38. SILICOFLAGELLATES AND EBRIDIANS FROM LEG 31[1]

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INTRODUCTION

Only a few works have been carried out from the western Pacific submarine deposits on the subject of silicoflagellates and ebridians. Therefore, Leg 31 of the Deep Sea Drilling Project provided a unique opportunity to examine their abundance and biostratigraphic occurrences of the area. The sites drilled, 13 in total (Figure 1, Table 1), fall into three geographic areas; namely, Philippine Basin, southwest of Japan, and the Japan Sea. Accordingly, the results on occurrences of silicoflagellates and ebridians at each site are grouped in the respective areas.

The procedures of sample preparation and the methods used for designating the location of illustrated specimens in the strewn slides as well as relative abundance of taxa in each sample are essentially the same as previously described in the Leg 19 report (Ling, 1973). All the microslides used for the present investigation, including the figured specimens, will be deposited permanently in the Micropaleontology Collection of the Department of Oceanography, University of Washington.

OCCURRENCES

In this section, prior to presenting the results of microscopic observation of samples from each site, pertinent information abailable up to the time of actual drilling by D/V *Glomar Challenger* in the area is presented to provide the background.

Biostratigraphic zonation of silicoflagellates and ebridians recognized from the results of Leg 19 from the subarctic Pacific is used for the discussion of the occurrences.

Philippine Sea

Background: Haeckel (1887) described *Distephanus corona* and *Cannopilus diplostaurus* from samples of *Challenger* Stations 231 and 225, respectively.

Results: From the samples examined from Sites 290-295, no silicoflagellates or ebridians were recovered. Their complete absence matched with that of diatoms on this cruise suggesting that these siliceous microplanktonic remains were controlled by the similar physicochemical factors. In addition, for silicoflagellates and ebridians, a general lower abundance in the modern watermass undoubtedly contributed as another major factor for their absence in the area.

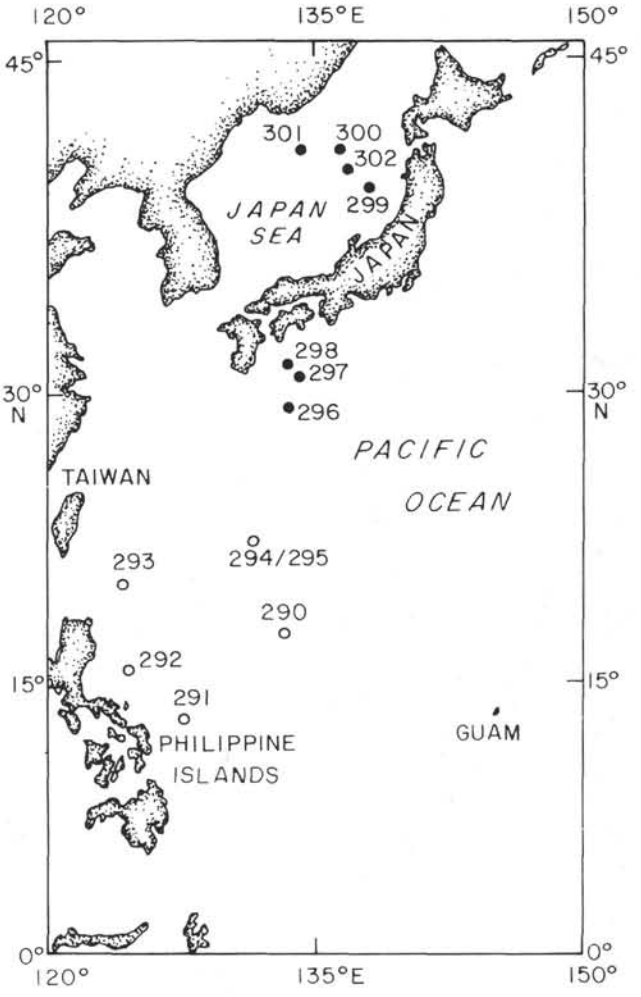

Figure 1. *Locations of drilling sites of Deep Sea Drilling Project, Leg 31. Filled circles = cored sediments in which silicoflagellates and ebridians were observed; open circles = cored sediments in which silicoflagellates and ebridians were absent.*

Southwest of Japan

Background: In 1943, Yanagisawa presented the distribution of silicoflagellates from the surrounding waters of Japan and related their occurrences with temperature and salinity of watermasses. His samples were collected from the near-shore areas or inside of bays.

In order to understand the distributional pattern of silicoflagellates from the surface sediments and to relate it to the overlying current pattern of the area, a sampling

[1]Contribution No. 776 from the Department of Oceanography, University of Washington.

TABLE 1
Coordinates of Drilling Sites, Deep Sea Drilling Project, Leg 31

Hole	Latitude (N)	Latitude (E)	Water Depth (m)
290	17°44.85′	133°28.09′	6062.5
290A	17°45.05′	133°28.44′	6062.5
291	12°48.43′	127°49.85′	5217
291A	12°48.45′	127°48.98′	5217
292	15°49.11′	124°39.05′	2943
293	20°21.25′	124°05.65′	5599
294	22°34.74′	131°23.13′	5784
295	22°33.76′	131°22.04′	5802
296	29°20.41′	133°31.52′	2920
297	30°52.36′	134°09.89′	4458
297A	30°52.36′	134°09.89′	4458
298	31°42.93′	133°36.22′	4628
298A	31°42.93′	133°36.22′	4628
299	39°29.69′	137°39.72′	2599
300	41°02.96′	136°06.30′	3427
301	41°03.75′	134°02.86′	3520
302	40°20.13′	136°54.01′	2399

program was carried out in 1970 by the present author during Cruise 49 aboard R/V *Thomas G. Thompson* of the University of Washington. The cruise track was laid out to cross longitudinally the so-called "subarctic boundary" of Dodimead et al. (1963).

The abundance of silicoflagellate taxa recovered from the surface sediments of cores are presented in Figures 2-6. Apparently three groups can be recognized; occurrences of *Distephanus speculum* and *D. octangulatus* characterize the northern part, while that of *Dictyocha fibula* is generally limited in the south. The two varieties of the latter taxon, var. *aculeata* and var. *messanensis*, are found in most of the samples in the area. Such biogeographic differentiation found in the bottom

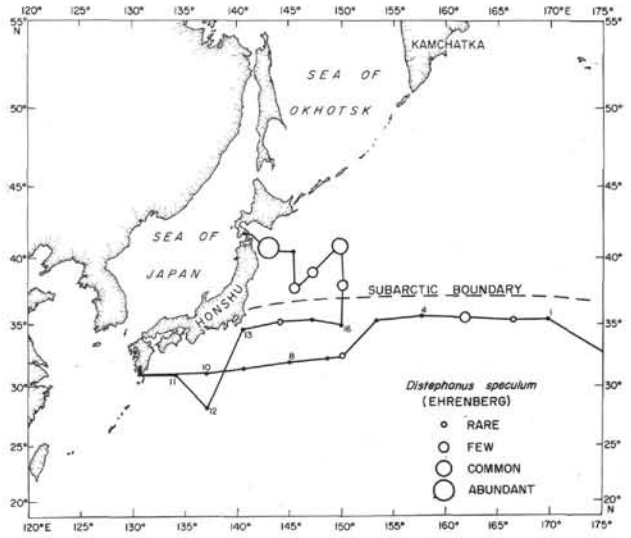

Figure 3. *Distribution of* Distephanus speculum *(Ehrenberg) from surface sediments of R/V* Thomas G. Thompson *Cruise 49 (TT-49).*

sediments is expected from the results of previous studies of the North Pacific (Ling, 1970, 1973, in press) and thus conforms with the modern regime of the surface circulation pattern of the area. The southern part of the area is under the direct passage of warm and high salinity Kuroshio, while the northern cores were collected from the area of the southward-flowing cold, low-salinity Oyashio watermass. The two currents converge in the northeast of Japan and apparently this mixing water provides a favorable condition for the two varieties of *Dictyocha fibula.*

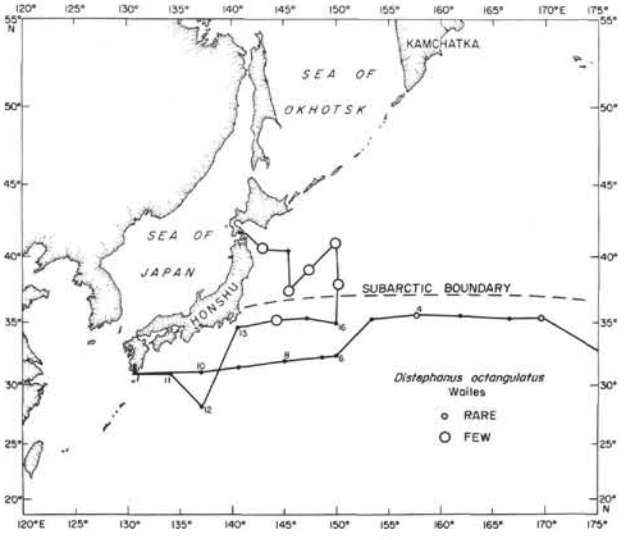

Figure 2. *Distribution of* Distephanus octangulatus *Wailes from surface sediments of R/V* Thomas G. Thompson *Cruise 49 (TT-49).*

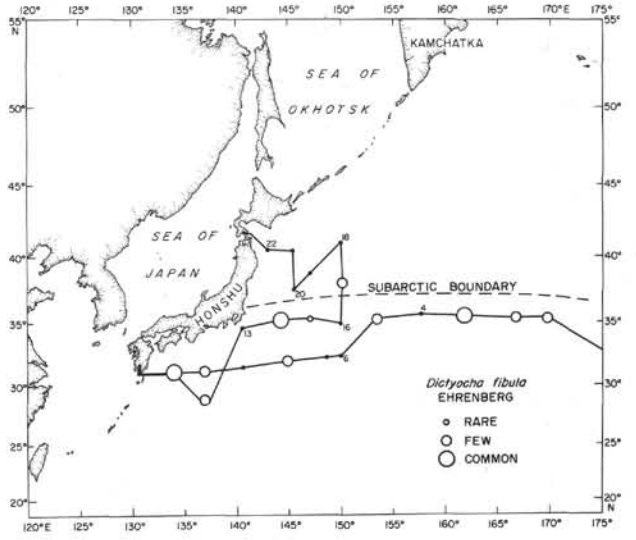

Figure 4. *Distribution of* Dictyocha fibula *Ehrenberg from surface sediments of R/V* Thomas G. Thompson *Cruise 49 (TT-49).*

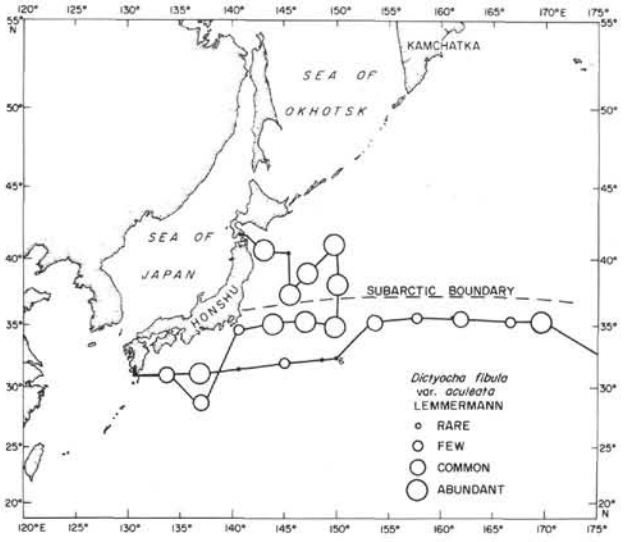

Figure 5. *Distribution of* Dictyocha fibula *var.* aculeata *Lemmermann from surface sediments of R/V* Thomas G. Thompson *Cruise 49 (TT-49).*

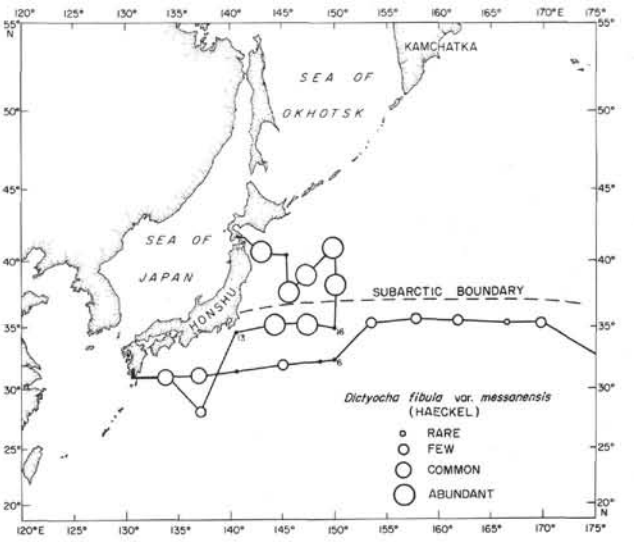

Figure 6. *Distribution of* Dictyocha fibula *var.* messanensis *(Haeckel) from surface sediments of R/V* Thomas G. Thompson *Cruise 49 (TT-49).*

Due to the rather rapid rate of sedimentation near Japan (Opdyke and Foster, 1970), only two piston cores collected during Cruise 49 penetrated below the extinction level of *Dictyocha subarctios*.

From the land section of the Pacific Ocean side of Honshu, Ling and Kurihara (1972) recorded the occurrence of *Distephanus crux* and *D. speculum* from the Miocene deposits of Hayama Group.

Results: Only rare to few silicoflagellates belonging to *Dictyocha fibula*, and its varieties, and *Distephanus speculum* are found from sediments of Pleistocene age. Their occurrences are limited to the uppermost part of the cored sediments: namely, Site 296, on a terrace of the northern Palau Kyushu Ridge, in Core Catcher 1 sample only; Site 297, in the Shikoku Basin immediately south of the Nankai Trough, from surface sediments to Core 6 (86.5 m) (Table 2); and Site 298, on the lower inner slope of the Nankai Trough, from the top of the sediments to 3-1, 130-132 cm, approximately 175.5 meters depth (Table 3).

Japan Sea

Background: Among the three geographic areas under consideration, occurrences of silicoflagellates and ebridians are best documented both from the subsurface deposits and from rocks exposed from western Honshu.

Based on plankton tow samples, Shitanaka et al. (1970) reported a quantitative distribution of silicoflagellates in the water columns and related it to physicochemical properties of the watermass. They also examined 19 surface sediments of the sea and proposed a relationship, *Dictyocha/Distephanus* = -1/4 (Latitude) + 12, in the area. Ichikawa (1972) recorded these microfossils from a siltstone collected from the Yamato Rise.

Investigations by Ichikawa since 1956, and later by Bachman (1964) alone or in collaboration with Ichikawa (1962) and Fuji (1968-1970) on Neogene siliceous sediments which crop out along the rim of the Japan Sea resulted in numerous publications. However, these works were limited lithologically only to diatomaceous beds as well as to the number of samples examined. Realizing this situation, Ling (1971) published the results of his study based on a series of samples from the

TABLE 2
Silicoflagellates and Ebridians From Site 297

Sample (Interval in cm)	Abundance	Preservation	*Dictyocha fibula*	*D. fibula* var. *messanensis*	*D. fibula* var. *aculeata*	*Distephanus speculum*	Age
1, CC	R	G	R	R			
2-1, 107-109							
2-1, 110-112	R	M	R	R	R		
2, CC	R	G	R	R			
3-1, 90-92	R	M		F	F	R	
3-3, 30-32	R	M	R				
3, CC	F	G	F	R			
4-1, 60-62	R	M	F	R			
4-3, 40-42							
4-5, 40-42	R	G	R	R	R		
4, CC	F	G		R	R		
5-1, 40-42	R	M			R		
5-3, 40-42	R	M		R			
5-5, 45-47	R	M			R		
5, CC	R	G	R				
6-1, 40-42	R	M	R				
6-3, 40-42							
6-5, 40-42							
6, CC	R	M	R				

Pleistocene

TABLE 3
Silicoflagellates and Ebridians From Site 298

Sample (Interval in cm)	Abundance	Preservation	*Distephanus speculum*	*Dictyocha fibula* var. *messanensis*	*D. fibula*	*D. fibula* var. *aculeata*	Age
1, CC	R	M	R	R			Pleistocene
2-1, 112-114	R	M			R	+	
2-3, 60-62							
2, CC							
3-1, 130-132	R	M			F		

Shinzan diatomaceous member of the Onnagawa Formation of Akita Prefecture. Recently, a similar investigation has been completed in the Nadaura region of Noto Peninsula (Ling and McPherson, in press a).

Therefore, one of the main objectives of the present author's in joining this particular leg was to document the microfloral succession of the Sea of Japan by the continuously cored sediments and to piece together the available data published on the discontinuous land sections into a single, stratigraphically workable framework. Unfortunately, this objective was not accomplished.

Results: Site 299 was located in the northwest part of the Yamato Basin, and 532 meters of sands, silts, clays, and claystones were collected. Silicoflagellates and ebridians are moderately preserved and are present from Cores 1 to 29 (304 m), but they are completely absent below this depth (Table 4).

From the topmost sediments to a sample, 4-2, 5-7 cm, approximately 30 meters, silicoflagellates are rare and belong to the *Distephanus octangulatus* Zone. Below this to Core 7 (66.5 m), complete absence of *Distephanus octonarius* Deflandre leaves this interval unassignable to zonation. Starting from Core 8 (66.5 m) to at least a sample, 13-4, 30-32 cm, about 119 meters, the sediments belong to the *Dictyocha subarctios* Zone. The top of *Ammodochium rectangulare* Zone is recognized from a sample, 17-2, 60-62 cm (about 154 m). This then leaves a zonal boundary which also marks the Plio-Pleistocene boundary within a section of Cores 14, 15, and 16. Silicoflagellates and ebridians are common to rare in the sediments below Core 17 down to Core 29 (304 m). Very rare occurrence of specimens belonging to *Cannopilus hemisphericus* (Ehrenberg) and only in Core Catcher 29 seem to suggest that silicoflagellate-bearing sediments of this section still belong to *Ammodochium rectangulare* Zone. No specimen of these groups of microfossils was found below this level.

Site 300 was drilled in the central portion of the Japan Basin adjacent to the north end of the Yamato Rise. Due to surface sand and gravel, only two core catcher samples, down to 117 meters depth, were recovered which contained *Distephanus octangulatus* Wailes together with apparent reworked specimens of *Ebriopsis antiqua* (without spine form).

Site 301 was located in the Japan Basin about 200 km southwest of Site 300. Moderately preserved silicoflagellates and ebridians are found throughout the upper 240.5-meter section of turbidites, sand, silts, and clay, and 256 meters of clayey diatomite and diatomaceous claystone below (Table 5).

Occurrence of *Distephanus octangulatus* Wailes in a sample, 2-3, 30-32 cm, approximately at 120 meters, suggests the sample may still be in the lower part of the *D. octangulatus* Zone. The stratigraphic section of Core Catchers 2 to 4, 126.5-164 meters, is identified belonging to *Dictyocha subarctios* Zone. Sediments of Cores 5, 6, and 7 contain rare specimens or are completely absent of these microfossils. The upper limit of the *Ammodochium rectangulare* Zone is placed at the top of Core 8 (240.5 m) where diatomaceous sediments are encountered at this site. Thus, the Plio-Pleistocene boundary apparently coincides with this lithological change. The *Ammodochium rectangulare* Zone seems to extend down to Core 9 (279 m) because the top of underlying *Ebriopsis antiqua* (without spine form) Zone is placed at the top of Core 10 (298 m). The lower boundary of the latter zone cannot be determined at this time because of rare and sporadic occurrence of *Cannopilus hemisphericus* (Ehrenberg). The top of the *Distephanus quinquangellus* Zone is tentatively placed at the top of Core 16 (421 m) and Core 20, the deepest of the site at 497 meters, is still within this zone.

Site 302, the last site of the leg, was located on the northern flank of the Yamato Rise. The upper unit of diatomaceous ooze and zeolitic clay down to Core 16 (361 m) yield the best assemblage of this group of microfossils observed during the entire leg and is particularly good as the drilling depth increased (Table 6).

The sediments retained in Core Catcher 1 belong to the *Distephanus octangulatus* Zone suggested by the presence of that species. Sample 2-5, 80-82 cm and Core 3 are assigned to the *Dictyocha subarctios* Zone. Core 4 (57-66.5 m) contains only reworked, rare specimens. In Core 5, joint occurrences of both *Ammodochium rectangulare* and *Ebriopsis antiqua* (without spine form) are noted. Apparently, an interval corresponding to an entire *Ammodochium rectangulare* Zone, and, also possibly an upper part of *Ebriopsis antiqua* (without spine form) Zone are missing from this site. The lower boundary of this zone and the upper limit of the underlying *Cannopilus hemisphericus* Zone were not determined from the present study. The top of the *Distephanus quinquangellus* Zone is drawn between Cores 7 and 8 (123.5-133 m), and this zone extends down to Core 14 (256.5 m). *Mesocena circulus* var. *apiculata* Zone, the oldest silicoflagellate zone that is recognized from the present Leg 31 sediments of the Sea of Japan, is found in sediments of Core 15 and in Sample 16-1, 96-98 cm (266-352.5 m).

Unfortunately, because of a shipboard medical emergency, drilling at this site had to be completed

TABLE 4

Silicoflagellates and Ebridians From Site 299

Sample (Interval in cm)	Abundance	Preservation	*Distephanus speculum*	*Dictyocha fibula*	*D. fibula* var. *aculeata*	*D. fibula* var. *messanensis*	*Distephanus octangulatus*	*D. crux* var. *stauracanthus*	*Mesocena* sp. cf. *M. elliptica*	*Dictyocha lingi*	*D. subarctios* var. *minoriformis*	*Mesocena* sp. cf. *M. elliptica*	*Dictyocha* sp. B.	*Ammodochium rectangulare*	*Parathranium tenuipes*	*Ebriopsis antiqua* (without spineform)	*Dictyocha pseudofibula* var. *complexa*	*Parathranium intermedium*	Age
1-1, 10-12	R	M	F																
1-4	R	M	R																
1, CC	R	M																	
2-2, 10-12	R	M	F	R	R	R													
2-4, 30-32	R	M	R																
2, CC	R	M					R												
3-2, 20-22	R	M	R		R														
3-4, 25-27	R	M	R																
3, CC	F	M	R	F	F	R	R	R											
4-2, 5-7	R	M					R												
4-4, 80-82		M	R	F	C			R											
4, CC	R	M	R	R															
5-2, 55-57	R	M	R																
5-5, 10-12	F	M			R			F											
5, CC	F	M	F	R		R		F											
6-2, 30-32	R	M	R	R															
6-4, 27-29	R	M		R															
6, CC	R	M																	
7-2, 22-24	C	M	R	R					F	F									
7-4, 22-24																			
7, CC	F	M	C																
8-2, 28-30	C	M	F	R	R				F		F								
8, CC	F	G	F						R	R	C								
9-2, 5-7	C	G	R	R					F		F								
9-4, 8-10	C	M		F	R				C	R	F								
9, CC	R	G		R	R				R		R								
10-2, 1-3	F	G	R	F					C	R	F								
10-4, 15-17																			
10, CC	F	M	R	C															
11-2, 30-32	C	G	R						R		F	C							
11-4, 25-27	C	G	F	F					F		F	C							
11, CC	F	M		F							F								
12-2, 70-72	F	M	R	F							F								
12-5, 30-32	R	M	R	F						R	F								
12, CC	R	M		R															
13-2, 30-32	R	M		R					F		R								
13-4, 30-32	R	M	R	R							F								
13, CC																			
14-2, 40-42	R	M	R	F					R			+							
14-4, 9-11																			
14, CC	R	M	R	F															
15-2, 18-20	F	M	F	C									R	?					
15-4, 25-27	C	M	C	R									R						
15, CC	R	M	F																
16-2, 130-132	F	M	F	F										?					
16-4, 55-57	C	M	F	C									R						
16, CC	F	M	C	F										R					
17-2, 60-62	C	M	C	C									R	F					
17-4, 100-102	C	M	A	C										F	R				
17, CC	F	M	C	F										R					
18-2, 68-69	C	M	C	C									F	F					
18-4, 50-52	C	M	C	C									R	F					
18, CC	R	M	F										R						
19-2, 25-27																			
19-4, 30-32	F	M	C										R	F					

Age: Middle – Late; Pleistocene; Early; ?; Late Pliocene

TABLE 4 – *Continued*

Sample (Interval in cm)	Abundance	Preservation	*Distephanus speculum*	*Dictyocha fibula*	*D. fibula* var. *aculeata*	*D. fibula* var. *messanensis*	*Distephanus octangulatus*	*D. crux* var. *stauracanthus*	*Mesocena* sp. cf. *M. elliptica*	*Dictyocha lingi*	*D. subarctios* var. *minoriformis*	*Mesocena* sp. cf. *M. elliptica*	*Dictyocha* sp. B.	*Ammodochium rectangulare*	*Parathranium tenuipes*	*Ebriopsis antiqua* (without spineform)	*Dictyocha pseudofibula* var. *complexa*	*Parathranium intermedium*	Age
19, CC													R						
20-2, 90-92	R	M	F											F					
20, CC																			
21-1, 46-48	R	M	F											R					
21, CC	R	M	F																Late Pliocene
22-2, 30-32	F	M	F	F										F		R			
22-4, 30-32	C	M	C	C										C			+		
22, CC	R	M												F		R			
23, CC	C	M	C	F										F		R	F		
24-1, 83-85	F	M	F										+	F					
24, CC	C	M	F	R										R			R		
25-1, 55-57	F	M	R											F			R		
25, CC	R	M	R	R										R				+	
26-1, 110-112	R	M	R											R		R			
26, CC	F	M	F											R		R			
27, CC	F	M	F	F															
28-1, 109-111	R	M												R	+				
28, CC																			
29-1, 133-135																			
29, CC	F	M	C	R									+	R					

rapidly below Core 16; therefore, when Core 17 (456-465.5 m) was retrieved, sediments were already in the clayey lower unit and completely barren of any microfossils. In Core 19 (529-530 m) 1 meter of unfossiliferous claystone, volcanic sand, and green tuff were recovered which is presumed to be correlative with similar rocks exposed in northeastern Japan.

COMPARISON WITH HIGH-LATITUDE SILICOFLAGELLATE AND EBRIDIAN ZONATION

In Table 7 an attempt is made to compare the biostratigraphic occurrences of silicoflagellates and ebridians found in Leg 31 materials with the zonation proposed from the results of Leg 19 in the high-latitude North Pacific including the Bering Sea.

It is apparent that the reason for differences in the results of two legs in the middle to high latitude North Pacific is the rare or complete absence of *Distephanus octonarius* and *Cannopilus hemisphericus* from the Sea of Japan sediments. Thus, it can only be stated here that future study from the land-sections of western Honshu is needed before firmly establishing the biostratigraphic occurrences of silicoflagellates and ebridians in the entire subarctic Pacific.

SILICOFLAGELLATE AND EBRIDIAN REFERENCE LIST

Almost all the silicoflagellate and ebridian species observed during the present investigation have been discussed recently (Ling, 1970, 1971, 1972, 1973). In this section, taxa are arranged alphabetically within silicoflagellates and ebridians, and their synonymy is kept to a minimum by listing only the original references for the named taxa and selected additional references wherever deemed appropriate. Remarks are directed to the new results obtained from present observations or are made when necessary to elucidate the concept of the taxon. Most of the taxa listed below are illustrated; their plate and figure numbers are shown in parentheses.

Cannopilus hemisphaericus (Ehrenberg): *Dictyocha hemisphaerica* Ehrenberg, 1844, p. 266; Remarks: Only a few specimens were found in the present study. (Plate 1, Figures 1, 2).

Dictyocha fibula Ehrenberg, 1839, p. 129; Ling, 1970, p. 90, 91, pl. 18, fig. 4-10. (Plate 1, Figures 3-6).

Dictyocha fibula var. *aculeata* Lemmermann, 1901, p. 261, pl. 11, fig. 1, 2; Ling, 1970, p. 91, 92, pl. 18, fig. 11-13. (Plate 1, Figures 7, 8).

Dictyocha fibula var. *messanensis* (Haeckel) = *Dictyocha messanensis* Haeckel, 1861, p. 799; Ling, 1970, p. 92, 93, pl. 18, fig. 14. (Plate 1, Figures 9, 10).

Dictyocha lingi Dumitrica, 1972, p. 906, pl. 8, fig. 1-7. Remarks: Found only from Hole 299. Like in the central North Pacific core sediments, range of the present species is approximately the same as that of *D. subarctios*. (Plate 1, Figure 11).

Dictyocha mutabilis Deflandre, 1950, fig. 203, 204, (?), 210 (?). Remarks: In contrast to previous discussions (Ling, 1970, p. 93-95), Deflandre's nomenclature is

TABLE 5
Silicoflagellates and Ebridians From Site 301

Sample (Interval in cm)	Abundance	Preservation	*Distephanus speculum*	*Dictyocha fibula*	*Distephanus crux* var. *stauracanthus*	*Dictyocha fibula* var. *aculeata*	*Distephanus octangulatus*	*Dictyocha subarctios*	*Ammodochium rectangulare*	*Dictyocha* sp. B.	*Ebriopsis antiqua* (without spine)	*Cannopilus hemisphaericus*	*Hermesium adriaticum*	*Distephanus quinquanseilus*	Age
2-1, 12-14	F	M	C	R											Mid-Late Pleistocene
2-3, 30-32	F	M	C	F	R	R	R								
2-5, 55-57	R	M			R										
2, CC	C	G	F		R			R							
3-1, 117-119	C	M	C	R				F							
3-2, 25-27	F	M						F							Early Pleistocene
3, CC	C	M	R					R							
4-2, 60-62	R	M						R							
4-4, 65-67	R	M	F												
4, CC	C	M	R	R				F							
5-2, 68-70	R	M	R												
5-4, 72-74	R	M		+											
5, CC	R	M	R												
6, CC	R	M	R												
7-1, 128-130															
7, CC															Late Pliocene
8-2, 6-8	F	M	C						C	F					
8, CC	R	M	R							R					
9-1, 130-132	C	M	F						F						
9, CC	F	M	F						R						
10-1, 25-27	C	M	F						F		F				Early Pliocene
10, CC															
11-1, 75-77	C	M	C						F		R				
11, CC	C	M	C						C		C				
12, CC	C	M	C						C		C				
13-1, 68-70	C	M	C						C		C				
13, CC	F	M	R						F		F				
14-1, 73-75	C	M	C						C		C				
14, CC	F	M	F						C						
15-1, 14-16	F	M	R						R		F				
15-3, 70-72	F	M	C	+					F		F	+			
15, CC	C	M	C						C		C		+		
16-1, 73-75	C	M	C						C		C		+	R	
16, CC	F	M	C						F		R	+	+		
17-1, 31-33	R	M	F						F		F				
17, CC	F	M	R						F		F	F			Late Miocene
18-1, 66-68	R	M									R				
18-3, 6-8	R	M							R						
18, CC															
19-1, 70-72	R	M	R								R				
19-4, 47-49	R	M							R					R	
19, CC	R	M										+		R	
20-2, 116-118	R	M							F		R			R	
20-4, 50-52	R	M							R						
20, CC	R	M												R	

retained here for those with basal accessory spines. The specimens are found only from Site 299. (Plate 1, Figure 12).

Dictyocha pentagona (Schulz) = *Dictyocha fibula* var. *pentagona* Schulz, 1928, p. 255, fig. 41 a, b; Bukry and Foster, 1973, p. 827, pl. 3, fig. 10. Remarks: Unusually few to abundant occurrences of this species is found in Hole 302. It is interpreted here that this may bear local significance. (Plate 1, Figures 13, 14).

Dictyocha pseudofibula var. *complexa* Tsumura, 1963, p. 56, 57, pl. XI, fig. 4; pl. XXIV, fig. 1. Remarks: The specimens recovered from Site 299 agree with those described by Tsumura from water off Hachijo Island in the Pacific Ocean except the size is larger. Tsumura

TABLE 6
Silicoflagellates and Ebridians From Site 302

Sample (Interval in cm)	Abundance	Preservation	*Distephanus speculum*	*Dictyocha fibula* var. *aculeata*	*D. fibula* var. *messanensis*	*Distephanus octangulatus*	*Dictyocha subarctios*	*Mesocena* sp. cf. *M. elliptica*	*Ammodochium rectangulare*	*Ebriopsis antiqua* (without spine)	*Distephanus crux*	*Dictyocha pentagona*	*Distephanus quinquangellus*	*Cannopilus hemisphaericus*	*Hermesium adriaticum*	*Parathranium intermedium*	*Dictyocha* sp. A.	*Paradictyocha polyactis*	*Dictyocha fibula*	*Mesocena circulus* var. *apiculata*	*Dictyocha mutabilis*	Age		
1, CC	R	M	R	F	+	+																M.-L.		
2-1, 90-92	F	G	F	R																				
2-3, 24-26	F	G	F																					
2-5, 80-82	R	G					F																	
2, CC	C	G	C				C	F														Early		Pleistocene
3-1, 125-127	R	M	R																					
3-3, 50-52																								
3-5, 20-22																								
3-6, 128-130	F	M	C				F																	
3, CC	R	M	R				R																	
4-1, 30-32																								
4-3, 20-22																						?		
4-5, 10-12																								
4, CC																								
5-1, 80-82	F	M	C					F	F															
5-3, 40-42	C	M	F					A	C															
5-5, 80-82	A	M	A					C	A															
5, CC	C	G	F					F	A													Early		Pliocene
6, CC	F	M	R					R	F															
7-1, 20-22	R	M							F															
7-3, 20-22	F	M	R					F	C															
7-5, 20-22	R	M	R					F	F															
7, CC	F	M						F	R															
8-1, 20-22	C	M	C					A	C		F	F	C	+										
8-3, 20-22	A	M	C					C	A		F	F	F	+	F									
8-5, 20-22	A	M	C					A	C			F	C		R									
8, CC	F	M	F					R	R				R											
9-1, 36-38	C	M	F				R	F	R		F		F	R										
9, CC	C	M					C	F	F		R		F		R									
10-1, 20-22	A	M	F					C	F			R	R											
10-3, 20-22	A	M					C	C	C			R	F	A										
10-5, 20-22	A	G					C	F	F		R	R	R	A	F									
10, CC	A	G					C	A	A					A										
11-1, 130-132	A	G	A					C	F		R	F	R	C	F									
11-3, 20-22	A	G	A					C	F		R	A		F										
11-5, 20-22	A	G	A					C	F		R	C	R	F	R	+								
11, CC	A	G	C					A	F		R	F		C	R		R	+						
12-1, 65-67	A	G	C					A	C			R	F	F	F		A							
12-3, 20-22	A	G	F					A	C		R	F		R	R		C							
12, CC	A	G	F					C	C			C	F	R	R		C							
13-1, 22-24	A	G	C						C				C	C			R							
13, CC	A	G	C					F	C				C	F			C							
14-1, 100-102	A	G	C				+	A	A		F	R	C	R	F		F		R					
14-3, 20-22	A	G	R					A	A		F	R	F	R	F				R					
14-5, 20-22	A	G	F					A	C		R	R	F						R					
14, CC	A	G	F					A	A		R	R	A						F					
15-1, 50-52	A	G	C					C	C		R	R			C	+	R	+	A	C	F			
15, CC	A	G	C					A	A			R			F		R		A	C	F			
16-1, 96-98	A	G	C				+	A	C		R				C		R		F	F				
16, CC																								

TABLE 7

Comparison of Silicoflagellate and Ebridian Zones Between the High Latitude North Pacific Ocean and the Japan Sea

Age		Silicoflagellates and Ebridian Zones		Sites		
		High Latitude North Pacific (Ling, 1973)	Japan Sea (in this paper)	299	301	302
Pleistocene	Late	*Distephanus octangulatus*	*Distephanus octangulatus*	1-1 (10-12)	2-1 (12-14)	1(CC)
	Middle	*Distephanus octonarius*		4-2 (5-7)	2-3 (30-32)	
	Early	*Dictyocha subarctios*	*Dictyocha subarctios*	8-2 (28-30) 13-4 (30-32)	2(CC) 4(CC)	2-5 (80-82) 3(CC)
Pliocene	Late	*Ammodochium rectangulare*	*Ammodochium rectangulare*	16(CC) 29(CC)	8-2 (6-8) 9(CC)	
		Ebriopsis antiqua (without spine)	*Ebriopsis antiqua* (without spine)		10-1 (25-27)	5-1 (80-82)
	Early	*Cannopilus hemisphaericus*	*Cannopilus hemisphaericus*		15(CC)	7(CC)
Miocene	Late	*Distephanus quinquangellus*			16-1 (73-75) 20(CC)	8-1 (20-22) 14(CC)
		Mescocena circulus var. *apiculata*				15-1 (50-52) 16-1 (96-98)
	Early	*Distephanus schauinslandii*				

regarded the occurrence as recent, however, no specimens were encountered from surface sediments of the R/V *Thomas G. Thompson* Cruise 49. It is believed that this taxon possesses rather limited geographical as well as geological distribution. (Plate 1, Figure 15).

Dictyocha subarctios Ling, 1970, p. 95, 96, pl. 18, fig. 16-18; pl. 19, fig. 1-4. (Plate 1, Figures 16-19).

Dictyocha sp. A. Remarks: This species resembles that found in the samples of the Shinzan diatomaceous member of Onnagawa Formation (Ling, 1971, pl. 1, fig. 2) by possessing an outwardly concave basal body ring and an apical bar which is subparallel to the minor axis. (Plate 1, Figures 20, 21).

Dictyocha sp. B. Remarks: The specimens with a hexagonal basal body ring like *Distephanus speculum,* but an apical structure is rather simple; the only apical bar is like *Dictyocha fibula.* An apical bar is always obliquely subparallel to the major axis. An apical accessory spine is near the middle of the bar. Found only in Core 11 sediments of Hole 299. (Plate 1, Figures 22, 23).

Distephanus crux (Ehrenberg) = *Dictyocha crux* Ehrenberg, 1840, p. 207, 208. (Plate 1, Figure 24).

Distephanus crux var. *stauracanthus* (Ehrenberg) = *Dictyocha stauracanthus* Ehrenberg, 1845, p. 76; Ling, 1970, p. 96, 97, pl. 19, fig. 7, 8. Remarks: Occurrence of this species in the subarctic Pacific region including the Bering Sea (Ling, 1970, 1972) seems to be between those of *Dictyocha subarctios* and *Distephanus octangulatus.* (Plate 1, Figures 25, 26).

Distephanus octangulatus Wailes, 1932, p. 216, fig. 3. Remarks: The distribution of this species is apparently limited to the subarctic watermass. (Plate 2, Figures 1, 2).

Distephanus quinquangellus Bukry and Foster, 1973, p. 828, pl. 5, fig. 4 = *Distephanus speculum* var. *pentagonus* Lemmermann, 1901, p. 264, pl. 11, fig. 19. (Plate 2, Figure 3).

Distephanus speculum (Ehrenberg) = *Dictyocha speculum* Ehrenberg, 1840, p. 150, pl. 4, fig. 4. (Plate 2, Figures 4-6).

Mesocena circulus var. *apiculata* Lemmermann, 1901, p. 257, pl. 10, fig. 9, 10. Remarks: Occurrence of this taxon is found only from Cores 16 and 17 of Hole 302 together with *Dictyocha mutabilis* Deflandre. (Plate 2, Figure 7).

Mesocena sp. cf. *M. elliptica* Ehrenberg. For synonymies and discussion, see Ling, 1970, p. 100-103, pl. 20, fig. 8-14. (Plate 1, Figure 8).

Mesocena sp. cf. *M. elliptica* var. *minoriformis* Bachmann and Papp = *Mesocena elliptica minoriformis* Bachmann and Papp, 1968, p. 121, pl. 3, fig. 9; Ling, 1972, p. 178, 179, pl. 29, fig. 4-7. Remarks: Specimens assignable to the present taxon are found commonly, but only in Core 11 of Site 299. During the present study, specimens with 4 and 5 radial spines were observed. (Plate 1, Figures 9, 10).

Paradictyocha polyactis (Ehrenberg) = *Dictyocha polyactis* Ehrenberg, 1839, p. 129; for synonymy, see Ling, 1972, p. 190-192, pl. 31, fig. 9-11. Remarks: This is merely to record the species' presence in this area. (Plate 1, Figures 11, 12).

Ammodochium rectangulare (Schulz) = *Ebria antiqua* var. *rectangularis* Schulz, 1928, p. 274, fig. 72 a-d. (Plate 3, Figures 13, 14).

Ebriopsis antiqua (Schulz) = *Ebria antiqua* Schulz (part), 1928, p. 273, 274, fig. 69 a-f. Remarks: Similar to the previous studies (Ling, 1972; Ling and McPherson, in press a), both forms, with and without axial spines, are included under this taxon. (Plate 2, Figures 15-18).

Hermesium adriaticum Zacharias, 1906, *fide* Loeblich et al., 1968, p. 168, fig. 20, pl. 40, fig. 9a, 10. Remarks: According to the present author's research, this is the first time that the taxon was recovered from this part of the world. (Plate 2, Figures 19, 20).

Parathranium intermedium Hovasse, 1932b, p. 465, 466, fig. 18. Remarks: This species and the following species have been discussed in detail recently (Lang and McPherson, in press b). (Plate 2, Figures 21, 22).

Parathranium tenuipes Hovasse = *Thranium tenuipes* Hovasse, 1932a, p. 123, fig. 5. (Plate 2, Figures 23, 24).

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PLATE 1

(Magnification 500× unless otherwise indicated)

Figures 1, 2 *Cannopilus himisphaericus* (Ehrenberg). 302-10, CC, R-1 (P30/1).

Figures 3-6 *Dictyocha fibula* Ehrenberg.
3, 4. 302-14-1, 100-102 cm, L-2 (W6/3).
5, 6. 302-15-1, 50-52 cm, R-2 (L36/0)

Figures 7, 8 *Dictyocha fibula* var. *aculeata* Lemmermann. 297-3-1, 90-92 cm, L-2 (V23/1)

Figures 9, 10 *Dictyocha fibula* var. *messanensis* (Haeckel). TT 49-22 AC, (0-3 cm), R-2 (G8/0).

Figure 11 *Dictyocha lingi* Dumitrica. 299-7-2, 22-24 cm, L-2 (X34/0).

Figure 12 *Dictyocha mutabilis* Deflandre. 302-15-1, 50-52 cm, R-1 (Y32/4).

Figures 13, 14 *Dictyocha pentagona* (Schulz).
13. 302-11-5, 20-22 cm, R-2 (N36/2).
14. 302-11-5, 20-22 cm, R-2 (F16/3).

Figure 15 *Dictyocha pseudofibula* var. *complexa* Tsumura. 299-5, CC, R-1 (P-38/0).

Figures 16-19 *Dictyocha subarctios* Ling.
16, 17. 299-11-2, 30-32 cm, L-2 (Q21/0).
18, 19. 302-2, CC, L-2 (G7/0).

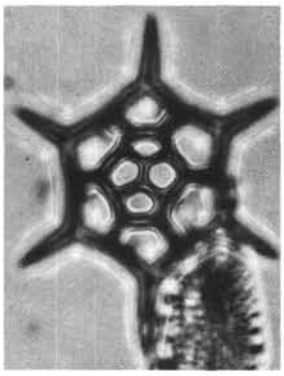
Figures 20, 21 *Dictyocha* sp. A. 302-12-1, 65-67 cm, L-2 (U9/0).

Figures 22, 23 *Dictyocha* sp. B. 299-15-4, 25-27 cm, L-2 (Y7/1).

Figure 24 *Distephanus crux* (Ehrenberg). 302-8-3, 20-22 cm, L-2 (S23/2).

Figures 25, 26 *Distephanus crux* var. *stauracanthus* (Ehrenberg). 301-2-3, 30-32 cm, R-1 (F38/0).

PLATE 1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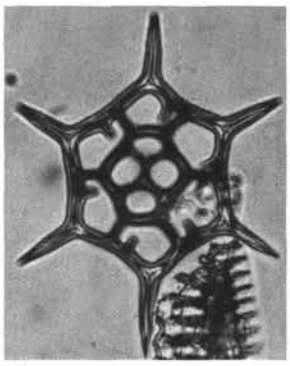
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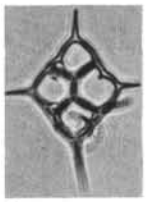
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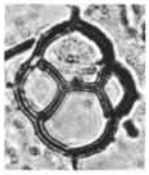
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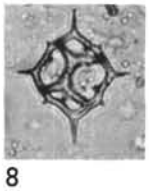
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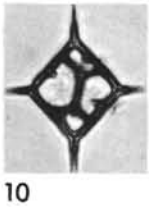
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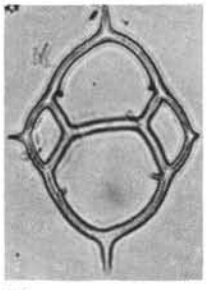
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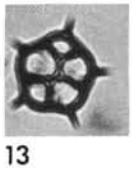
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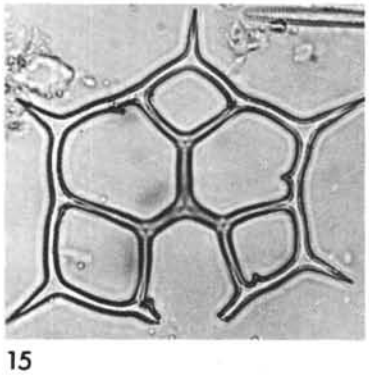
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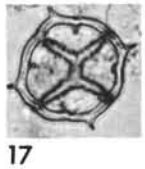
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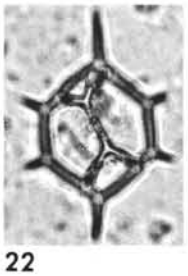
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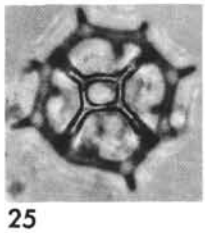
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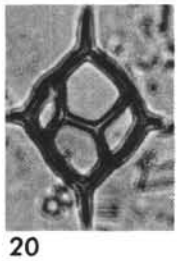
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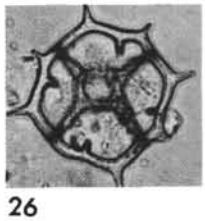
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PLATE 2

(Magnification 500× unless otherwise indicated)

Figures 1, 2 — *Distephanus octangulatus* Wailes. 299-3, CC, L-2 (O2/0).

Figure 3 — *Distephanus quinquangellus* Bukry and Foster. 302-14, CC, R-1 (X16/2).

Figures 4-6 — *Distephanus speculum* (Ehrenberg).
4, 5. 298-1, CC, L-1 (R40/0).
6. 302-16-1, 96-98 cm, L-2 (F13/0).

Figure 7 — *Mesocena circulus* var. *apiculata* Lemmermann. 302-15, CC, R-1 (V38/1).

Figure 8 — *Mesocena* sp. cf. *M. elliptica* Ehrenberg. 302-9, CC, R-1 (D20/1).

Figures 9, 10 — *Mesocena* sp. cf. *M. elliptica* var. *minoriformis* Bachmann and Papp.
9. 299-11-4, 25-27 cm, L-2 (L17/3).
10. 299-11-2, 30-32 cm, L-2 (L17/2).

Figures 11, 12 — *Paradictycha polyactis* (Ehrenberg). 302-11, CC, R-1 (L30/1).

Figures 13, 14 — *Ammodochium rectagulare* (Schulz). 302-10-1, 20-22 cm, R-1 (C42/0), ×800.

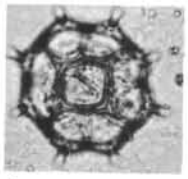
Figures 15-18 — *Ebriopsis antiqua* (Schulz).
15, 16. 302-14-1, 100-102 cm, R-2 (G7/0), ×800.
17, 18. 302-13, CC, R-1 (X22/4), ×800.

Figures 19, 20 — *Hermesium adriaticum* Zacharias. 302-15, CC, R-1 (Y7/0), ×800.

Figures 21, 22 — *Parathranium intermedium* Hovasse. 299-25, CC, L-2 (Q19/0), ×800.

Figures 23, 24 — *Parathranium tenuipes* Hovasse. 299-17-4, 100-102 cm, R-2 (P15/4), ×800.

PLATE 2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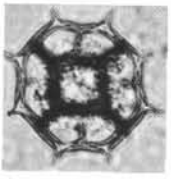
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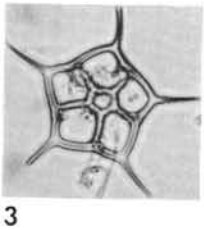
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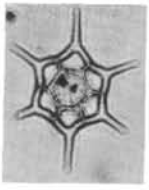
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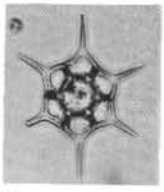
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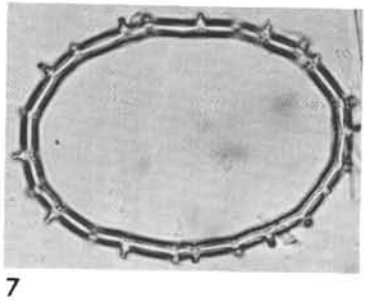
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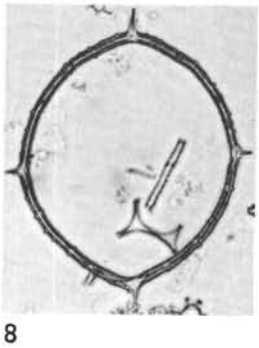
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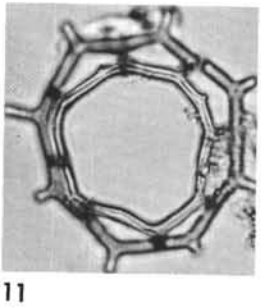
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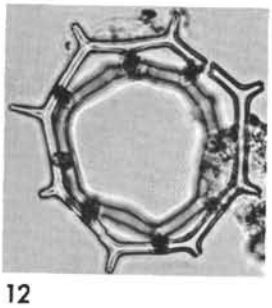
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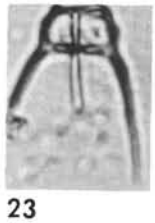
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