarius*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Ebriopsis antiqua* (without spine)	*Cannopilus hemisphaericus*	*"Mesocena elliptica"*	*"Mesocena diodon"*	*Dist. speculum* var. *pentagonus*	*Dictyocha fibula*	*Distephanus crux*	*Mesocena circulus* var. *biapiculata*	*Ebriopsis antiqua* (with spine)	*Distephanus schauinslandii*	*Corbisema triacantha*	Age
1-1(90-92)	F																	Late
1(CC)	C	C																
2(CC)		R																
3(CC)																		
4-1(132-134)	+	F		R														
4-2(82-84)	R	+																Middle
4-3(68-70)	R	C	F	R														
4-4(82-84)	R	C	F	R														
4(CC)																		
5-3(90-92)																		
5(CC)			+															
6-1(112-114)																		
6-2(82-84)		F																
6-3(82-84)																		
6-4(82-84)	R		F															
6-5(82-84)	F	R	R															
6(CC)	R			R														
7-3(34-36)	+																	
7(CC)	+																	
8-3(56-58)	F				A													
8(CC)																		Early
9-3(132-134)																		
9(CC)																		
10-1(82-84)				A	A													
10-2(82-84)				R	R													
10(CC)				+	R													
11-1(82-84)	R																	Early Pliocene
11-2(82-84)																		
11-3(82-84)																		
11-4(82-84)																		
11-5(82-84)																		
11(CC)																		
12-1(92-94)	C					R	R											
12-2(82-84)																		
12-3(82-84)	R					+												
12-4(82-84)																		
12-5(82-84)						+												
12(CC)						+												
13-4(0-2)																		
13(CC)	+																	
14(CC)	F					R	F	C	F	R								
15-4(0-2)							R	R	R	R								
15(CC)							R	R										
17-1(82-84)	+					+	F				C	+						Late Miocene
17-2(82-84)											F	+						
17-3(82-84)						+					F	R						
17-4(82-84)											F							
17-5(82-84)							+				C							
17-6(82-84)											C	R						
17(CC)											R	R	R					

TABLE 2 – *Continued*

Sample	Taxa																Age	
	Distephanus speculum	*Distephanus octangulatus*	*Dist. crux* var. *stauracanthus*	*Distephanus octonarius*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Ebriopsis antiqua* (without spine)	*Cannopilus hemisphaericus*	*"Mesocena elliptica"*	*"Mesocena diodon"*	*Dist. speculum* var. *pentagonus*	*Dictyocha fibula*	*Distephanus crux*	*Mesocena circulus* var. *biapiculata*	*Ebriopsis antiqua* (with spine)	*Distephanus schauinslandii*	*Corbisema triacantha*		
18-1(140-142)						R	R					+	R					Late	Miocene
18-2(82-84)													R						
18-3(82-84)						R	C					R	R	R					
18-4(82-84)	+					+	+					F	R	F					
18(CC)												R	R	F					
19-1(120-122)							C								R				
19-2(82-84)							C												
19-3(80-82)						R	F	+											
19-4(80-82)							F												
19(CC)							+	+											
20-1(80-82)	+						R	+					C			+	+	Middle	
20-2(80-82)	+						+	R					F						
20(CC)													+			+	+		
21-1(80-82)																			
21-2(82-84)								+											
21-3(80-82)							+	+											
21-4(82-84)							+												

Earlier, Jousé (1969, 1971) reported the occurrence of these microplanktonic remains from the deep-sea sediments of a core, V (Vema) 20-119, taken at 47°57′N, 168°47′E, at a water depth of 2739 meters. The paleomagnetic polarity of this core was measured by Ninkovich et al. (1966) and Hays and Ninkovich (1970), while Radiolaria and diatoms from the core were also examined by Hays (1970) and Donahue (1970) respectively. Note here a difference in age assignment for the core; Jousé drew the Plio-Pleistocene boundary at a depth of 785 cm, while others placed the top of the Olduvai normal event approximately 1100 cm from the top of the core. The possibility of the existence of an unconformity at 800 cm depth within the core is also mentioned (Kanaya and Koizumi, 1970, p. 51). Silicoflagellate occurrence from the mid-latitude deep-sea sediments of the central North Pacific was reported by Ling (1970).

These are the previous records of silicoflagellates and ebridians from the submarine deposits in this region of the ocean; it is therefore necessary to compare the range of taxa recognized in the samples with those from the land deposits of the circum-North Pacific and such previous works are briefly summarized as follows. Mandra (1968) studied the California assemblages and related their occurrences to standard marine stages of the west coast of the United States. Ling (1972) discussed these planktonic remains from core sediments recovered during the experimental drilling phase of the Mohole Project at Guadalupe site and compared the results with those of co-occurring diatoms, calcareous nannoplankton, and planktonic foraminifera. Sheshukova-Poretskaya (1967) tabulated and illustrated the Tertiary occurrences of these microfossils from the land deposits of Sakhalin and Kamchatka (her Table 19), but did not give any detailed description of the taxa.

Miocene silicoflagellates and ebridians from diatomaceous mudstones in the Noto Peninsula of Japan have been the subject of investigation by Ichikawa (1956, 1960), Bachmann (1964, 1967), Bachmann and Ichikawa (1962), and Fuji and Bachmann (1969, 1970); however these works are concerned with the taxonomy and the intraspecific variation. Microfossils from the Shinzan diatomaceous member of the Onnagawa Formation were investigated by Ling (1971) with emphasis on their stratigraphic occurrences. At the same time consideration was also given to comparing their occurrences with other microfossil groups, diatoms and Radiolaria studied previously from the same locality. From the Pacific side of Japan, silicoflagellates and ebridians are reported from the Hayama Group of the Kanagawa Prefecture (Ling and Kurihara, 1972), and here again their occurrence is discussed with the co-occurring foraminiferal and radiolarian assemblage.

Definition and Discussion of Zones

From Leg 19 samples, nine silicoflagellate and ebridian zones are recognized between middle Miocene and Recent

TABLE 3
Silicoflagellates and Ebridians from Site 184

Sample	Taxa										Age	
	Distephanus octangulatus	*Dictyocha fibula*	*Distephanus speculum*	*Ammodochium rectangulare*	*Dist. crux* var. *stauracanthus*	*Ebriopsis antiqua* (without spine)	*Parathranium tenuipes*	*Cannopilus hemisphaericus*	*"Mesocena elliptica"*	*Dist. speculum* var. *pentagonus*		
1-1(75-77)	C	R	R								Late Pleistocene	
1(CC)			R									
2-3(132-134)			F									
2-5(132-134)			R									
2(CC)			R									
3-3(102-104)			C								Late	Pliocene
3-5(102-104)				R								
3(CC)				R	R							
4-4(142-144)			R	F								
4(CC)			R	R								
5(CC)			R	R								
6-4(142-144)			A	F								
6(CC)			R	R								
7-4(142-144)			F	R								
7(CC)			R	R								
8-4(142-144)			C	F								
8(CC)			R									
9-4(52-54)			C									
9(CC)												
10-3(72-74)			R									
10(CC)			R									
11-3(62-64)			R	C		C	R				Early	
11(CC)												
12-1(82-84)			A	C		C	R	R				
12-2(82-84)				R		R						
12-3(82-84)			R	F		F						
12(CC)			R	R		F						
13-2(82-84)			R									
13(CC)			R					F				
14-3(52-54)				R		C		R				
14(CC)			R			F		R				
15-1(132-134)			R	R		C		R				
15(CC)			R			R						
16-2(32-34)			F	R		F	R	F				
16(CC)			R	R		R		R				
17-2(42-44)			F	R		R		R				
17-3(22-24)			R			R		R				
17(CC)			F			F		F		F		
18-1(22-24)			R			R		C	R	C		
18(CC)			R	R		F		F				
19(CC)			R	R		R		R			Late Miocene	
20-3(122-124)				R		F						
20(CC)												
21-1(132-134)			R			R		F				
21(CC)			R									
22(CC)			R									

intervals, and they are discussed in ascending order below. All the zones here considered are interval zone (biointerval zone) of Hedberg (1971) or successive disappearance zone of Vella (1964). At the same time, by arranging the sequence of each drilled site into the zones, a correlation, Table 13, is formulated.

TABLE 4
Silicoflagellates and Ebridians from Site 185

Sample	Taxa: *Distephanus speculum*	*Distephanus octangulatus*	*Dist. crux* var. *stauracanthus*	*Distephanus octonarius*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Parathranium*	*Ebriopsis antiqua (without spine)*	*Cannopilus hemisphaericus*	*Dist. speculum* var. *pentagonus*	*"Mesocena elliptica"*	*Ebriopsis antiqua* (with spine)	*Distephanus crux*	Age	
1-1(22-24)														Late	Pleistocene
1(CC)															
2(CC)	R														
3-1(52-54)	C	R													
3(CC)		R													
4-2(32-34)			R	R										Middle	
4-4(32-34)			R												
4(CC)				R											
5(CC)	R	F	F	F											
6-4(142-144)				R											
6(CC)	R			R	F									Early	
7-1(104-106)	A					F								Late	Pliocene
7-3(102-104)	A					R									
7(CC)	F					F									
8-1(122-124)	C														
8-3(132-134)	F					C	R	C	R					Early	
8(CC)	R					R		R	R						
9(CC)	R					R		R	R						
10-3(52-54)	R							R	R						
10(CC)	R							R	R						
11-1(132-134)	C					F	R	F	R	R				Late Miocene	
11(CC)	R					R		R	R	R			R		
12-1(112-114)	R					R		R	F	F	R				
12(CC)	R							R	R	F	R				
13-1(132-134)	R					R		R	F	R		R			
13(CC)	F							R	R	R					
14-1(72-74)	R					R		R	C		R				
14(CC)	R								F						
15-1(122-124)	R					R		F	C				R		
15(CC)	R							R	R						
16-1(112-114)						R		R	R						
16(CC)	R								R						
17(CC)						R			R	R					

Distephanus schauinslandii Zone

Top: Upper limit of *Distephanus schauinslandii* Lemmerman.

Base: Not defined in the present study.

Occurrence of reference section: Site 183.

Remarks: Stratigraphically this is the lowest zone that can be recognized from this region of the Pacific at present. *Ammodochium rectangulare, Ebriopsis antiqua* (spineless form), and *Distephanus crux* are already present. The highest occurrence of *Corbisema triacantha* seems to coincide with the top of this zone. Thus, although the matrix of Sample 192-31-1 at 88 cm was barren of microfossils, the age of the limestone pebbles found in the sample may belong to this zone.

Mesocena circulas var. *apiculata* Zone

Top: Upper limit of *Mesocena circulus* var. *apiculata* Lemmermann.

Base: Upper limit of *Distephanus schauinslandii* Lemmermann.

Occurrence of reference section: Sites 183 and 192.

Remarks: The zone thus defined likely coincides with the local range of the named taxon. *Dictyocha fibula, Distephanus speculum* var. *pentagonus* show their initial appearance from near the top of the zone.

Distephanus speculum var. *pentagonus* Zone

Top: Upper limit of *Distephanus speculum* var. *pentagonus* Lemmermann.

TABLE 5
Silicoflagellates and Ebridians from Site 186

Sample	Taxa											Age	
	Distephanus speculum	*Distephanus octangulatus*	*Distephanus octonarius*	*Dist. crux* var. *stauracanthus*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Cannopilus hemisphaericus*	*Ebriopsis antiqua* (without spine)	*Naviculopsis lata*	*Mesocena pappi*	*Distephanus crux*	*Dist. speculum* var. *pentagonus*	*Ebriopsis antiqua* (with spine)		
1-1(122-124)															
1(CC)	+													Late	Pleistocene
2-3(77-79)	R	F													
2(CC)	R	R													
3-3(102-104)	R	R													
4-2(132-134)	A	F	F											Middle	
4-4(132-134)															
4(CC)															
5-3(120-122)		+													
5(CC)															
6(CC)															
7-3(32-34)	R	+		R											
7(CC)				+											
8-3(34-36)	R			+											
8(CC)															
9-2(112-114)															
9-4(142-144)															
9(CC)	R			+											
10-3(40-42)															
10(CC)															
11-4(132-134)															
11(CC)															
12-1(102-104)	R		+		A										
12(CC)	+				+									Early	
13-1(122-124)	A		A												
13(CC)															
14(CC)															
15(CC)															
16-1(25-27)	R													Late	Pliocene
16(CC)	+					+									
17-1(132-134)	C					R									
17(CC)	+					R									
18-1(132-134)	R														
18(CC)							+	+							
19(CC)	+													Early	
20-1(132-134)															
20(CC)															
21(CC)															
22-1(122-124)															
22(CC)						+				+					
23-1(122-124)	R													Early	
23-2(122-124)	F					+		**R**							
23-3(52-54)	R					+	+	**R**	+	R	R	+	+	Middle Miocene	
23(CC)						+		**R**	+						
24-1(52-54)						+		**R**							
24(CC)														Pliocene	
25(CC)						+									

TABLE 6
Silicoflagellates and Ebridians from Site 187

Sample	Taxa: *Distephanus speculum*	*Distephanus octonarius*	*Dictyocha subarctios*	*Ebriopsis antiqua* (without spine)	*Cannopilus hemisphaericus*	Age
1(CC) 1st part	R	R	F			Early Pleistocene
1(CC)				R		Early Pliocene
2(CC)					R	
3(CC)				R	R	

Base: Upper limit of *Mesocena circulus* var. *apiculata* Lemmermann.
Occurrence of reference section: Sites 183 and 192.
Remarks: The extinction of *Distephanus crux* and *D. speculum* var. *pseudofibula* in this region is found within this interval. Also disappearing from near the top of this zone is *Dictyocha fibula* which is generally regarded as a warm-water form. The Mio-Pliocene boundary based on silicoflagellates is drawn at the top of this zone in present study.

Cannopilus hemisphaericus Zone

Top: Upper limit of *Cannopilus hemisphaericus* (Ehrenberg).
Base: Upper limit of *Distephanus speculum* var. *pentagonus* Lemmermann.
Occurrence of reference section: Site 192.
Remarks: Although in Sites 183 and 190, the upper boundary of this zone coincides with the extinction level of *"Mesocena elliptica"* and *"M. diodon,"* in other sites, 184 and 185, it occurs slightly below the top of the zone. This indicates a possibility that an additional datum plane can be recognized but this is not done at this time.

Ebriopsis antiqua (spineless form) Zone

Top: Upper limit of *Ebriopsis antiqua* (spineless form) Schultz.
Base: Upper limit of *Cannopilus hemisphaericus* Ehrenbert).
Occurrence of reference section: Site 192.
Remarks: With the final appearance of *Cannopilus hemisphaericus* and *"Mesocina diodon,"* and the Miocene occurrence of *"M. elliptica"* in the underlying zone, the present zone is characterized by the occurrence of *Ebriopsis antiqua* (spineless form), *Ammodochium rectangulare*, and a long-ranging species, *Distephanus speculum.*

Ammodochium rectangulare Zone

Top: Upper limit of *Ammodochium rectangulare* (Schultz).
Base: Upper limit of *Ebriopsis antiqua* (spineless form) Schultz.
Occurrence of reference section: Site 192.
Remarks: In all sites drilled during this leg, the present interval is rather characteristic by its low species diversity. Besides the named species, *Distephanus speculum* is the only form found from this zone and even *Ammodochium rectangulare* shows a decrease in abundance in comparison with the Miocene interval. It is believed that the extinction of the above named species occurs near or approximately at the Plio-Pleistocene boundary in this area.

Dictyocha subarctios Zone

Top: Upper limit of *Dictyocha subarctios* Ling.
Base: Upper limit of *Ammodochium rectangulare* (Schultz).
Occurrence of reference section: Sites 183 and 190.
Remarks: The present zone can also be considered as the local range zone of the named taxon according to the American Stratigraphic Code (1961). The initial appearance of the present species is near the Plio-Pleistocene boundary, but in a few sites including the reference sites, there is an interval subsequent to the extinction of *Ammodochium rectangulare* and prior to the initial appearance of *Dictyocha subarctios*, but samples at this critical interval are unfortunately barren of these microfossils.

Concerning the top of this zone, Ling (1970) suggested a possible biostratigraphic datum plane indicated by the extinction level of *Dictyocha subarctios*, D. cf. *ausonia* and *Mesocena* cf. *elliptica* from the central subarctic Pacific sediments. Present study now confirms that this datum plane can be recognized by the extinction level of the *D. subarctios*. The other two species were never found in the Pleistocene section from this high-latitude region.

It now seems that the latest occurrence of *Dictyocha subarctios* occurs slightly above the polarity change from Matuyama reversed to Bruhnes normal, thus the top of this zone is slightly higher than the extinction level of *Actinocyclus oculatus* Jousé (Donahue, 1970).

Within this interval, *Distephanus octonarius, D. crux* var. *stauracanthus* make their first appearance.

Distephanus octonarius Zone

Top: Upper limit of *Distephanus octonarius* Deflandre.
Base: Upper limit of *Dictyocha subarctios* Ling.
Occurrence of reference section: Sites 185 and 192.
Remarks: The latest occurrence of *Distephanus crux* var. *stauracanthus* is observed at slightly below the upper boundary of this zone. Throughout the present study, the top of a diatom species, *Rhizosolenia curvirostris* Jousé, corresponds in general with that of this zone.

Distephanus octangulatus Zone

Top: Not defined in the present study.
Base: Upper limit of *Distephanus octonarius* Jousé.
Occurrence of reference section: Site 183.
Remarks: This is the youngest zone recognized from this region subsequent to the extinction of *Distephanus octonarius*. Occurrence of *D. octangulatus* has been observed from surface sediments in this part of the North Pacific and

TABLE 7
Silicoflagellates and Ebridians from Site 188

Sample	*Distephanus octangulatus*	*Distephanus speculum*	*Distephanus octonarius*	*Dist. crux* var. *stauracanthus*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Ebriopsis antiqua* (without spine)	*Cannopilus hemisphaericus*	*Ebriopsis antiqua* (with spine)	*Dist. speculum* var. *pentagonus*	Age	
1-1(63-66)	C	F									Late	Pleistocene
1(CC)		+										
2(CC)		+										
3-2(132-134)	R	F										
3-4(132-134)	F											
3(CC)	F	R	+								Middle	
4(CC)	F		R	R								
5(CC)	F	R		F								
6-2(62-64)		C										
6(CC)	R	R	R	F	R						Early	
7-1(103-105)			C		A							
7-4(52-54)					A							
7(CC)		+										
8-1(102-104)		A										
8(CC)		+										
9-1(42-44)		C				F					Late	Pliocene
9-3(142-144)		F										
9-3(150)		R										
10(CC)												
11-1(54-56)		F										
11(CC)		+				+						
12-1(62-64)		A										
12(CC)							F				Early	
13-1(103-105)		R					C					
13(CC)							C	R				
14-1(31-33)		C					C	F	+		Late Miocene	
14(CC)		R				R	**F**	F		R		
15-2(22-24)		R					R		+			
15(CC)		R					R	R		**R**		

the Bering Sea (see Figure 4). *Distephanus speculum*, a cold-water species, is generally found in the same samples.

ADDITIONAL OCCURRENCES IN THE BERING SEA

In connection with the present investigation of the Deep Sea Drilling Project materials, additional samples from the Bering Sea were examined (Figure 2) and the results are presented here briefly.

From the surface sediments studied previously for radiolarians (Ling et al., 1971), only *Distephanus speculum* and *D. octangulatus* were found. Figures 3 and 4 present their distribution in the area, respectively.

Rocks from the continental margin of the Bering Sea were dredged by personnel from the U.S.N.S. *Bartlett* in 1970 and part of the samples were placed at the writer's disposal through the kind arrangement of Dr. David W. Scholl. Geographic location, microfossil assemblage recovered, and the probable geologic age assigned for the samples are shown in Table 14.

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REFERENCES

American Commission on Stratigraphic Nomenclature, 1961. Code of stratigraphic nomenclature. Bull. Am. Assoc. Petrol. Geologists. **45** (45), 645.

Bachmann, A., 1962. Eine Mesocena-Art (Silicoflagellidae) aus dem Kalifornischen Eozän. Verh. Geol. B.–A. Wien. 2, 378.

TABLE 8
Silicoflagellates and Ebridians from Site 189

Sample	Taxa: *Distephanus octangulatus*	*Distephanus speculum*	*Dictyocha subarctios*	*Ebriopsis antiqua* (without spine)	*Ammodochium rectangulare*	Age	
1-1(73-75)	+					Late	Pleistocene
1(CC)	R						
2(CC)	R	R					
3-1(112-114)							
3(CC)	R	R					
4-2(12-14)		+	C			Early	
4(CC)							
5-1(32-34)		R		?			
5(CC)		R					
6-1(86-88)		C			C	Late Pliocene	
6(CC)		R			R		
7(CC)					R		
8(CC)					R		
9-1(102-104)		R			+		
9(CC)							
10(CC)					+		

_____, 1964. Pt. II. Silicoflagellidae und Arachaeomonadaceae. *In* W. Ichikawa et al., Fossil diatoms, pollen grains and spores, silicoflagellates and archaeomonads in the Miocene Hojuji diatomaceous Mudstone, Noto Peninsula, Central Japan. Kanazawa Univ. Sci. Rept. **9** (1), 87.

_____, 1967. Part. II. Silicoflagellidae im Iida Diatomit. *In* W. Ichikawa et al., Fossil silicoflagellates and their associated uncertain forms in Iida Diatomite, Noto Peninsula. Kanazawa Univ. Sci. Rept. **12** (1), 149.

_____, 1970. Flagellata (Silicoflagellata). *In* Catalogus Fossilium Austriae, H. Zapfe (Ed.) **1b**. 28. p.

Bachmann, A and Ichikawa, W., 1962. The silicoflagellides in the Wakura Beds, Nanao City, Prefecture Ishikawa, Japan. Kanazawa Univ. Sci. Rept. 8 (1), 161.

Deflandre, G., 1932. Sur la systématique des Silicoflagellés. Bull. Soc. Bot. France. **79**, 494.

_____, 1950. Contribution a l'etude des Silicoflagellides actuels et fossiles. Microscopie. **2**. 82 p.

_____,1951. Recherches sur les Ebriediens. Paléobiologie, Evolution. Systematique. Bull. Biol. France, Belique. **85** (1) 84.

Donahue, J. G., 1970. Pleistocene Diatoms as Climatic Indicators in North Pacific sediments. Geol. Soc. Am. Mem. 126, 121.

Ehrenberg, C. G., 1839. Uber die Bildung der Kreidefelsen und des Kreidelmergels durch unsichtbare Organismen. Abh. Kgl. Akad. Wiss. Berlin. Jahrg. 1838, 59.

_____, 1840. . . . 274 Blatter von ihm selbst ausgeführter Zeichnungen von ebensa vielen Arten. Ber. Verh. Kgl. Preuss. Akad. Wiss. Berlin. 197.

_____, 1843. Verbreitung und Einfluss des mikroskopoischen Lebens in Sud-und Nord-Amerika. Abh. Kgl. Akad. Wiss. Berlin. Jahrg. 1841, 291.

_____, 1844a. Uber 2 neue Lager von Gebirgsmassen aus Infusorien. Ber Verh. Kgl. Preuss. Akad. Wiss. Berlin. Jahrg. 1844, 57.

_____,1844b. Untersuchhungen über die kleinsten Lebensformen im Quellenlande des Euphrats und Araxes, so wie über eine an neuen Formen sehr reiche marine Tripelbildung von den Bermuda-Inseln vor. Ber. Verh, Kgl. Preuss. Akad. Will. Berlin. Jahrg. 1844, 253.

_____, 1845. Neue Untersuchungen über das kleinste Leben als geologisches Moment. Ber. Verh. Kgl. Preuss. Akad. Wiss. Berlin. Jahrg. 1845, 53.

Frenguelli, J., 1940. Consideraceiones sobre los Silicoflagelades Fósiles. Rev. Mus. La Plata. N. S. 2. Paleont. (7), 37.

Fuji, N. and Bachmann, A., 1968. Fossil Pollen, Sporen und Silicoflagellaten aus den Hijirikawa-Schichten (Obermiozän) der Halbinsel Noto, Zentral-Japan (I). Kanazawa Univ., Fac. Educ., Natural Sci. Bull. **17**, 41.

_____, 1969. Silicoflagellaten in Hijirikawa-Schichten. Kanazawa Univ., Fac. Educ., Natural Sci. Bull. **18**, 79.

_____, 1970. Silicoflagellaten in den Hijirikawa-Schichten. Fossile Pollen, Sporen und Silicoflagellate aus den Hijirikawa-Schichten (Obermiozän) der Halbinsel Noto, Zentral-Japan (III). Kanazawa Univ., Fac. Educ., Natural Sci. Bull. **19**, 77.

Gemeinhardt, K., 1930. Silicoflagellatae. *In* Kryptogamen-Flora von Deutschland, Osterreich und der Schweiz, L. Rabenhorst (Ed.). **10** (2), 1.

_____, 1931a. Organismenformen auf der Grenze zwischen Radiolarien und Flagellaten. Ber. Deutsch. Bot. Gesell. **49** (2). 103.

_____, 1931b. Die Silicoflagellaten der Deutschen Südpolar-Expedition, 1901-1903. Deutsche Südpolar-Expedition. **20** (Zool , vol. 12), 221.

_____, 1934. Die Silicoflagellaten des Südatlantischen Ozeans. Wiss. Ergebn. Deutsch. Atlant. Exped. METEOR 1925-1927. **12** (1), Sect. 3, 274.

Glezer, Z. I., 1966. Silicoflagellatophyceae. *In* Cryptogamic plants of the U. S. S. R., M. M. Gollerbakh (Ed.). Nauka, Moscow. (Translated from Russian by Israel Program for Scientific Translations Ltd., Jerusalem, 1970). 7.

Haeckel, E., 1887. Report on the Radiolaria collected by H.M.S. *Challenger* during the years 1873-1876. Rept. Voyage *Challenger*. Zool. **18**. 1809 p.

Hanna, G. D., 1928. Silicoflagellates from the Cretaceous of California. J. Paleontol. **1** (4), 259.

Hays, J. D., 1970. Stratigraphy and evolutionary trends of Radiolaria in North Pacific Deep-Sea sediments. Geol. Soc. Am. Mem. 126, 185.

Hays, J. D. and Ninkovich, D., 1970. North Pacific Deep-Sea Ash Chronology and Age of present Aleutian underthrusting. Geol. Soc. Am. Mem. 126, 263.

Hedberg, H. D., (Ed.), 1971. Preliminary report on biostratigraphic units. International Subcommission on Stratigraphic Classification, Report No. 5. Intern. Geol. Congr., Montreal, Canada. **5**, 1.

Hovasse, R., 1932a. Note Préliminaire sur les Ébracées. Bull. Soc. Zool. France. **57** (2), 118.

_____, 1932b. Troisième note sur les Ébriacées. Bull. Soc. Zool. France. **57** (5), 457.

Ichikawa, W., 1956. Preliminary Report on Silicoflagellates from the Neogene Tertiary of the Hokuriku District, Japan. Kanazawa Univ. Sci. Rept. **5** (1), 31.

TABLE 9
Silicoflagellates and Ebridians from Site 190

Sample	Taxa												Age		
	Distephanus speculum	*Distephanus octangulatus*	*Distephanus octonarius*	*Distephanus crux* var. *stauracanthus*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Ebriopsis antiqua* (without spine)	*"Mesocena elliptica"*	*Cannopilus hemisphaericus*	*Distephanus crux* var. *pentagonus*	*Mesocena circulus* var. *apiculata*	*Ebriopsis antiqua* (with spine)	*Cannopilus sphaericus*	*Dictyocha formosa*			
1-1(67-69)															Late		Pleistocene
1(CC)	R	R															
2(CC)	R		R												Middle		
3-2(112-114)																	
3(CC)	A	F	F														
4-1(112-114)	C	R															
4(CC)	+																
5-2(102-104)	R			+													
5-5(42-44)																	
5(CC)	+	R		F													
6-3(32-34)	F	R		F													
6(CC)	R	R	R	R													
7-2(112-114)	R																
7(CC)	R			R													
8-3(42-44)	R				C										Early		
8(CC)	R				A												
9-1(52-54)			R														
9(CC)					F												
10-2(30-32)																	
10(CC)																	
11-1(137-139)	C					C									Late		Pliocene
11-3(137-139)																	
11(CC)	C					+											
12-1(72-74)	C																
12-3(32-34)	F					+											
12(CC)	F					F	R								Early		
13-1(102-104)	F					F	R										
13(CC)	R						F	R	R			R					
14-2(102-104)	C					F	F	R	F	+	+						
14-4(102-104)	R					C	C		F							Late Miocene	
14(CC)	+						F		+			+					
15(CC)																	
16(CC)									F				F	+			

_____, 1960. On the fossil marine diatoms in the Wakura Beds, Noto Peninsula, Japan. Kanazawa Univ. Sci. Rept. **7** (1), 175.

Jousé, A. P., 1969. Silicoflagellates in bottom sediments of Pleistocene and Late Pliocene of the Pacific Ocean. *In* Micropaleontology and Organogenous sedimentation in the Oceans. A. P. Jousé (Ed.). Nauka, Moscow, 105.

_____, 1971. Diatoms in Pleistocene sediments from the northern Pacific Ocean. *In* The Micropaleontology of Oceans, B. M. Funnell and W. R. Riedel (Eds.). Cambridge (Cambridge Univ. Press), 407.

Kanaya, T. and Koizumi, I. 1970. The progress in the younger Cenozoic diatom biostratigraphy in the northern Circum-Pacific Region. Marine Geol. **6** (2), 47.

Lemmermann, E., 1901a. Beiträge zur Kenntniss der Planktonalgen. Ber. Deutsch. Bot. Gesell. **19**, 85.

_____, 1901b. Silicoflagellatae. Ber. Deutsch. Bot. Gesell. **19**, 174.

Ling, H. Y., 1970. Silicoflagellates from central north Pacific core sediments. Bull. Am. Paleontol. **58** (259), 85.

_____, 1971. Silicoflagellates and Ebridians from the Shinzan diatomaceous mudstone member of the Onnagawa Formation, (Miocene), Northeast Japan. *In* Proc. 2nd Planktonic Conference, A. Farinacci (Ed.). **2**, 689.

_____, 1972. Upper Cretaceous and Cenozoic Silicoflagellates and Ebridians. Bull. Am. Paleontol. **61** (273), 135.

TABLE 10
Silicoflagellates and Ebridians from Site 191

Sample	Taxa: *Distephanus octangulatus*	*Distephanus octangulatus*	*Dictyocha fibula*	*Distephanus octonarius*	*Ammodochium rectangulare*	*Dist. spec.* var. *stauracanthus*	Age	
1(CC)		R					Late	Pleistocene
2-1(52-54)		F	R					
2(CC)								
3(CC)								
4-1(102-104)	F			C			Middle	
4-5(112-114)	F	F		F				
4(CC)								
5-6(72-74)								
5(CC)								
6-2(122-124)								
6(CC)								
7(CC)								
8-2(132-134)								
8(CC)	R							
9(CC)	R			R			?	
10-2(62-64)								
10(CC)								
11-2(10-12)								
11(CC)	R				R		Late Pliocene	
12-1(123-125)					R			
A-1-1(0-2)								
A-1(CC)								
A-2-2(80-82)								
A-2(CC)	R	F				R		
A-4-1(137-139)	F	C				F		
A-4(CC)								

Ling, H. Y. and Anikouchine, W. A., 1967. Some spumellarian Radiolaria from the Java, Philippine, and Mariana Trenches. J. Paleontol. **41** (6), 1481.

Ling, H. Y. and Kurihara, K., 1972. Radiolaria and Silicoflagellates from Hayama Group, Kanagawa Prefecture, Japan. Acta Geol. Taiwanica. **15** 31.

Ling, H. Y., Stadum, C. J. and Welch, M. L., 1971. Polycystine Radiolaria from Bering Sea surface sediments. **In** 2nd Proc. Planktonic Conference, A. Farinacci (Ed.). **2**, 705.

Mandra, Y. T., 1968. Silicoflagellates from the Cretaceous, Eocene, and Miocene of California, U. S. A. Proc. Calif. Acad. Sci. **36** (9), 231.

Ninkovich, D. et al., 1966. Paleomagnetic stratigraphy, rates of deposition and teprachronology in North Pacific Deep-Sea sediments. Earth Planet. Sci. Letters. **1**, 476.

Schulz, P., 1928. Beiträge zur kenntnis fossiler und rezenter Silicoflagellaten. Bot. Archiv. **21** (2), 225.

Sheshukova-Poretskaya, V. S., 1967. The Neogene marine Diatomaceae of Sakhalin and Kamchatka. Izd. Leningrad Univ. 327 p.

Stöhr, E., 1880. Die Radiolarienfauna der Tripoli von Grotte Provinz Girgenti in Sicilien. Palaeontographica. **26**, 69.

Vella, P., 1964. Biostratigraphic units. New Zealand J. Geol. Geophys. **7** (3), 615.

Wailes, G. H., 1928. Fresh-water and marine Protozoa from British Columbia with descriptions of new species. Vancouver Mus. Notes. **3** (3, 4), 9.

, 1932. Description of new species of Protozoa from British Columbia. Contr. Canadian Biol. Fish. **7** (17). (Ser. A, Gen. No. 14), 215.

TABLE 11
Silicoflagellates and Ebridians from Site 192

Sample	*Distephanus speculum*	*Distephanus octangulatus*	*Distephanus octonarius*	*Distephanus crux* var. *stauracanthus*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Ebriopsis antiqua* (without spine)	*Parathranium tenuipes*	*Distephanus crux*	*Cannopilus hemisphaericus*	*Parathranium californicum*	*"Mesocena elliptica"*	*"Mesocena diodon"*	*Distephanus speculum* var. *pentagonus*	*Distephanus speculum* var. *pseudofibula*	*Dictyocha fibula*	*Mesocena circulus* var. *apiculata*	*Corbisema triacantha*	Age		
1-1(56-58)	+																		Late	Pleistocene	
1(CC)	+	+																			
2-2(137-139)																					
2(CC)	+																				
3-3(22-24)																					
3(CC)	+	+	+																Middle		
4-3(22-24)			+																		
4-5(17-19)			+																		
4(CC)	R	+	A	+																	
5-3(12-14)	R	R		R																	
5(CC)	+	+	+	+	+														Early		
6-1(137-139)			+		R																
6(CC)					F																
7-2(22-24)	F																				
7(CC)	C																				
8-1(137-139)																			Late	Pliocene	
8-4(72-74)	R					+															
8(CC)	C					F															
9-2(52-54)	R					+															
9-4(102-104)	+					+															
9(CC)	R					+	R												Early		
10-1(122-124)	F					R	C	+													
10-4(32-34)	R					R	F														
10(CC)	+					R	R														
11-1(120-122)							R		+												
11(CC)										+											
12-1(52-54)	F					R	C			C											
12(CC)	R																				
13-2(52-54)	A					C	C	F		A	F	F	C								
13-4(32-34)	A					R	F	R		F		R	F								
13(CC)	F					R	R			F	+	R	R								
14-1(52-54)	C					R	F			C	R	R		F							
14(CC)	F					R	F			F		R		F							
15-1(110-112)						F	F			F		R		F							
15-3(102-104)	R					R	R			F		F		R							
15(CC)	R					F	F			F		F		F	R						
16-1(102-104)	C					R	R		R	C		F		C		R					
16(CC)						R	F			C		R	R	F	R						
17-1(125-127)	R					R	C			R						R					
17(CC)						R	R		R	R											
18-2(52-54)	F						F			F					R						
18-4(100-102)	R					R	F			C						R					
18(CC)	R					R	R			F				R							
19-1(50-52)	F					F	C														
19(CC)							R														
20-1(32-34)							R			R											
20(CC)	R					R	R			R				R							
21-1(52-54)	R						R			R											
21(CC)	R					R	R		F					R		R					
22-1(102-104)	R						R		R												

TABLE 11 – *Continued*

Sample	Taxa												Age
	Distephanus speculum	*Distephanus octangulatus*	*Distephanus octonarius*	*Distephanus crux* var. *stauracanthus*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Ebriopsis antiqua* (without spine)	*Parathranium tenuipes*	*Distephanus crux*	*Cannopilus hemisphaericus*	*Parathranium californicum*	*"Mesocena elliptica"*	*"Mesocena diodon"*	*Distephanus speculum* var. *pentagonus*	*Distephanus speculum* var. *pseudofibula*	*Dictyocha fibula*	*Mesocena circulus* var. *apiculata*	*Corbisema triacantha*	
22(CC)	R					F	F						R	R		F	R		Late Miocene
23-1(102-104)	F					R	R		R					R	R	R	F		
23(CC)						R	R												
24-2(22-24)						R	R		R										
24(CC)									R								R		
25-1(82-84)							R												
25(CC)							R												
26-1(108-110)																			?
26(CC)																			
26(CC)[a]																			
27-3(20-23)																			
27(CC)																			
28(CC)																			
29(CC)																			
30(CC)																			
31-1(88-90)[b]						R	R		R	F								R	

[a]Diatom ooze part.

[b]Brown limestone.

TABLE 12
Silicoflagellates and Ebridians from Site 193

Sample	Taxa						Age		
	Distephanus speculum	*Ebriopsis antiqua* (without spine)	*"Mesocena elliptica"*	*"Mesocena diodon"*	*Distephanus octangulatus*	*Distephanus octonarius*			
1-1(122-124)	+						Late	Late	Pleistocene
1-2(130-132)		+							
1(CC)	R		+	+	+				
2-1(117-119)						+	Mid		
2-3(40-42)						+			

TABLE 13
Silicoflagellate and Ebridian Zones Observed at Sites of Deep Sea Drilling Project, Leg 19

Age		Zone	183	184	185	186	187	188	189	190	191	192	193
Pleistocene	Late	*Distephanus octangulatus*	1-1 (90-92) 3-CC	1-1 (75-77) ?	1-1 (22-24) 3-CC	1-1 (122-124) 3-CC		1-1 (63-65) 3-4 (132-134)	1-1 (73-75) ?	1-1 (67-69) 1-CC	1-CC 2-1 (52-54)	1-1 (50-58) 3-3 (22-24)	1-1 (122-124) 1-CC
	Middle	*Distephanus octonarius*	4-1 (132-134) 7-CC		4-2 (32-34) 6-4 (142-144)	4-2 (132-134) 11-CC		3-CC 6-2 (62-64)		2-CC 7-CC	4-1 (102-104) ?	3-CC 5-3 (12-14)	2-1 (117-119) ?
	Early	*Dictyocha subarctios*	8-3 (56-58) 10-CC		6-CC	12-1 (102-104) 3-1 (122-124)	1-CC (ls)	6-CC 8-CC	4-2 (12-14) 5-CC	8-3 (42-44) 10-CC		5-CC 8-1 (137-139)	
Pliocene	Late	*Ammodochium rectangulare*	12-1 (92-94) 13-CC	3-5 (102-104) 10-CC	7-1 (104-102) 8-1 (122-124)	13-CC 18-1 (132-134)		6-1 (42-44) 12-1 (62-64)	6-1 (86-88) 10-CC	11-1 (137-139) 12-3 (32-34)	11-CC 12-1 (123-125)	8-4 (72-74) 9-4 (102-104)	
	Early	*Ebriopsis antiqua* (without spine)		11-3 (62-64) 11-CC			1-CC 3-CC	12-CC 13-1 (103-105)		12-CC 13-1 (102-104)		9-CC 11-1 (120-122)	
		Cannopilus hemisphaericus	14-CC 15-CC	12-1 (82-84) 17-3 (22-24)	8-3 (132-134) 10-CC	18-CC 25-CC		13-CC 14-1 (33-35)		13-CC		11-CC 13-CC	
Miocene	Late	*Distephanus speculum* var. *pentagonus*	17-1 (82-84) 18-2 (82-84)	17-CC 22-CC	11-1 (132-134) 17-CC			14-CC 15-CC		14-2 (102-104) 14-CC		14-1 (52-54) 22-1 (102-104)	
		Mesocena circulus apiculata	18-3 (82-84) 19-CC									22-CC 25-CC	
	Early	*Distephanus schauinslandii*	20-1 (80-82) 21-4 (82-84)										

TABLE 14
Dredge Stations and Samples of USNS *Bartlett*, 1970

Dredge Station and Sample	Latitude	Longitude	Depth (m)	Silicoflagellate and Ebridian Assemblage	Age
70-B49-1R1	55°40.2′N	165°11.8′E	1400-1800	–	
70-B49-1R2	55°40.2′N	165°11.8′E	1400-1800	*Cannopilus hemisphaericus, Distephanus crux, D. speculum* var. *pentagonus, Septamesocena apiculata*	Late Miocene
70-B52-1R1	58°08.2′N	164°01.4′E	1400-1800	*Distephanus speculum, Ammodochium rectangulare, Ebriopsis antiqua* (Without spine)	Miocene-Early Pliocene
70-B55-1R	56°40.2′N	169°38.1′E	2200-2500	*Cannopilus hemisphaericus, Distephanus speculum, D.* spec. var. *pseudocrux, Ammodochium rectangulare, Ebriopsis antiqua* (without spine)	Late Miocene
70-B56-3R1	53°32′N	170°00′E	1700-1800	–	
70-B56-3R2	53°32′N	170°00′E	1700-1800	–	
70-B81-1R	58°22.1′N	169°44.5′E	2250-2350	*Distephanus speculum*	
70-B86-1R	60°30.6′N	172°22.1′E	1100-1300	–	
70-B92-3R	59°33.1′N	178°54.7′W	2400-2600	–	
70-B97-1R1	58°17.2′N	174°49.0′W	1300-1500	–	
70-B97-1R2	58°17.2′N	174°49.0′W	1300-1500	*Cannopilus hemisphaericus, Distephanus speculum, D.* spec. var. *pseudofibula, D.* spec. var. *pseudocrux, Ebriopsis antiqua* (without spine)	Late Miocene
70-B111-1	53°31.9′N	170°49.8′W	2800-3000	–	

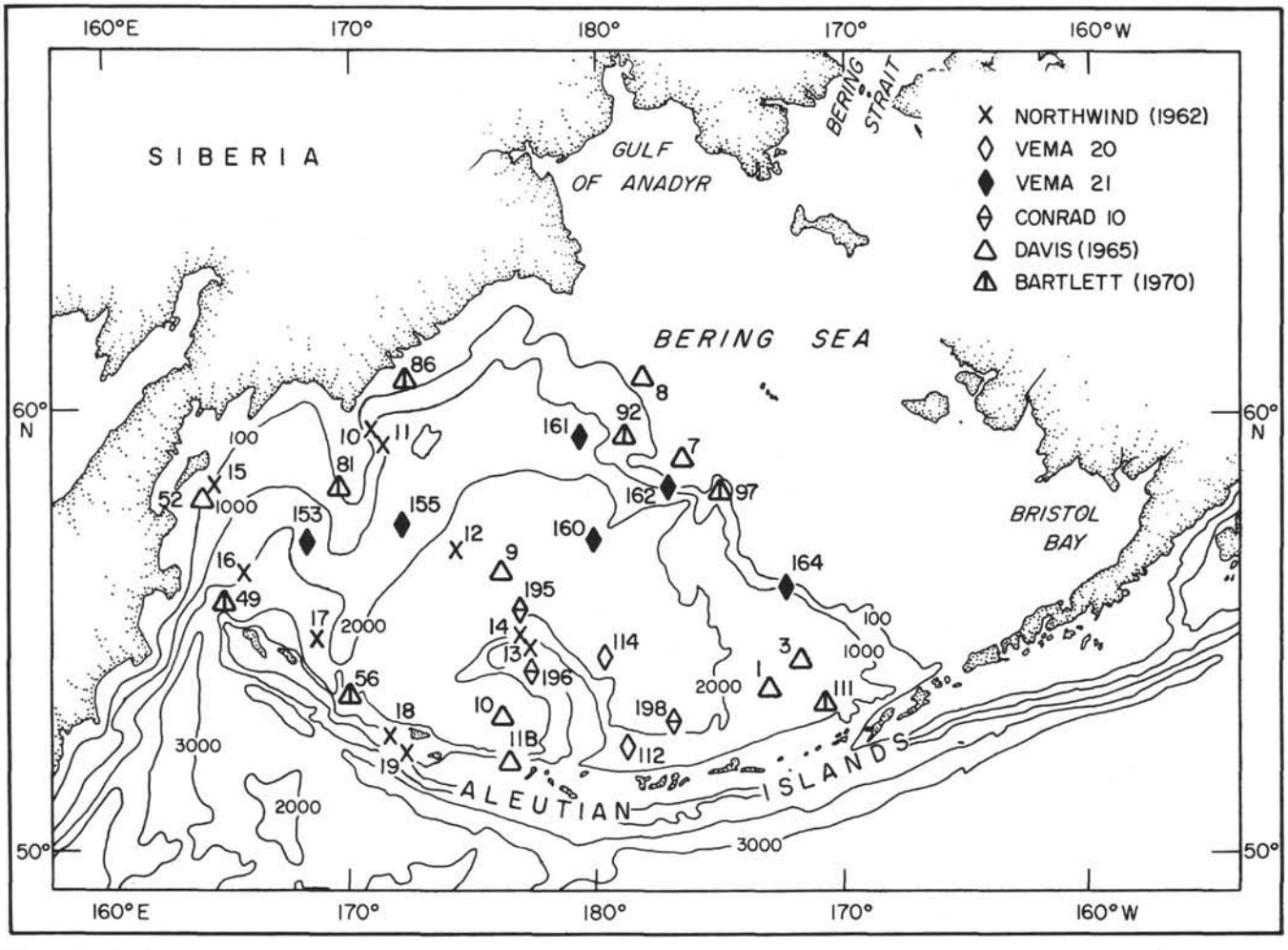


Figure 2. *Bathymetry of the Bering Sea and the locations of core sediments and dredged rocks studied.*

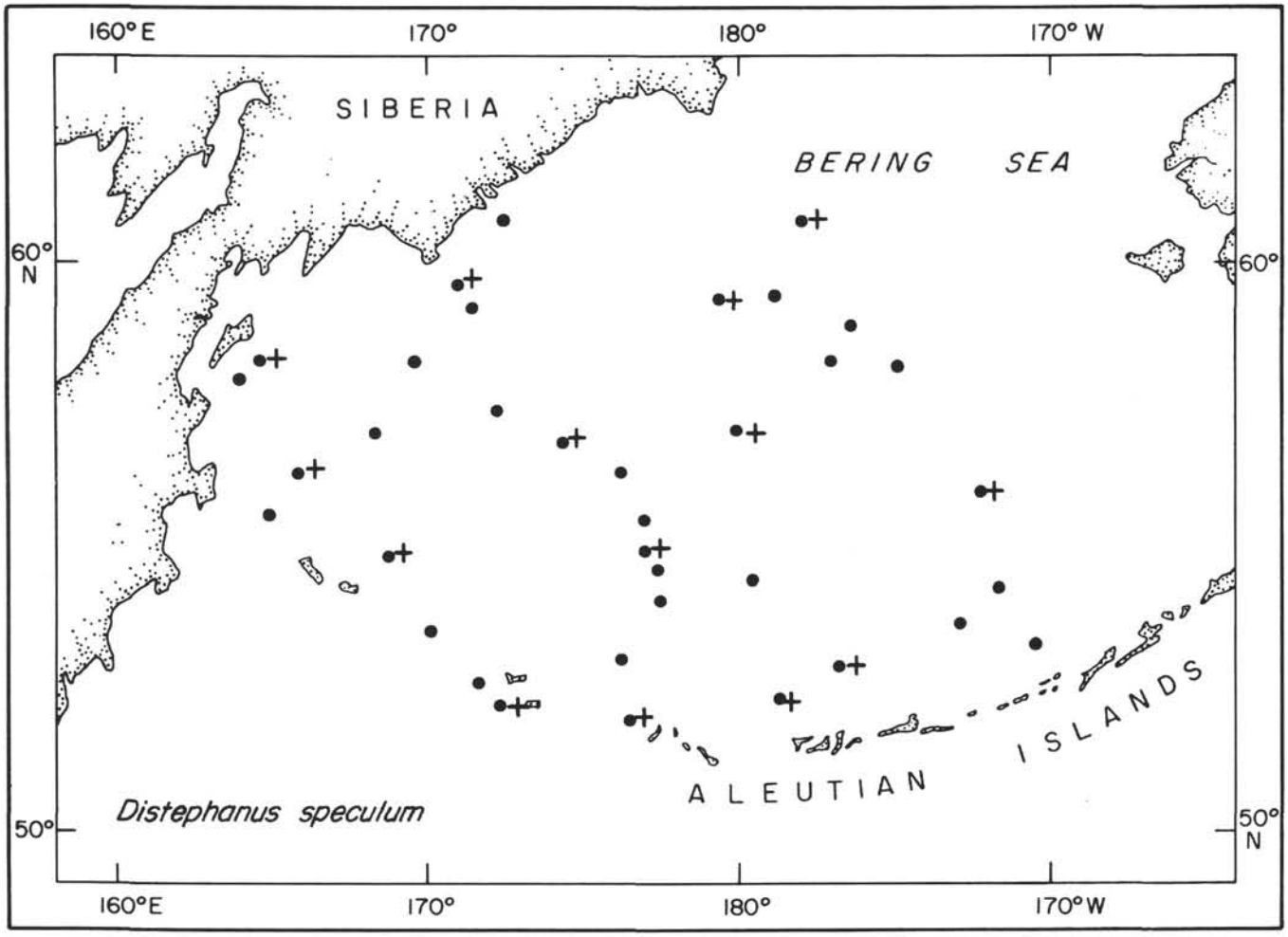


Figure 3. *Distribution of* Distephanus speculum *in surface sediments + = present.*

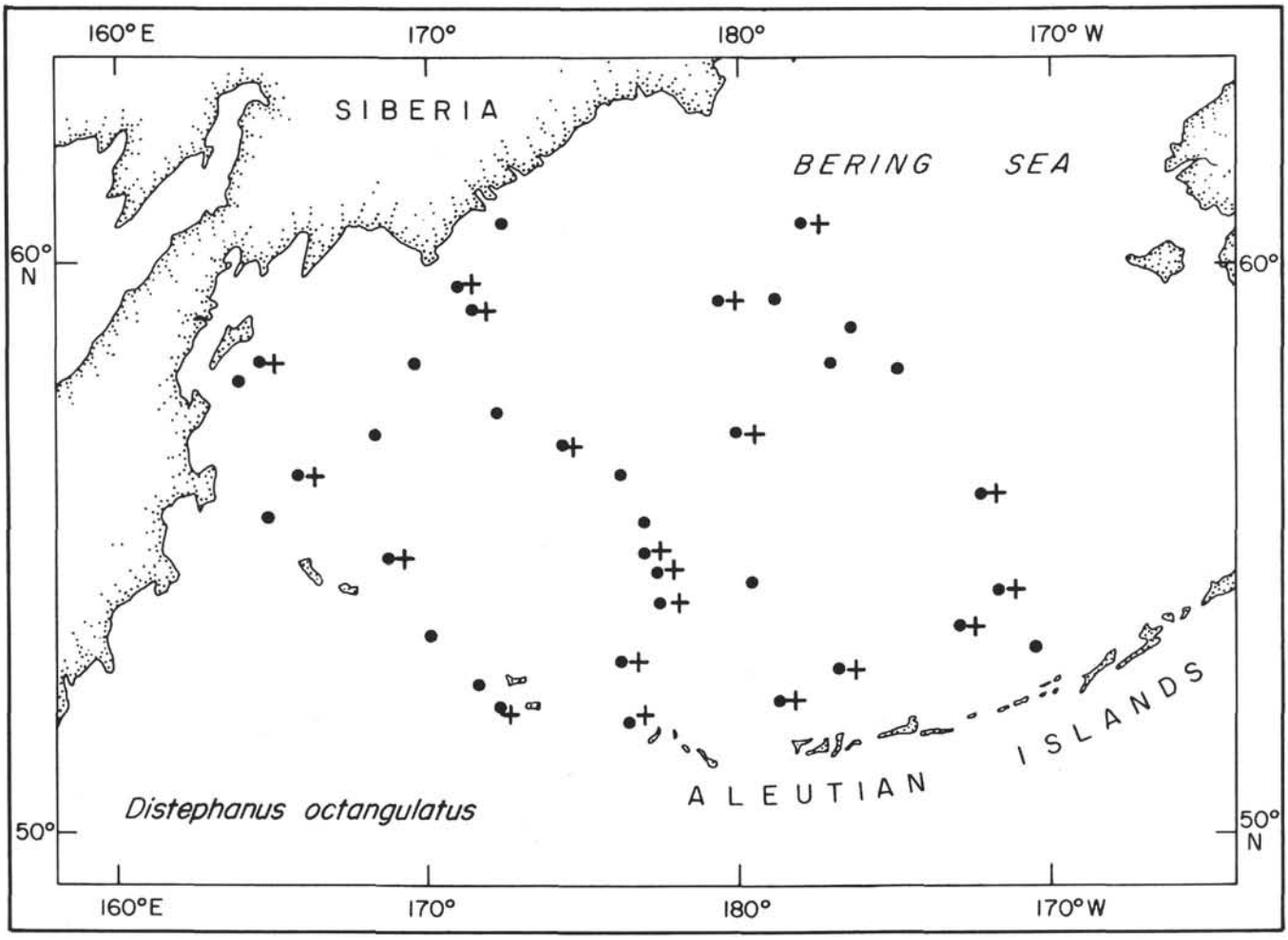


Figure 4. *Distribution of* Distephanus octangulatus *in surface sediments. + = present.*

PLATE 1
(Magnification 500X unless otherwise indicated)

Figures 1-4 *Cannopilus hemisphaericus* (Ehrenberg)
1: 183-14(CC) R-2 (J4/0).
2: 183-14(CC) R-1 (M4/0).
3: 190-16(CC) (limestone), L-1 (V5/0).
4: 190-16(CC) (limestone), L-3 (P29/2).

Figures 5, 6 *Cannopilus sphaericus* Gemeinhardt
5: 190-16(CC) (limestone), L-1 (R5/0).
6: 190-16(CC) (limestone), L-2 (M5/4).

Figures 7, 8 *Corbisema triacantha* (Ehrenberg)
7: 192-31-1(88-90), L-1 (N12/2).
8: 192-31-1(88-90), L-2 (J37/3).

Figures 9, 10 *Dictyocha fibula* Ehrenberg
9: 183-17(CC), L-2 (C24/0).
10: 183-18(CC), L-2 (J1/0).

Figure 11 *Dictyocha formosa* Bachmann
190-16(CC) (limestone), L-2 (R18/2).

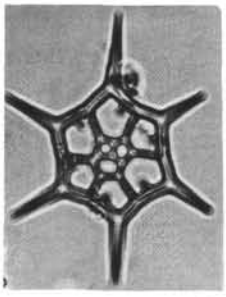
Figures 12-16 *Dictyocha subarctios* Ling
12: 183-8-3(56-58), L-1 (H14/0).
13: 183-8-3(56-58), L-2 (H14/0).
14: 190-8(CC), R-1 (L31/4).
15: 190-8(CC), R-1 (L31/4).
16: 190-8-3(42-44), Abapical view under the scanning electron microscope, X1000.

Figures 17-19 *Distephanus crux* Ehrenberg
17: 183-20-1(80-82), L-1 (Q26/0).
18: 192-31-1(88) (limestone), L-1 (N4/1).
19: 70-B49-1R2, R-2 (H28/1).

Figures 20, 21 *Distephanus crux* var. *stauracanthus* (Ehrenberg)
20: 192-5-3(12-14), L-2 (W15/1).
21: 192-5-3(12-14), L-2 (W15/1).

21: 192-5-3(12-14), L-2 (W15/1)

PLATE 1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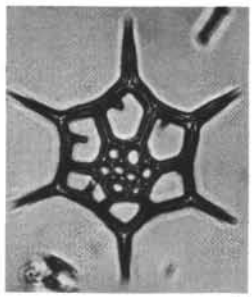
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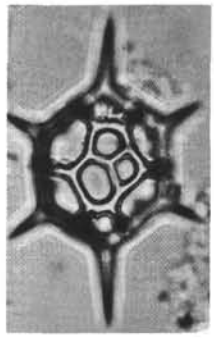
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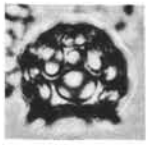
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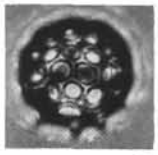
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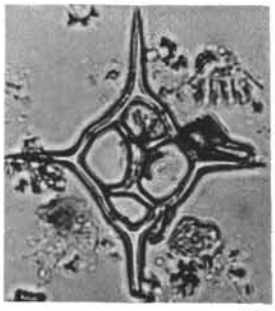
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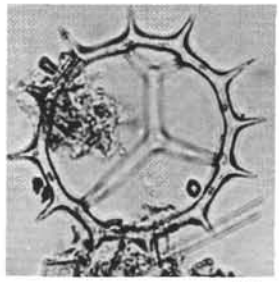
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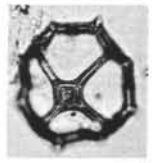
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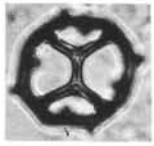
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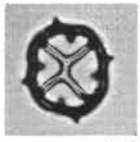
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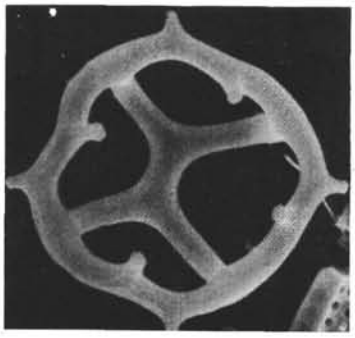
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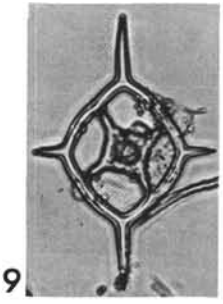
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PLATE 2

(Magnification 500X unless otherwise indicated)

Figures 1-4 *Distephanus octangulatus* Wailes
1: 188-1-1(63-66), L-1 (K31/3).
22: CD 11B, R-2 (M16/0).
3: CD 11B, R-2 (M16/0).
4: 183-4-4(82-84), Apical view under the scanning electron microscope, X1690.

Figures 5, 6 *Distephanus octonarius* Deflandre
5: 184-4-2(132-134), L-2 (X44/3).
6: 191-4-1(102-104), R-2 (X15/1).

Figures 7-9 *Distephanus schauinslandii* Lemmermann
7: 183-20-1(80-82), L-2 (R19/3).
8: 183-20(CC), R-1 (E4/1).
9: 183-20(CC), R-1 (E4/1).

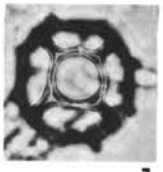
Figures 10-15 *Distephanus speculum* Ehrenberg
10: 183-6-5(82-84), L-2 (K35/4).
11: 183-14(CC), L-2 (Q16/4).
12: 186-3(CC), L-2 (F17/0).
13: 183-7(CC), L-2 (X14/1).
14: 183-6(CC), L-2 (N19/0).
15: 183-6(CC), R-1 (Y25/0).

Figures 16, 17 *Distephanus speculum* var. *pentagonus* Lemmerman
16: 183-17(CC), R-1 (R6/2).
17: 183-17(1), R-1 (Z8/2).

Figures 18-20 *Distephanus speculum* var. *pseudocrux* Schulz
18: 70-B97-1R2, L-2 (P48/1).
19: 70-B97-1R2, L-2 (T29/1).
20: 70-B97-1R2, L-2 (T29/1).

Figures 21, 22 *Mesocena circulus* var. *apiculata* Lemmermann
21: 183-18-4(82-84), R-1 (L21/1).
22: 192-23-1(102-104), R-1 (J28/3).

PLATE 2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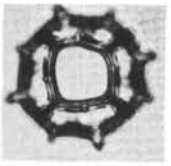
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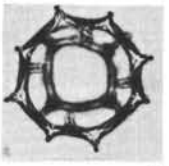
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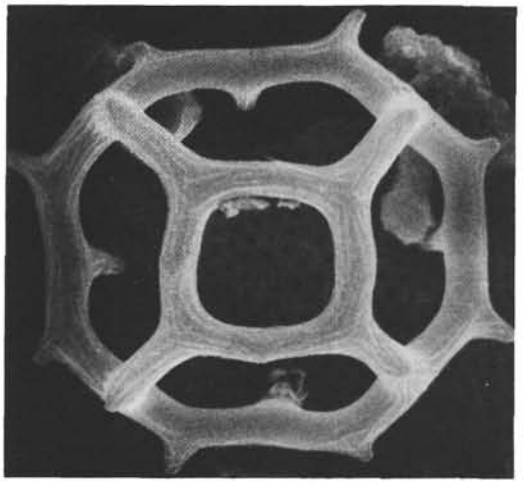
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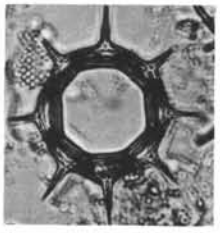
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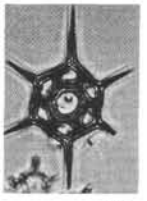
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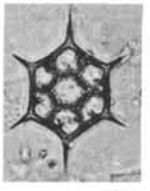
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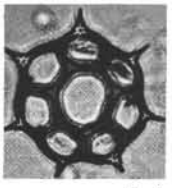
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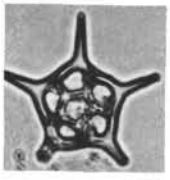
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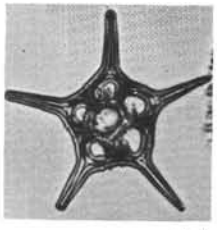
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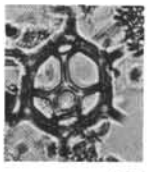
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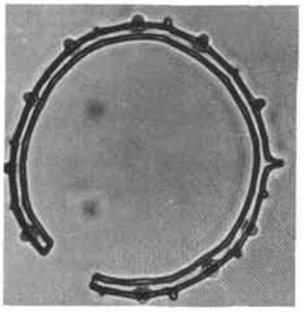
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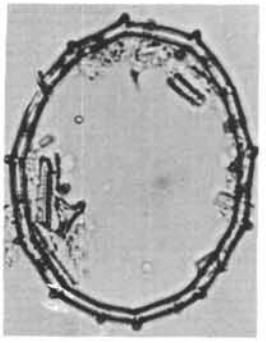
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PLATE 3

(Magnification 500X unless otherwise indicated)

Figures 1-4 *Mesocena* cf. *elliptica* Ehrenberg
1: 183-14(CC), R-1 (U20/1).
2: 192-13-2(52-54), R-1 (Q40/1).
3: 183-15-4(0-2), R-1 (W39/1).
4: 192-15-3(104-104), L-2 (R24/2).

Figures 5, 6 *Mesocena pappi* Bachmann
5: 186-23(CC), R-2 (G41/4).
6: 186-23-2(52-54), L-3 (G55/1).

Figures 7, 8 *Mesocena* ? sp.
7: 192-31-1(88) (limestone), L-3 (H29/0).
8: 192-31-1(88) (limestone), L-3 (M3/1).

Figures 9, 10 *Naviculopsis lata* (Deflandre)
9: 182-22(CC), R-1 (R36/4).
10: 186-23-1(52-54), L-4 (W42/3).

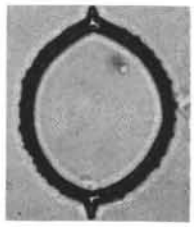
Figures 11, 12 *Septamesocena apiculata* Bachmann
11: 70-B49-1R2, R-1 (G30/3).
12: 70-B49-1R2, L-2 (X47/0).

Figures 13-16 *Ammodochium rectangulare* (Schulz)
13: 192-13-2(52-54), L-2 (M8/4).
14: 192-13-2(52-54), L-2 (M8/4).
15: 192-31-1(88) (limestone), L-2 (W8/2).
16: 192-31-1(88) (limestone), L-2 (W8/2).

Figures 17-21 *Ebriopsis antiqua* (Schulz)
17: 183-14(CC), L-2 (H31/0).
18: 183-14(CC), L-2 (H31/0).
19: 183-19-1(120-122), L-2 (T27/3).
20: 183-19-1(120-122), L-2 (T27/3).
21: 192-31-1(88) (limestone), L-2 (C11/2).

Figures 22-25 *Parathranium californicum* Deflandre
22: 192-13-2(52-54), R-1 (R17/3).
23: 192-13-2(52054), R-1 (N37/0).
24: 192-13-2(52-54), R-1 (N37/0).
25: 192-13-2(52-54), R-1 (N37/0).

PLATE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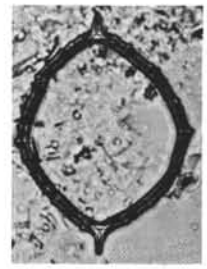
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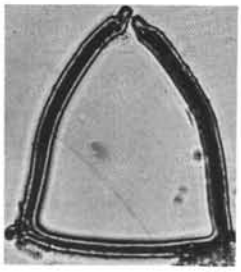
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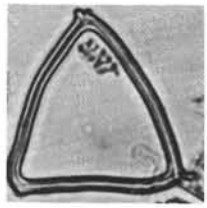
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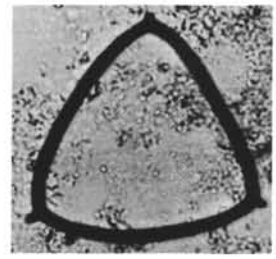
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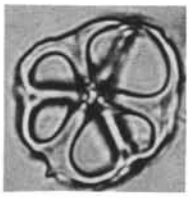
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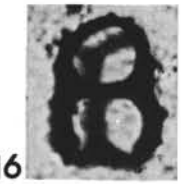
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