41. QUATERNARY THROUGH NEOGENE HISTORY OF THE BLACK SEA, DEDUCED FROM THE PALEOECOLOGY OF DIATOMS, SILICOFLAGELLATES, EBRIDIANS, AND CHRYSOMONADS

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ABSTRACT

This paper is an attempt to gain insight into the environmental changes of the Black Sea over the past six million years. In the late Miocene the Black Sea was a shallow marine basin which, by subsidence during latest Miocene-earliest Pliocene time, became a deep (1000 m) marine basin. At the time of the first major northern hemisphere cooling, at about 2.5 m.y.B.P., it became a freshwater lake. As a result of climatic changes the lake was subjected to evaporation. Floral analysis reveals that several colder assemblages and several ecologically stressed diatom assemblages can be defined and are correlated with the Praetiglian, the Tiglian, the Eburonian, the Waalian, and the Cromerian. The period from 2.6 to 0.75 million years ago was a time of chemically and climatically controlled sedimentation. The Cromerian was characterized by deposition of large slump *seekreide* deposits; it ended with a short marine period. During the Elsterian, the Black Sea was cut off again from the Mediterranean Sea and became a deep freshwater lake. A gradual worldwide rise in sea level during the Holsteinian returned the Black Sea to a marine environment. The Saalian cold period followed, and was characterized by massive turbidite deposition and freshwater conditions. These conditions were interrupted during the interglacial Eemian and then returned to freshwater conditions with a somewhat lowered lake-level during the Weichselian. The Recent marine spill is defined to have occurred around 8000 years ago.

Past surface salinity maxima and minima, diversity of opal skeletons, trophic status, *p*H, and dissolved silicate in surface waters were calculated and are incorporated in the paper.

INTRODUCTION

The Black Sea is one of the largest semienclosed marine basins, with surface salinities of about 18‰ (Kremling, 1974). It is connected with the Mediterranean Sea by the narrow Bosporus, which has a sill depth of about 50 meters (Scholten, 1974). This shallow sill has caused environmental conditions within the Black Sea to be altered considerably during Quaternary through Pliocene eustatic sea-level changes (compare models in Scholten, 1974, fig. 7). When sea level changed during glacial and interglacial episodes, the Black Sea became connected with or disconnected from its marine source and changed back and forth from marine to brackish to freshwater environments. These primarily climate-controlled environmental changes have influenced sedimentation processes and the deposition of freshwater, brackish to marine microfossils (Bukry, 1974; Wall and Dale, 1974; Manheim and Chan, 1974).

Diatoms are of great importance in understanding past environments because they inhabit all aqueous environments, they have short reproduction times and thus react rapidly to changing environmental conditions. Diatoms produce opal skeletons which are often preserved in the fossil record. Study of diatom thanatocoenoses permits interpretation of the conditions of the biosphere and hydrosphere, and estimation of such quantities as salinity, oxygen content, and dissolved-silicate availability.

The following objectives may be realized from study of the remains of diatoms and a few additional groups of organisms which also produce opal skeletons (Chrysophyta, Silicoflagellatae, and Ebriaceae) in sediment sections drilled during DSDP Leg 42B (Figure 1): (1) develop as complete as possible Quaternary to Miocene biostratigraphic scheme; (2) find evidence of the interaction between the Black Sea and the Mediterranean Sea; (3) establish a paleoclimatic Black Sea surface-water record; (4) infer surface water conditions (e.g., salinity, available dissolved silicate, etc.) from changes in microfossil assemblages and their diversity; and (5) compare data obtained by diatom assemblage analysis to geochemical data.

PREPARATION OF SAMPLES AND METHOD OF STUDY

In addition to a set of samples collected aboard the *Glomar Challenger* during Leg 42B (marked with an asterisk in the tables of relative abundance), the total set of sedimentologi-

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[1] Present address.

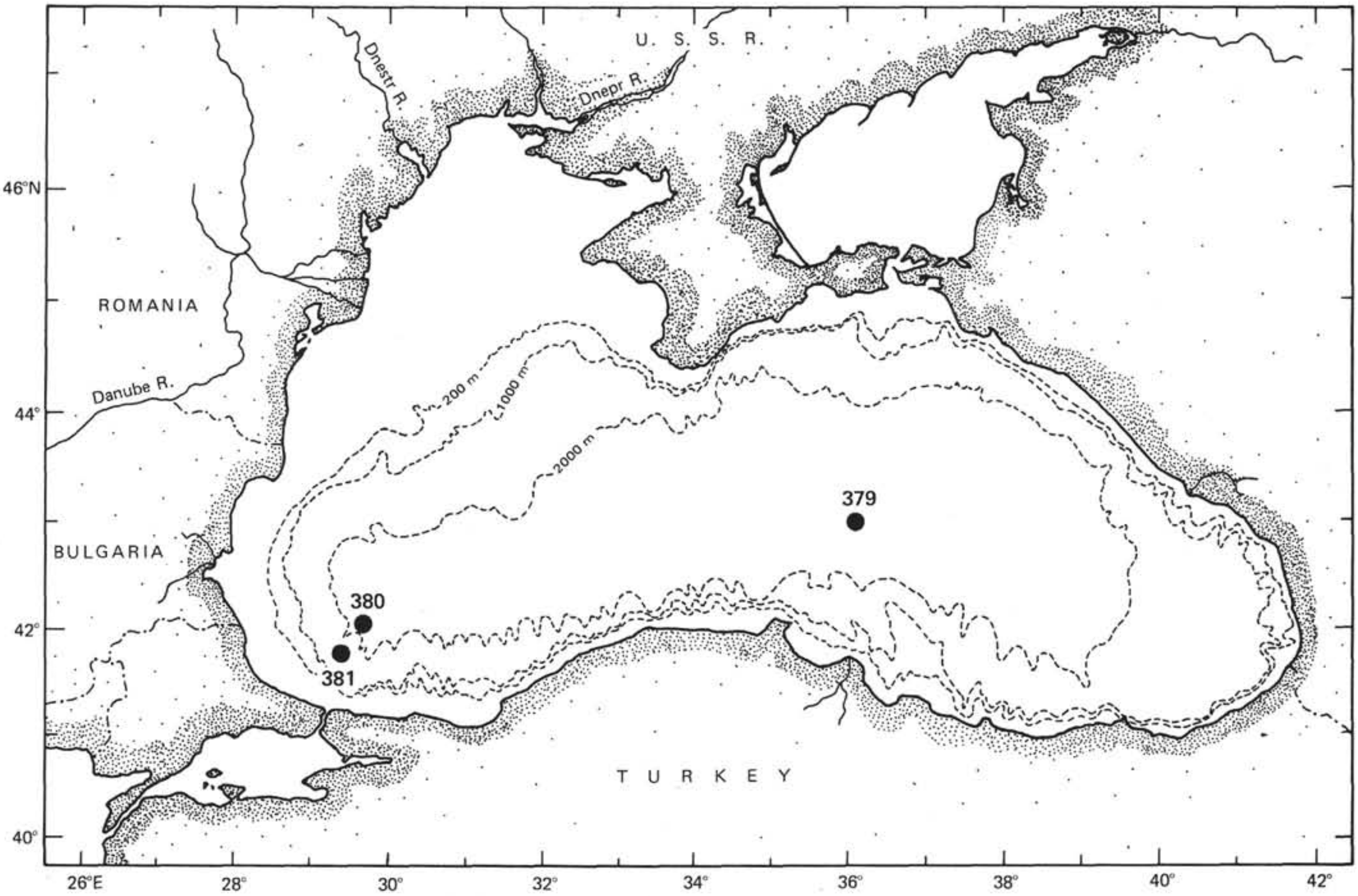


Figure 1. *Location of Leg 42B drill sites.*

cal smear slides prepared on a routine basis by the Shipboard Scientific Party was made available by P. Stoffers (Holes 379A and 381) and by K. Hsü (Holes 380 and 380A), and was used in this report. A few additional samples (also marked with an asterisk in the tables of relative abundance) were supplied by E. Degens and P. Stoffers.

Except for the smear slides, all other samples were prepared for diatom study according to a standardized procedure (Schrader, 1973; Schrader and Fenner, 1976) using Aroclor 4465 (nd. 1.66, Xylene solvent) as a mounting medium. All DSDP Leg 42B samples were prepared in a semi-quantitative way; thus no counts on the quantitative abundance of diatoms were made.

Four samples from the *Atlantis* II cruise were prepared in a quantitative way starting with a 0.5 g dry sample split.

Smear slides as prepared aboard *Glomar Challenger* caused difficulties in identification and in counting, since the original material was only smeared onto a slide and mounted in Caedax, which required long working-distance microscope objectives, especially at high silt- and sand-sized particle contents. This coupled with the use of a low-refractive-index mounting medium, increased identification problems. Identifications on all smear slides could only be made using a lower resolution 54× FL oil (0.95 N.A.) objective and 25× oculars.

Microscopic examinations were otherwise made with a Leitz Orthoplan light microscope with apochromatic lenses (Objectives FL oil 54×, 0.95 N.A. and Apo oil 90×, 1.40 N.A.). Photomicrographs were made with an automatic Leitz Orthomat camera using a zoom ocular of 6 to 10× magnification and Agfa-Ortho document films.

Counting was carried out at the highest available and possible magnification, and up to 300 to 400 valves (standards defined in Schrader, 1973) per slide were identified as encountered in random traverses over the middle of the slide. Occasionally, only quantitative abundance estimates in 25 per cent steps are employed, as previously used (Schrader, 1976), when either the preservation was too poor and/or the abundance too low to obtain reliable data, or in cases where diatom frustules were too damaged and deformed by compression, as in the lower part of Hole 380.

The classifications of abundances (B = barren; R = rare; F = few; C = common and A = abundant) were determined in the following way:

I. Normal cleaned samples (using standard procedures):
B = barren, no diatoms complete or fragmented within five traverses of 200 × 18,000 μm per slide;
R = rare, 0.5 to 9 complete or fragmented diatoms within *three* microscopic fields of 300 × 200 μm;
F = few, three to ten complete or fragmented diatoms within *one* microscopic field of 300 × 200 μm;
C = common, eleven to twenty complete or fragmented diatom frustules within *one* microscopic field of 200 × 200 μm;

A = abundant, more than twenty-one complete or fragmented diatom valves within *one* microscopic field of 300 × 200 μm; and

T = trace, one to ten complete or fragmented diatom frustules within *one* traverse of 200 × 18,000 μm.

II. Smear slides:

Estimates of abundances on these slides are rather subjective, since all acid-soluble particles are still present and dilute the diatom content. Generally, for each of the above-mentioned categories, the number of scanned microscopic fields was increased by a factor of 5, otherwise using the same criteria.

The classification of preservation categories was obtained subjectively and qualitatively by calculating the percentages of partially etched or robust diatom valves over well-preserved less silicified frustules. Occurrences of *Stephanodiscus hantzschii, S. binderianus, Gyrosigma* spp., *Sceletonema* spp., Rhizosolenia spp., *Synedra* spp., *Thalassiosira* spp., and *Melosira islandica* var. *helvetica* indicate well-preserved assemblages, whereas high proportions of *Stephanodiscus astraea, S. robustus, Melosira islandica, Coscinodiscus obscurus,* Chrysophyta cysts, and sponge spicules point to moderately well-preserved and/or poorly preserved assemblages.

Because until now only minor attempts have been made to quantify the preservation of the various diatom assemblages (Schrader, 1972; Mikkelsen, 1976), most of these preservation categories are subjective (in P = poor, M = moderate, and G = good), and depend on the experience of the investigator.

Relative abundances in Tables 1 to 4 are calculated from 300 to 400 individual counts of *all* opal skeletons (diatoms, Chrysophyta, Ebriaceae, Silicoflagellatae, and sponge spicules). The calculation methods for salinity ranges, diversity, etc. are defined and listed under the specific heading.

RESULTS

Sediment Surface Samples (Figures 2 and 3)

Four surface sediment samples were investigated for their opal skeleton content in quantitative sample splits, in order to gain an idea about the modern composition of opal thanatocoenoses in the Black Sea. Figure 2 shows positions of the cores (A II, 49 - STA 1476, Core 33 GC, sampled at 5-7 cm depth; - STA 1466, Core 26 PG, sampled at 5-6 cm depth; - STA 1436, Core 7 PG, sampled at 4-5 cm depth; and - STA 1461, Core 23 PG, sampled at 6-7 cm depth; sedimentological and depth data are listed in Ross and Degens, 1974).

Table 5 lists the abundance of each taxon observed, the relative abundance, and the salinity tolerance (data from Simonsen, 1962; Pankow, 1976) of the individual species (Figure 3). The unusually high relative abundance of *Distephanus speculum* (Silicoflagellatae) in all easterly cores, together with the high proportions of *Cyclotella caspia*, is most striking. Absolute numbers of opal skeletons per gram of dried sediment range from 12 to 6 to 2 to 7 x 10^6 skeletons. Sedimentation rates for sedimentological Unit 1 (Ross and Degens, 1974) are > 30 cm to 10-30 cm to 10-30 cm to > 30 cm/1000 years from west to east. Conversion to absolute diatom opal sedimentation rates is not possible, since no water-content data are available at this moment. Generally, the relatively high numbers of opal skeletons per dry weight coincide with areas of high opal primary production (Morozova-Vodyanitskaya, 1941) and with previously reported areas of high opal concentration (in specific areas) in the Black Sea Abyssal plain sediments (Kriss et al., 1951). These observations contrast sharply with those of Gebbelein-Maynard (1974), who stated that the expectation of high abundance of opal skeleton "was not fulfilled." Rough calculations of opal accumulation in the upper sediment layers within the Black Sea are made under the following assumptions: specific gravity ranges from 1.8 to 2.6, sediment accumulation rates are on the order of 0.3 to 0.1 cm per year. These calculations reveal maximum and minimum accumulation rates (in number of skeletons) as follows:

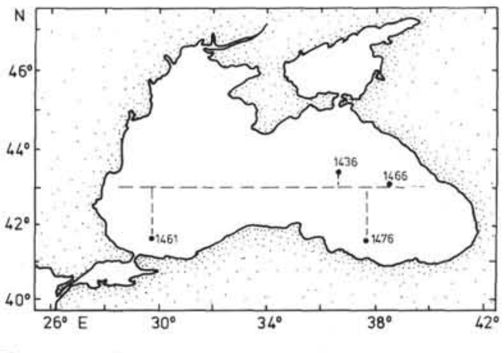


Figure 2. *Location of sediment surface samples from* Atlantis II *expedition.*

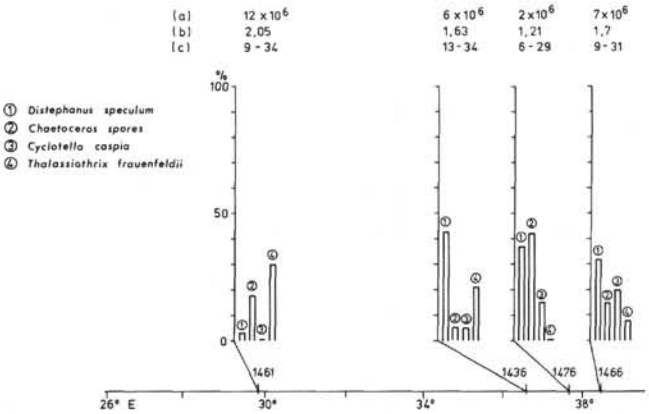


Figure 3. *Per cent of the four main opal phytoplankton species of the* Atlantis II *expedition samples. a = number of opal skeletons per gram dried sediment, b = Shannon-Wiener diversity index, and c = calculated salinity ranges. Stations are projected to a west-east line (compare Figure 2.)*

Station 1461—maximum 9×10^6, minimum 7×10^6

Station 1436—maximum 5×10^6, minimum 1×10^6

Station 1476—maximum 1.5×10^6, minimum 0.5×10^6

Station 1466—maximum 5×10^6, minimum 4×10^6 (Figure 3).

These calculations agree well with the primary production data of Finenko (1967).

Shannon-Wiener diversity values for the total opal fraction, inclusive of Silicoflagellatae and Chrysophyta, cysts are:

Station 1461—2.05

Station 1436—1.63

TABLE 1
Per Cent Diatoms, Ebridiaceae, Silicoflagellatae, and Chrysophyta at Site 379

	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes* spp.	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Ceratoneis arcus*	*Chaetoceros* spores	*Cocconeis pediculus*	*Coscinodiscus* sp. 1	*Actinocyclus ehrenbergii*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella striata*	*Cymatopleura solea*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Epithemia zebra*	*Grammatophora oceanica*	*Hermesinum adriaticum*	*Melosira granulata*	*Melosira islandica*	*Melosira sulcata*	*Meridion circulare*	*Opephora martyi*	*Rhizosolenia alata*	*Rhizosolenia bergonii*	*Rhizosolenia calcaravis*	*Rhoicosphenia curvata*	Sponge spicules	*Stephanodiscus astraea* and *robustus*	*Stephanodiscus hantzschii*	*Stephanodiscus* spores	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira subsalina*	*Thalassiothrix frauenfeldii*	A	B	C
Hole 379																																										
1-1, 45	B																																									
1-1, 90	B																																									
1-1, 120	B																																									
Hole 379A																																										
1-2, 66	B																																									
1-2, 80	B																																									
1-2, 128	B																																									
1-4, 61	B																																									
1-4 132	B																																									
1, CC*	B																																									
4-2, 100	B																																									
4-3, 135	T	P																																								
4-4, 63	B																																									
4-5, 0	B																																									
4-5, 34-35*	B																																									
4-5, 42	T	P																																								
4-5, 110	B																																									
4-5, 113	B																																									
4-5, 129*	R	G										7					24															51	17				1			0.22	3.08	31.29
4-5, 129; 2	R	G										8					18					1				1						40	32							0.00	4.45	31.29
4, CC	T	P																																								
6-1, 75	R	G										6						42								3						15	34							0.00	7.03	45.75
6-1, 100	T	P																																								
6-2, 135-137*	B																																									
6-4, 140-142*	B																																									
6-5, 34	B																																									
6-5, 105	B																																									
6-5, 128	B																																									
6-5, 129-131*	B																																									
6-6, 64	B																																									
6-6, 110	B																																									
6-6, 146	B																																									
6, CC	B																																									
7-2, 81-83*	B																																									
7-2, 98	B																																									
7-5, 40	B																																									

7-5, 138-140*	R	G					5				25									21	49				0.00	6.71	61.90
7-5, 140	B																										
8-1, 95	A	G		1			9				10									11	69				0.03	8.17	64.95
8-1, 100-102*	F	G		1			11			3	9									6	70				0.03	8.44	65.01
8-2, 130	F	G		1		1	6				40									6	46				0.13	8.65	66.80
8-3, 68	R	G					2			2	33									15	48				0.00	7.52	67.68
8-3, 100-102*	R	G		1			5			3	10					1				21	58			1	0.32	7.62	68.01
8-4, 100	C	G				2	1				22									18	57				0.13	7.89	69.50
8-5, 76-78*	F	G					4				13			2						25	55		1		0.20	6.90	70.77
8-5, 140	R	G				2					34		1							14	49				0.15	8.08	71.40
9-1, 106	R	M								1	43		1		2					12	41				0.11	8.69	74.56
9-2, 23	A	G									58		2							27	13				0.00	3.44	75.23
9-3, 94	F	G	3	1						1	31									23	39		2		0.57	7.79	77.44
9-4, 60-62*	F	G						2		6	12	1						1		75			3		0.74	2.20	78.61
10-1, 110	F	M		9		21		13		57															3.07	19.14	84.10
10-2, 137-139*	B	–																									
10-4, 100	T	P				98				2															5.00	18.00	88.50
10-5, 128	T	P			50								15	4									31		13.77	28.45	90.28
10-6, 57	T	P			5								82	13											0.85	2.23	91.07
10-6, 130	F	M			2	39			1														55	3	12.05	28.37	91.80
11-1, 100	F	M		2		74				2												2	19		7.48	17.95	93.50
11-1, 120	T	P				63																	37		9.44	24.29	93.70
11-1, 140	B	–																									
11-2, 15	B																										
11-2, 72	R	M		1		67			2														30		8.82	23.61	94.72
11-3, 47	R	M		4		4			44								9		4				35		17.14	34.29	95.97
11-3, 80	B																										
11-4, 52	B																										
11-4, 120-122*	B																										
11-4, 125	B																										
11-5, 24	B																										
11-5, 41	B																										
11-5, 44	B																										
11-5, 50	B																										
11-5, 81	B																										
11-5, 97	B																										
11-5, 116	B																										
11-5, 122	B																										
12-1, 50	B																										
12-1, 140	B																										
12-2, 75	B																										
12-2, 140	B																										
13-1, 32	B																										
13-1, 106	B																										
13-1, 129	B																										
13-2, 132	B																										
13-4, 48-50*	B																										
13-6, 11	B																										
13-6, 26	B																										
13-6, 70	B																										
13-6, 133	B																										
14-4, 85	B																										
14-5, 42-44*	B																										
15-2, 39	B																										
15-4, 51	B																										
15-4, 58-60*	B																										
15-5, 133	B																										

TABLE 1–*Continued*

	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes* spp.	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Ceratoneis arcus*	*Chaetoceros* spores	*Cocconeis pediculus*	*Coscinodiscus* sp. 1	*Actinocyclus ehrenbergii*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella striata*	*Cymatopleura solea*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Epithemia zebra*	*Grammatophora oceanica*	*Hermesinum adriaticum*	*Melosira granulata*	*Melosira islandica*	*Melosira sulcata*	*Meridion circulare*	*Opephora martyi*	*Rhizosolenia alata*	*Rhizosolenia bergonii*	*Rhizosolenia calcaravis*	*Rhoicosphenia curvata*	Sponge spicules	*Stephanodiscus astraea* and *robustus*	*Stephanodiscus hantzschii*	*Stephanodiscus* spores	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira subsalina*	*Thalassiothrix frauenfeldii*	A	B	C
Hole 379A – *Continued*																																										
16-1, 127	T	M																					49									51								0.00	0.50	141.27
16-1, 132	B																																									
16-2, 56	B																																									
16-3, 57-59*	B																																									
16-4, 69-71*	B																																									
17-1, 60	R	M																13														30	57							0.00	6.72	150.10
17-1, 93	R	M											7				5															88								0.00	0.50	150.43
18-2, 85	R	P		61							20		8																			11								1.09	10.60	161.35
18-2, 115	F	G		31							64																					5								3.20	14.65	161.65
18-2, 116-118*	B																																									
18-2, 134	F	G		2							98																													5.00	17.84	161.84
18-2, 137-139*	R	M					4	<1			29			13			47	4		<1																	<1	1		3.88	18.51	161.88
19-1, 148	B																																									
19-2, 23	B																																									
19-2, 27	T	P																																								
19-2, 68	B																																									
19-2, 114	B																																									
19-3, 112	F	M																59				3										38								0.00	0.50	172.62
19-3, 120	B																																									
19-3, 130	B																																									
19-5, 102-104*	B																																									
19-6, 39	B																																									
19-6, 68-70*	B																																									
19-6, 75	B																																									
20-3, 82	T	M																																								
21-6, 77	T	P																														100								0.00	0.50	195.77
22-2, 48	B																																									
22-2, 54-56*	B																																									
22-2, 80	B																																									
22-4, 86-88*	B																																									
22-4, 123	B																																									
22-4, 137	B																																									
22-6, 47-49*	B																																									
22-6, 60	B																																									
23-2, 54	B																																									

24-2, 33-35*	B																				
24-2, 52	T P																				
24-2, 54	T P										6		2			92			0.36	1.23	218.40
24-2, 100	T P										72	1			9	17			0.00	1.03	218.86
24-4, 122-123*	B																				
24-4, 141	C M	4	2								56		4			34			1.68	6.07	221.91
24-6, 36-37*	F G	15								1	1					82	1		0.00	2.08	223.86-87
24-6, 37	A M	3											1			96			0.17	1.13	223.87
24-6, 95	C M	3									3		1		5	88			0.19	1.19	224.45
25-1, 10	A M	2									7					91			0.00	0.70	225.60
25-1, 140	A M	32	4								22		33			9			6.51	18.40	226.90
25-1, 142	B																				
25-2, 83	B																				
25-2, 137	A M	35	8								12		45						8.97	25.06	228.37
25-2, 140	A M	11	1			23	4						61						11.55	26.96	228.40
25-3, 14	C M	29	1			10	11				2		47						8.69	22.00	228.64
25-3, 32	A G	2														98			0.00	0.69	228.82
25-3, 90	F M	35	2								3				3	57			0.06	4.77	229.40
25-3, 94	F M	10	13					54			13					10			1.18	16.97	229.44
25-3, 106	R M	30						8			3			3	3	53			0.00	3.81	229.56
25-5, 72	B																				
25-5, 88	B																				
25-5, 110-112*	B –																				
25-6, 127	T P	8		56							1			1	5	29			10.13	21.86	234.27
26-2, 90	B																				
26-4, 80	B																				
26-4, 90	B																				
26, CC	B																				
27, CC	T P																				
28-4, 88-90*	B –																				
30-2, 38-40*	T P																				
29-3, 25	T P																				
29-4, 15	R G	41	14						25		9				5	6			0.49	13.41	268.15
29-4, 32	A G	56	9						13		10					12			0.30	11.23	268.32
29-4, 64	A G	89	4								6					1			0.13	10.96	268.64
29-5, 10	A G	100																			
29-5, 100	B																				
29-5, 104	B																				
29-5, 110	B																				
29-6, 1	B																				
29-6, 5	B																				
29-6, 53	B																				
29-6, 58	B																				
29-6, 65	B																				
30-2, 38-40	R P	25	4		2	63					2				3	1			3.80	16.78	274.89
31-1, 98-100*	R P	69	5		5	16					1				4				2.00	13.98	283.49
31-3, 100	B																				
31-3, 115-117*	B –																				
31-5, 81-83*	B –																				
34-2, 15	B																				
34-4, 135	B																				
34-6, 75	B																				
35-3, 100-102*	B –																				
35-3, 112	B																				
35-3, 130	B																				
36-2, 100	B																				

TABLE 1–*Continued*

	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes* spp.	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Ceratoneis arcus*	*Chaetoceros* spores	*Cocconeis pediculus*	*Coscinodiscus* sp. 1	*Actinocyclus ehrenbergii*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella striata*	*Cymatopleura solea*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Epithemia zebra*	*Grammatophora oceanica*	*Hermesinum adriaticum*	*Melosira granulata*	*Melosira islandica*	*Melosira sulcata*	*Meridion circulare*	*Opephora martyi*	*Rhizosolenia alata*	*Rhizosolenia bergonii*	*Rhizosolenia calcaravis*	*Rhoicosphenia curvata*	Sponge spicules	*Stephanodiscus astraea* and *robustus*	*Stephanodiscus hantzschii*	*Stephanodiscus* spores	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira subsalina*	*Thalassiothrix frauenfeldii*	A	B	C
Hole 379A – *Continued*																																								
36-2, 110	B																																							
36-4, 116	B																																							
37-3, 108	B																																							
37-3, 139	B																																							
37-3, 142	B																																							
38-2, 10	B																																							
38-2, 107	B																																							
38-4, 100	B																																							
39-5, 135-137*	B	–																																						
40-6, 170	B																																							
45-2, 86	B																																							
45-6, 130	B																																							
47-4, 74	B																																							
47-4, 130	B																																							
47-6, 110-112*	B	–																																						
49-1, 62-64*	B	–																																						
49-4, 87	B																																							
50-3, 90	B																																							
50-5, 5	B																																							
50-5, 13	B																																							
50-5, 88	B																																							
51-4, 80	B																																							
51-4, 137	B																																							
51-6, 20	B																																							
51-6, 129	B																																							
52-1, 63	B																																							
52-1, 140	B																																							
52-3, 26	B																																							
52-3, 139	B																																							
54-2, 56	B																																							
54-2, 79	B																																							
54, CC	B																																							
55-2, 110	B																																							
55-2, 137	B																																							

56-1, 25	B									
56-1, 43	B									
57-3, 131	B									
58-2, 143	B									
58-4, 68	B									
58-4, 130-132*	B	—								
59-1, 149	B									
59-3, 51	B									
59-3, 110	B									
59-3, 143	B									
60-2, 5	B									
60-2, 123	B									
60, CC	B									
64-1, 95 (105)	B									
64-3, 75 (100)	B									
64, CC	B									
65-4, 59 (62, 68)	B									
65-6, 25 (65-125)	B									
66-2, 96-98*	B	—								
66-4, 138-140*	B	—								
67-4, 49	B									
68-3, 118	B									

Note: Samples with an asterisk are cleaned ones, others are smear slides. Abundance and preservation defined in text, A = minimum and B = maximum salinity range computed; C = depth below bottom (m). All opal skeletons = 100 per cent.

Station 1476—1.21
Station 1466—1.70 (Figure 3),

and calculated maximum and minimum salinity values are:

Station 1461 S°/oo 9-34
Station 1436 S°/oo 14-34
Station 1476 S°/oo 6-29
Station 1466 S0/oo 9-30 (Figure 3),

indicating a gradual decrease of the percentages of polyhalobous species from west to east.

Site 379 (Figures 4 and 5)

Site 379 lies in the central euxinic abyssal plain in the central Black Sea, and was drilled at an actual water depth of 2165 meters; total penetration was 624.5 meters.

On the basis of sediment structure and composition, seven lithologic units were distinguished (shipboard scientific party, this volume) and used in preparing Figure 5. Unit I (Cores 1-7) contains high amounts of clay, quartz, and feldspar. Because of the occasional presence of graded beds, this zone is interpreted as a turbidite sequence. Most samples are barren of opal skeletons. A few contain trace to rare amounts with poorly preserved to well-preserved opal assemblages containing high proportions of *Stephanodiscus astraea* and *S. hantzschii*. No marine diatoms were found.

Unit II (Cores 8-11) is characterized by diatoms and calcareous nannofossils in greenish gray silty clay. Diatoms occur in trace to abundant amounts, and are poorly preserved to well-preserved. The lower part of this unit (Core 11) contains high proportions of *Cyclotella caspia, Thalassiosira* spp. (marine), and the upper part (Cores 8-9) contains high proportions of *Stephanodiscus hantzschii* associated with *S. astraea* (also see Figure 4).

Unit III, Section 11-5, at 52-61 cm, is a black sapropel layer and contains common calcareous nannofossils (*Braarudosphaera bigelowi;* Percival, this volume). All samples from this interval are barren of diatoms.

Unit IV (Cores 12-24) is a dark greenish gray terrigenous mud with sand and silt layers from Core 19 downward. Diatom abundance is barren to few, with poorly preserved to well-preserved assemblages. *Actinocyclus normannii* and *Cyclotella caspia* are common in Core 18, and high proportions of *Stephanodiscus astraea* occur below and above Core 18.

Unit V (Cores 24-29) is a diatom calcareous nannofossil marl with intercalated sandy mud and silty turbidite layers. Both diatomaceous units in Core 24 and 25 and Core 29 are separated by a turbidite sequence, and contain abundant diatoms. The lower diatomaceous sequence is characterized by the first occurrence of authigenic carbonates (calcite) and by the high proportion of *Actinocyclus normannii* and the absence of *Hermesinum adriaticum*, indicating less saline surface waters; the upper sequence is characterized by high proportions of *Hermesinum adriaticum* and *Actinocyclus normannii*, indicating higher saline surface water. The turbidite sequence separating the two marine sequences was probably caused by a marine influx initiated at Core 31. These sequences thus differ in cause from the turbidite sequences of lithologic Units I and IV, which may have resulted from eustatic sea level changes accompanied by evaporation of the freshwater lake.

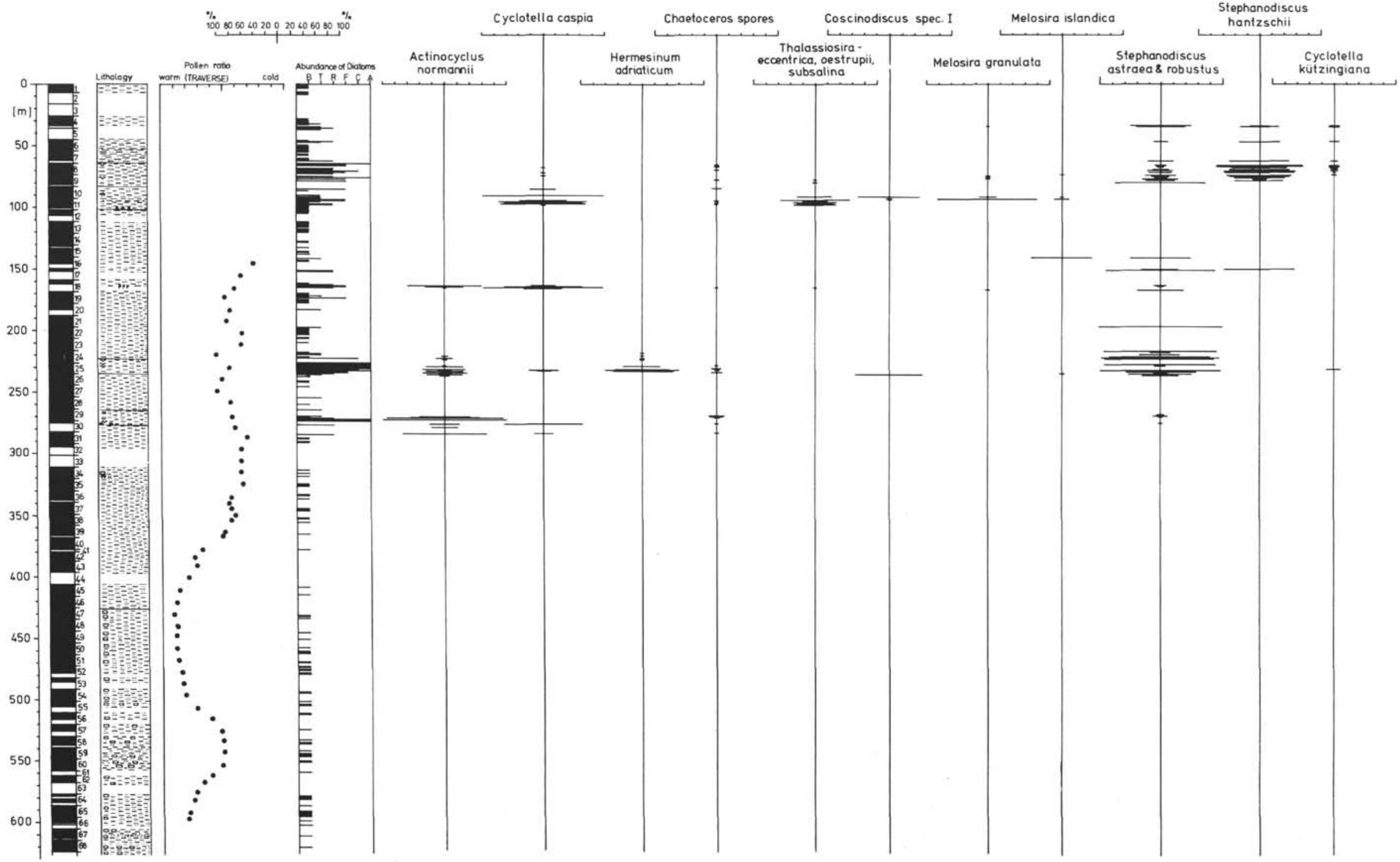


Figure 4. *Site 379, Hole 379A, from left to right: Cored sequence, black intervals recovered, white intervals no recovery, core numbers, lithology, Pollen ratio curve from Traverse (this volume). Abundance of diatoms: B = barren, T = trace, R = rare, F = few, C = common, A = abundant. Each bar represents one sample, percent of individual species in total opal fraction, the same value drawn to both sides of the centre line.*

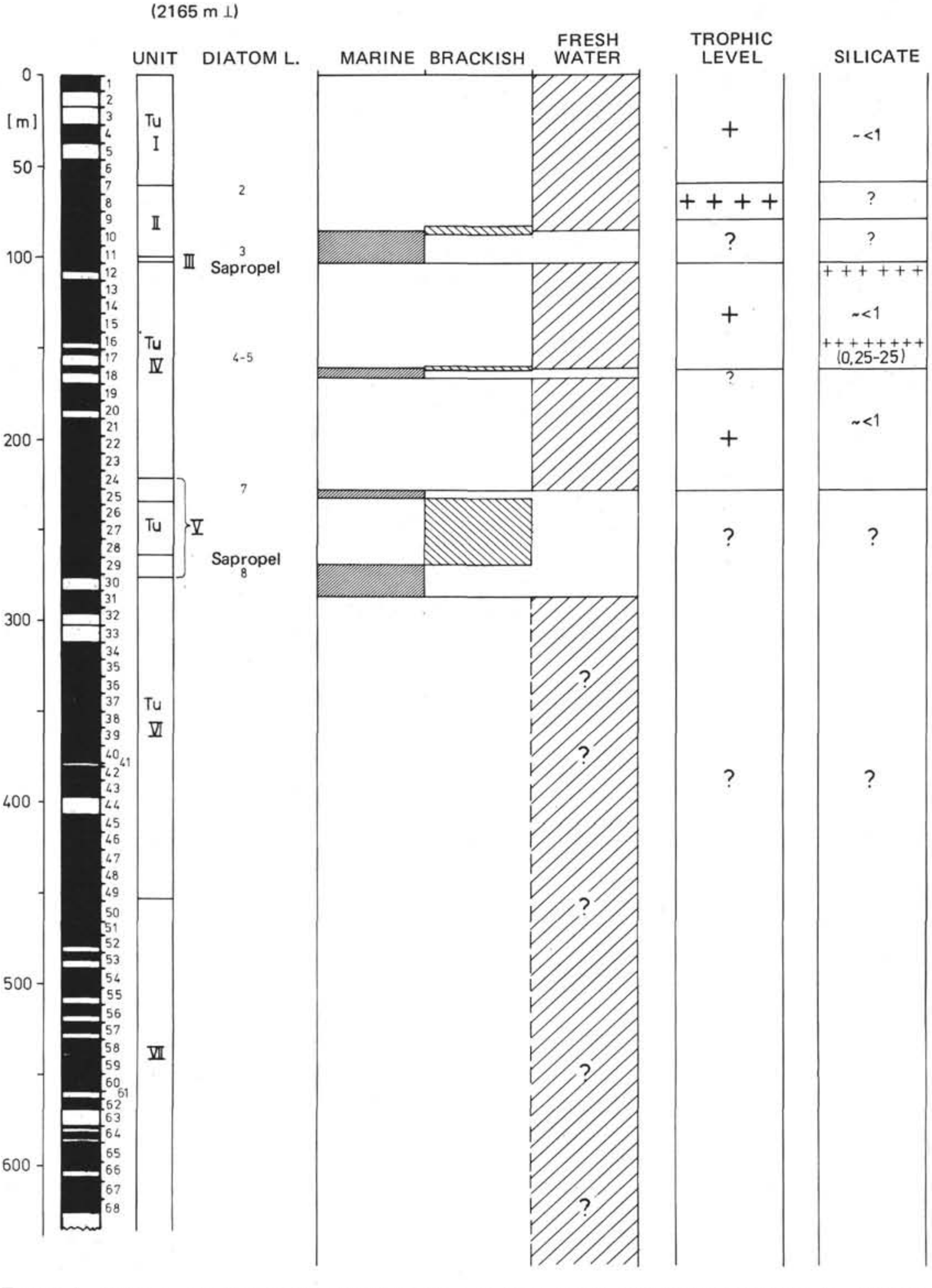


Figure 5. *Summary figure of important findings at Hole 379A. Sedimentological units, diatomaceous intervals, sapropels, marine-brackish-freshwater conditions, status level changes, and dissolved silicate.*

Unit VI (Cores 29-50) is a greenish gray terrigenous mud with frequent turbidites in a rhythmic pattern. All samples examined are barren of opal skeletons.

Unit VII (Cores 50-68) is a dolomite-rich mud consisting of alternating sequences of dark clay, dolomite, and pyrite. All samples studied are barren of opal skeletons.

Floral composition, relative per cent abundance, total abundance, preservation, and calculated minimum and maximum salinity ranges are tabulated in Table 1 and are partly illustrated in Figure 4. A more detailed paleoecological interpretation of the different levels will be found in the following sections.

TABLE 2
Per Cent Diatoms, Ebridiaceae, Silicoflagellatae, and Chrysophyta at Site 380 (legend compare Table 2)

Hole 380 Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes spp.*	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Ceratoneis arcus*	*Chaetoceros spores*	*Cocconeis pediculus*	*Coscinodiscus obscurus*	*Coscinodiscus sp.*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella striata*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha fibula*	*Chrysophyta cysts B*	*Chrysophyta cysts A*	*Epithemia sorex*	*Epithemia zebra*	*Grammatophora oceanica*	*Hermesinum adriaticum*	*Melosira granulata*	*Melosira islandica*	*Melosira sulcata*	*Meridion circulare*	*Opephora gemmata*	*Opephora martyi*	*Rhizosolenia alata*	*Rhizosolenia bergonii*	*Rhizosolenia calcar avis*	*Rhoicosphenia curvata*	*Sceletonema costatum*	*Sponge spicules*	*Stephanodiscus astraea and robustus*	*Stephanodiscus hantzschii*	*Stephanodiscus hantzschii (B)*	*Stephanodiscus spores*	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira subsalina*	*Thalassiothrix fruaenfeldii*	*Campylodiscus echeneis*	*Melosira distans*	A	B	C
1-1, 5	F	M												2						3																	95											0	0.5	0.05
1-1, 10	C	G												3																						1	96											0	0.5	0.10
1-1, 28	C	G												6						4																	90											0	0.5	0.28
1-1, 65	C	G																		2																	98											0	0.5	0.65
1-1, 96*	F	M											18							4					2				3								74											0	0.5	0.96
1-1, 100	C	M												14						13					1												68	4										0	1.02	1.00
1-2, 15*	F	M											14							1																	85											0	0.5	1.65
1-2, 88	B																																																	
1-3, 16	B																																																	
1-3, 105	B																																																	
1-3, 114	B																																																	
1-3, 142	B																																																	
1-6, 133	B																																																	
2-1, 40	B																																																	
2-2, 70	B																																																	
2-2, 86*	B																																																	
2-3, 120	B																																																	
3, CC	T	P																		70																	21	9										0	3.35	27.25
4-1, 36	F	M											2						3	10																	21	62					2					0.39	8.1	27.86
4-1, 42	B																																																	
4-1, 69	B																																																	
4-1, 137*	B																																																	
4-2, 78*	B																																																	
4-2, 96	B																																																	
4-2, 116	B																																																	
4-4, 32	B																																																	
4-4, 74*	T	M																																																
4-4, 108	F	M																		7				1													86	6										0.18	1.48	33.08
5-2, 121*	B																																																	
5-3, 70	T	P																																																
5-3, 148	C	G											11																								4	85										0	8.57	42.48
5-4, 52	C	G																	1	3																	26	70										0	7.42	43.02
5-4, 56 (a)*	C	G						2				4							8	17																	27	39					2	1				0.91	8.67	43.06
5-4, 56 (b)	C	G																		16					1												41	41						1				0.10	5.55	43.06
5-4, 68	A	G																		2																	2	96										0	9.81	43.18
5-4, 73	A	G																		6					1												15	77										0	8.37	43.23
5-4, 90	A	G																		2																	2	96										0	9.81	43.40
5-4, 94	A	G																		2																	2	96										0	9.81	43.44
5-4, 122	F	G																		16					1												9	74										0	8.87	43.72
6-1, 75	F	G						7				12						1	10	22							1						1				18	15					8	5				4.22	17.10	48.25
6-1, 129	B																																																	
6-3, 38	F	G								3		51						1	9	1																							35					10.20	25.37	50.88

6-3, 62	C	G										14			1						85			0	9.89	51.12
6-3, 75	C	G										10								5	85			0	9.47	51.25
6-4, 77	A	G										71			6					9	14			0	5.09	52.77
6-4, 88	F	G										40								23	37			0	6.36	52.88
6-4, 139	A	G									1	46								33	20			0	4.09	53.39
6-6, 10	T	P																								
6-6, 100	T	P																								
6, CC	A	G										83								4	13			0	7.77	56.75
7-1, 142	A	G										28								31	34		7	0.78	8.34	58.42
7-2, 11	A	G		1			1					38								27	24		9	1.21	9.74	58.61
7-2, 22	B																									
7-2, 24	F	G				1		1				11								57	14		16	1.49	8.44	58.74
7-2, 33*	A	G									4	3								68	9		16	1.38	7.36	58.83
7-2, 34	A	G				2						8			1					67	9		13	1.24	6.69	58.84
7-2, 130	F	G				2		1	1		2	16								64	5		9	1.00	5.59	59.80
7-3, 125	A	G				8		2	10			8								46	26			0.44	6.92	61.25
7-3, 129	A	M										2								65	28		5	0.41	4.97	61.29
7-4, 8	A	G							2			1								58	38		1	0.08	4.89	61.58
7-4, 9	A	G						1			1	13								72	8		5	0.47	3.44	61.59
7-4, 40	A	G						1			1	8								86	1		3	0.26	1.79	61.90
8-1, 68*	C	G		29		25					13	2						22					9	3.09	30.00	67.18
8-1, 70	C	G		43		32					13					2							10	4.24	27.95	67.20
8-1, 74	C	G		36		52					11									1				4.14	24.68	67.24
8, CC	C	G		50		29					20									1				3.69	28.41	75.75
9-1, 57	B																									
9-1, 77	B																									
9-1, 85	B																									
9-1, 87	B																									
9-1, 88	B																									
9-1, 95*	B																									
9-1, 98	B																									
10-1, 36	B																									
10-2, 36*	R	M		9		46				2	24						4			2		15		7.34	24.72	87.36
10-4, 105	B																									
10, CC	B																									
11-1, 140	R	M	65	6	5	2						1		11					6	4				3.23	15.68	96.40
12-1, 0	T	M	20									6								71	3			0	2.82	104.50
12-1, 128	T	P																								
12-1, 136	R	M										6								94				0	0.5	105.86
13-1, Top	R	P	2									4								94				0	0.70	114.00
13-1, 50	B																									
13-3, 90	B																									
13-3, 130	B																									
13-5, 70	B																									
13-5, 75	B																									
13-6, 50	B																									
13-6, 77	B																									
13-6, 120	B																									
13-6, 148	B																									
14-1, 120	B																									
14-1, 147	B																									
14-2, 45	B																									
14-2, 145	B																									
14-2, 148	B																									
15-1, 94*	B																									
15-1, 95	T	P																								
15-2, 137	T	P																								
15-4, 20*	B																									
15-4, 56	B																									
15-5, 100	R	M										35	8							57				0	1.70	140.00

TABLE 2–*Continued*

Hole 380 Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes* spp.	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Ceratoneis arcus*	*Chaetoceros* spores	*Cocconeis pediculus*	*Coscinodiscus obscurus*	*Coscinodiscus* sp.	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella striata*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Epithemia sorex*	*Epithemia zebra*	*Grammatophora oceanica*	*Hermesinum adriaticum*	*Melosira granulata*	*Meloisira islandica*	*Melosira sulcata*	*Meridion circulare*	*Opephora gemmata*	*Opephora martyi*	*Rhizosolenia alata*	*Rhizosolenia bergonii*	*Rhizosolenia calcar avis*	*Rhoicosphenia curvata*	*Skeletonema costatum*	Sponge spicules	*Stephanodiscus astraea and robustus*	*Stephanodiscus hantzschii*	*Stephanodiscus hantzschii* (B)	*Stephanodiscus* spores	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira subsalina*	*Thalassiothrix frauenfeldii*	*Campylodiscus ecseneis*	*Melosira distans*	A	B	C
15, CC	B																																																	
16-1, 106*	C	M										3								28																	65	3		1								0.21	163	143.56
16-1, 110	F	M														2				45					1												48	4										0	1.36	
16-1, 129	B																																																	
17-1, 93	F	M														1				2					2												81	14										0	1.90	152.93
17-4, 120	F	M			6															4				3													87											0.53	2.17	157.70
17-4, 131	B																																																	
18-4, 114*	R	M			3															12																3	76			6								0	0.84	167.14
18-6, 90*	R	P		2	4															3																3	81			7								0.36	1.64	169.90
18-6, 115	B																																																	
19-1, 144*	B																																																	
19-1, 147	B																																																	
19-2, 75	B																																																	
19-2, 76*	B																																																	
19-6, 108	B																																																	
19-6, 143*	B																																																	
20-1, 95*	B																																																	
20-2, 137*	B																																																	
20-4, 60	B																																																	
20-6, 90*	B																																																	
20, CC	B																																																	
21-3, 75	B																																																	
21-3, 129*	B																																																	
21-4, 4	B																																																	
21-5, 70*	B																																																	
21-6, 105	T	M																																			100											0	0.50	
21-6, 136*	B																																																	
22-1, 110	B																																																	
22-4, 106	T	M																		8																	90	2										0	0.71	205.06
22-4, 113	F	M																		29																	70	1										0	0.63	205.13
22-4, 130	F	M			3															16				2												3	74	2										0.42	1.94	205.30
22-4, 140	B																																																	
22-4, 150	F	M						1												5																1	93											0.03	0.87	205.50
22, CC	F	M																		17																5	75	3										0.	0.87	208.75
22, CC	T	P																		17																	81	2										0	0.73	208.75
23-2, 59*	B																																																	
23-2, 75	B																																																	
23-6, 120	B																																																	
23-6, 130*	B																																																	
24-1, 110	B																																																	
24-1, 140	B																																																	
24-1, 147	B																																																	
24-2, 75	B																																																	

24-6, 100	B																													
25-1, 140	B																													
25-2, 9	B																													
25-2, 60	B																													
25-6, 37	B																													
25-6, 111	B																													
25, CC	B																													
26-1, 78	B																													
26-1, 131	B																													
26-2, 92	B																													
26-3, 100	B																													
26, CC	B																													
27-3, 46*	B																													
27-3, 71	B																													
27-3, 92	B																													
27-3, 137	B																													
28-1, 102*	B																													
28-1, 118	B																													
28-1, 123	B																													
29-1, 111	B																													
29-1, 121	B																													
29-1, 127	B																													
29-1, 140	B																													
29-2, 140	B																													
29-2, 146	B																													
30-1, 87	B																													
30-2, 77	B																													
31-2, 25	T	M										37			4			5	54									0	1.02	286.75
31-2, 102	R	M										48	1		6	1		16	28									0	0.76	287.52
32-3, 90	R	M										22							78									0	0.5	298.40
32-3, 92	T	M										9							91									0	0.5	298.42
32-3, 93	R	M										3		2		1			94									0.35	1.21	298.43
32-3, 109*	R	M			2					2		15							81									0.07	1.33	298.59
32-4, 89*	R	M		4								28							68									0	1.03	299.89
32-5, 94	T	M										16							84									0	0.5	300.99
32-5, 124*	F	M										22			2				72	4								0	0.99	301.74
32-6, 106	F	M										39							55	6								0	1.43	303.06
32-6, 114	F	M								3		11						5	71	10								0	1.79	303.14
32-6, 116	T	M		2				1				16							81									0.06	0.94	303.16
32, CC	A	G																	100									0	0.5	303.75
32, CC*	F	M		2	1					7		3							86			1						0.03	1.34	303.75
33-3, 130*	R	M										9							91									0	0.5	308.30
33-3, 132	R	M										3						2	95									0	0.5	308.32
33-3, 139	B																													
33-3, CC	B																													
35-1, 144*	R	P		6	4			9				3		73				1	4									13.52	30.41	324.44
35-2, 35*	F	M		14	1			16			3	2		63					1									11.27	28.09	324.85
35-2, 90	A	G		9				4				10		75					2									14.39	30.98	325.40
35-3, 21	A	G		10				10						80														14.10	30.80	326.21
35-3, 52*	F	G		32				11						53					4									9.56	14.21	326.52
35-4, 54*	R	P		53			5					4		4				7	25				2					2.10	10.42	328.04
36-1, 139	R	M		17	7	13			1			4		10	1			20	27									5.42	16.24	333.89
36-2, 15*	F	M		23	5							8		19				18	20					7				4.37	17.91	334.15
36-3, 135	R	M		14	5	11			7			4		8	7			17	27									4.28	12.67	336.85
36-3, 138	R	M					13					4		20	2	4		51	2					1		1	2	13.36	28.43	336.43
36-3, 140	T	M																												
36-3, 146*	F	M	2	30	3			2				12		13				11	16		2			9				5.55	16.75	336.96
36, CC	R	M		13	4	3	6	13		1		13		33	1	2		9							2			10.58	26.29	341.75
37-1, 48	B																													
37-1, 55	B																													

TABLE 2–*Continued*

Hole 380 Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes* spp.	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Ceratoneis arcus*	*Chaetoceros spores*	*Cocconeis pediculus*	*Coscinodiscus obscurus*	*Coscinodiscus* sp.	*Cyclotella caspia*	*Cyclotella kutzingiana*	*Cyclotella ocellata*	*Cyclotella striata*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Epithemia sorex*	*Epithemia zebra*	*Grammatophora oceanica*	*Hermesinum adriaticum*	*Melosira granulata*	*Melosira islandica*	*Melosira sulcata*	*Meridion circulare*	*Opephora gemmata*	*Opephora martyi*	*Rhizosolenia alata*	*Rhizosolenia bergonii*	*Rhizosolenia calcaravis*	*Rhoicosphenia curvata*	*Skeletonema costatum*	Sponge spicules	*Stephanodiscus astraea and robustus*	*Stephanodiscus hantzschii*	*Stephanodiscus hantzschii* (B)	*Stephanodiscus* spores	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira subsalina*	*Thalassiothrix frauenfeldii*	*Campylodiscus echeneis*	*Melosira distans*	A	B	C
37-1, 96*	B																																																	
37-2, 44	B																																																	
38-2, 90	B																																																	
37, CC	B																																																	
37-2, 90	B																																																	
38-2, 100	B																																																	
39-1, 103	F	M			25							3																								11	61											0.17	3.76	362.03
39-1, 110	F	M			43			1				4								1																8	43											0.25	6.14	362.10
39-1, 115	B																																																	
39-1, 139*	R	M																		22																5	73											0	0.50	362.39
39-3, 76*	C	M			85							2								>0																	12		1									0.10	8.93	364.76
39-3, 110	A	G			60														2	5																	9		20									0	6.90	365.10
39-3, 112	A	G			38							1								4																	32		25									0.05	4.44	365.12
39-4, 35	C	M			9							2							2	1						1										2	79		4									0.11	1.77	365.85
39-4, 140	C	M			29			59											1	4						1										1	5		>0									1.88	25.09	365.90
39-5, 134	B																																																	
39-5, 135	A	G			87			4											1	2																	6											0.12	10.44	368.35
39-5, ?*	A	G			68			1				4								1																1	25											0.24	8.16	?
39-6, 50	F	M			93			2											1	4																												0.06	10.53	369.00
39-6, 93*	B																																																	
39-6, 128	B																																																	
40-1, 80	B																																																	
40-1, 114*	B																																																	
40-1, 119	B																																																	
40-1, 138	B																																																	

Figure 5 is a generalized summary of the important paleoecological interpretations, demonstrating four marine periods which coincide fairly well with the pollen ratio curve (Traverse, this volume) at those levels where the pollen ratio indicates a warmer climate. The marine phases change at levels 1, 3, and 4 to brackish and to freshwater phases; one freshwater phase is represented by sedimentological Unit II (upper part). Here, eutrophic waters and abundant rather delicate *Stephanodiscus hantzschii* occur which may indicate restricted volume and lowered sea level.

Sapropelitic muds and muds rich in organic matter occur at the following levels: (1) coccolith-bearing mud, Sample 379A-6-5, 123-125 cm: no diatoms present; (2) sapropel, Sample 379A-11-5, 52-61 cm: no diatoms present; (3) organic-rich mud, Sample 279A-20-2, 80-86 cm: diatoms trace with *Stephanodiscus astraea, Actinocyclus normannii*, and abundant Chrysophyta cysts; (4) sapropels, Samples 379A-29-4, 127-134 to 29-5, 0-13 cm: abundant well-preserved diatom assemblages *(Actinocyclus normannii* and *Cyclotella caspia)* revealing a surface-water salinity range of 0.1 to 13.4‰ at the time of deposition.

Site 380 (Figures 6, 7, 8a, 8b)

Site 380 (Figure 1) lies at the base of the continental rise in the southwest Black Sea, and was drilled at an actual water depth of 2107 meters; total penetration was 1073.5 meters (Holes 380 and 380A).

On the basis of sediment structure, composition, and micropaleontological evidence, six lithological units were distinguished in Hole 380 and were adjusted by numbers to the same units being defined at Site 379 (Shipboard Scientific Party, this volume).

Hole 380 (Figures 6 and 8a)

Unit 0 (Core 1) is badly disturbed and consists of black sediment rich in organic matter, with up to 15 per cent diatoms. It is tentatively correlated with Unit II as defined by Ross and Degens (1974) from Black Sea piston cores. This unit was not recovered at Site 379. Diatoms are few to common, with moderate to good preservation, and the assemblages are characterized by abundant *Stephanodiscus astraea* and *S. robustus*. Diatom frustules are partly filled with black organic matter and the opal in some frustules has been replaced by pyrite (?), which is most pronounced in the preservation of opal phytolith remains. No marine diatom indicator species was found, even after intensive search.

Unit I (Cores 1-5) consists of muds and sandy silts, and represents one of the sandiest intervals at this hole. Terrigenous sediments contain less detrital carbonates than those recovered at Site 379. Most samples are barren of opal skeletons, others contain trace to few diatoms with poor to moderate preservation. *Stephanodiscus astraea* and *S. robustus* are the main constituents besides *Stephanodiscus hantzschii* and *Chrysophyta* cysts.

Unit II (Cores 5-8) is a diatomaceous mud with up to 10 to 25 per cent diatoms (smear-slide determination) and occasionally up to 10 per cent pyrite. A dusty yellow marl occurs at numerous thin laminae in Core 7 and contains up to 60 per cent carbonates, 25 per cent diatoms, and only 15 per cent terrigenous clastics. Diatoms are few to abundant and moderately to well preserved; two samples (380-6-1, 129 cm, and 380-7-2, 22 cm) are barren of opal skeleton remains. *Stephanodiscus hantzschii* is, besides *Stephanodiscus astraea, S. robustus,* and Chrysophyceae cysts, the main constituent of this flora. During short intervals of deposition within this unit, sharp marine injections occurred, as indicated by the presence, in Cores 6 and 8, of *Cyclotella caspia* associated with *Chaetoceros* spores and marine species of the genus *Thalassiosira*.

Unit III: Not present at this site, which may be partly explained by the poor recovery over the interval of Cores 7 through 10.

Unit IV (Cores 9-34) consists of terrigenous muds with diatom-bearing intervals. Cyclic variations in grain size and color occur. Four intervals of diatom-bearing sediments have been recognized (D 3 through 6). Coarser and thicker turbidite sequences are present below 266 meters sub-bottom in Cores 29 through 34. The occurrence of diatoms varies from barren to common; they are poorly to moderately well preserved. This total interval has high proportions of *Stephanodiscus astraea* and *S. robustus,* and lesser amounts of *S. hantzschii,* Chrysophyceae cysts, and *Melosira granulata.* Marine to brackish diatom species (*Actinocyclus normannii, Cyclotella caspia,* and *Chaetoceros* spores) were found in varying percentages at the following levels: 380-10-2, 36 cm; Cores 11 through 12, 380-17-4, 120 cm; 380-18-4, 114 cm; 380-18-6, 90 cm; 380-22-4, 130 cm; 380-32-4, 89 cm; 380-32-6, 116 cm; 380-32, CC.

Unit V (Cores 35-39) is a diatomaceous marl with intercalated sandy mud and silt turbidite layers containing trace calcareous nannofossils. Two diatomaceous layers (D 7 and 8) are separated by a dolomitic marl section with trace calcareous nannofossils. Diatoms occasionally make up 55 per cent of the total sediment (smear-slide determination). The lower diatomaceous sequence in Core 39 is characterized by high proportions of *Actinocyclus normannii* and the absence of *Hermesinum adriaticum*, the upper sequence in Core 35 by high proportions of both species. Diatoms are absent from a few samples in Cores 37 and 38, and are rare to abundant in the remaining intervals; assemblages are poorly to well preserved. Marine and brackish water elements are the main constituents, except for the upper part of Core 36 and the upper and lower part of Core 39.

Unit VI (Core 40) is a brown clay with a few silty layers of siderite clay laminae. All samples examined are barren of opal skeletons.

Hole 380A (Figures 7 and 8b)

Unit V (Cores 1-3) represents the lower part of Unit V at Hole 380, and corresponds to diatomaceous layers D7-8 of the same unit at Hole 380. The correlation between the lower part of Hole 380 and the upper part of Hole 380A was made using the composition of the diatom assemblage; thus, correlation lines were drawn between Hole 380A and Core 1 and Hole 380, Core 36 and between Hole 380A, Core 3 and Hole 380, Core 39. The upper diatomaceous layer has rare and poorly preserved diatom assemblages. The extremely high proportion of *Hermesinum adriaticum*, a strongly silicified species, is probably explained by its ability to resist dissolution longer than other species. Both diatomaceous sequences are separated by a dolomitic marl which contains no opal skeletons (Core 2). The lower diatomaceous sequence in

TABLE 3
Per cent Diatoms, Ebridiaceae, Silicoflagellatae, and Chrysophyta at Site 380, Hole 380A (legend compare Table 2)

Hole 380A Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphiprora* aff. *palludosa*	*Amphora proteus*	*Biddulphia pulchella*	*Biddulphia tuomeyi*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus daemilianus*	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Cocconeis quarnerensis*	*Cocconeis scutellum*	*Coscinodiscus obscurus*	*Coscinodiscus* spp. (huge)	*Coscinodiscus stokesianus* ?	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Melosira undulata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha crux*	*Dictyocha fibula*	*Chrysophyta cysts* B	*Chrysophyta cysts* A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma acuminatum*	*Gyrosigma kützingii* and sp. I*	*Hermesinum adriaticum*	*Mastogloia braunii*	*Melosira arenaria*
1-1, 137	R	P			3	7							3											38										4	6							34		
1-2, 88	R	P				1								1							10														5							72		
1-3, 115	B																																											
1-3, 125	B																																											
1, CC	B																																											
2-6, 81-83*	B																																											
2-6, 105	B																																											
2-6, 114	B																																											
2, CC	B																																											
3-4, 67-69*	A	M			1	63																																						
3-4, 140	C	M				77							13																															
3-4, 142	A	G				58							33																															
4-1, 37	B																																											
4-1, 39	B																																											
4-2, 110	B																																											
4-3, 130	B																																											
4-3, 130, 5	B																																											
4-3, 131	B																																											
4-4, 22	B																																											
5-1, 40-42*	B																																											
5-1, 44	B																																											
5-3, 70	B																																											
5-4, 94-96*	B																																											
5-4, 101	B																																											
5-5, 125	B																																											
5-5, 129, 5	B																																											
6-1, 123	B																																											
6-1, 125	B																																											
6-1, 134	B																																											
6-1, 144	B																																											
6-3, 75	B																																											
6-3, 78	B																																											
6-3, 92	B																																											
6-3, 92-94*	B																																											
6-4, 8	B																																											
6-4, 47-49*	B																																											
8-2, 66	B																																											
8-2, 105	B																																											
8-2, 110	B																																											
8-3, 65-67*	B																																											
8-4, 60	B																																											
8-5, 150	B																																											
9-1, 120	B																																											
9-1, 128	B																																											
9-2, 86-88*	B																																											
9-3, 130	B																																											
9-3, 133	B																																											
9-3, 138	B																																											
9-5, 108-110*	B																																											
9-6, 58-60*	B																																											
9-6, 99	B																																											
9-6, 100	B																																											
10-1, 41	B																																											
10-1, 52	B																																											
10-1, 55	B																																											
10-1, 150	B																																											
11-1, 135	B																																											
11-2, 42-44*	B																																											
11-2, 78	B																																											
11-2, 98	B																																											
11-3, 58-60*	B																																											
12-2, 95	B																																											

TABLE 3–*Continued*

Melosira distans	*Melosira distans (curvata)*	*Melosira islandica*	*Melosira granulata* var. ang. f. *curvata*	*Melosira islandica* var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Rhopalodia gibberula*	*Skeletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus* - *Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus hantzschii* (B)	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis* (plicate)	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus* spores (Pl. 1, Figs. 2-4)	*Stephanodiscus carconensis* g	*Surirella costata*	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	A	B	C
																3	1																					1	9.52	24.77	333.87
		1														7	1																					2	5.90	32.88	334.88
																	16						19																0.18	8.90	356.68
																1	9																						0.39	12.42	357.40
																1	8																						1.00	17.57	357.42

TABLE 3–*Continued*

Hole 380A Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphiprora* aff. *palludosa*	*Amphora proteus*	*Biddulphia pulchella*	*Biddulphia tuomeyi*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus daemilianus*	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Cocconeis quarnerensis*	*Cocconeis scutellum*	*Coscinodiscus obscurus*	*Coscinodiscus* spp. (huge)	*Coscinodiscus stokesianus* ?	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Melosira undulata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha crux*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma acuminatum*	*Gyrosigma kützingii* and sp. I	*Hermesinum adriaticum*	*Mastogloia braunii*	*Melosira arenaria*
12-3, 50	B																																											
12-4, 73	B																																											
13-1, 81-83*	B																																											
13-1, 96	B																																											
14-2, 103-105*	B																																											
14-2, 142	B																																											
14-3, 47	B																																											
14-3, 49	B																																											
14-6, 94-96*	B																																											
15-2, 54	B																																											
15-2, 56	B																																											
15-2, 105-107*	B																																											
15-2, 125	B																																											
15-5, 115	B																																											
16-1, 55	B																																											
16-1, 115	B																																											
17-1, 37-39*	B																																											
17-1, 50	A	G																								10																
17-1, 89	A	M																								90																
17-2, 48	B																																											
17-2, 50	R	P																																										
17-2, 140	B																																											
17-4, 114	B																																											
18-2, 89-91*	B																																											
18-2, 127	B																																											
18-2, 147	B																																											
18-3, 43	B																																											
18-3, 44	B																																											
19-4, 141	B																																											
20-2, 19	B																																											
20-2, 21	B																																											
20-2, 27	B																																											
20-2, 67-69*	B																																											
20-3, 10	B																																											
21-1, 124	B																																											
22-3, 36-38*	B																																											
22-3, 85	B																																											
22-3, 90	B																																											
22-6, 145	B																																											
23-1, 57-59*	B																																											
23-2, 120	B																																											
23-5, 96	B																																											
23-5, 98	B																																											
25-2, 37	B																																											
25-2, 45	B																																											
25-2, 46	B																																											
25-3, 26	B																																											
25-5, 45-47*	B																																											
26-1, 110	B																																											
26-1, 134	B																																											
27-3, 24	B																																											
27-3, 35	B																																											
29-1, 9	B																																											
29-1, 145	B																																											
29-2, 140	B																																											
29-6, 100	B																																											
30-1, 114	B																																											
30-2, 80-82*	B																																											
31-1, 32	B																																											
31-1, 80	B																																											
31-1, 145	B																																											
31-4, 56	B																																											

TABLE 3–*Continued*

Melosira distans	*Melosira distans (curvata)*	*Melosira islandica*	*Melosira granulata* var. *ang.* f. *curvata*	*Melosira islandica* var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Rhopalodia gibberula*	*Skeletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus - Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus hantzschii* (B)	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis* (plicate)	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus* spores (Pl. 1, Figs. 2-4)	*Stephanodiscus carconensis* g	*Surirella costata*	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	A	B	C
																	10						80																0.00	8.94	485.00
																	10																						0.00	0.50	485.39

TABLE 3–*Continued*

Hole 380A Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphiprora* aff. *paludosa*	*Amphora proteus*	*Biddulphia pulchella*	*Biddulphia tuomeyi*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus daemilianus*	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Cocconeis quarnerensis*	*Cocconeis scutellum*	*Coscinodiscus obscurus*	*Coscinodiscus* spp. (huge)	*Coscinodiscus stokesianus* ?	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Melosira undulata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha crux*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma acuminatum*	*Gyrosigma kützingii* and sp. I	*Hermesinum adriaticum*	*Mastogloia braunii*	*Melosira arenaria*
32-4, 100	T	P																																										
32-6, 15	B																																											
32-6, 25	B																																											
33-2, 120	B																																											
33-3, 4-5*	B																																											
33-3, 27	B																																											
34-3, 60	R	P																															1	77										
34-5, 104	B																																											
34-5, 128	B																																											
34, CC	C	P																																2										
35-3, 90-92*	C	M																																										
35-3, 122-124*	B																																											
35-4, 50-52*	A	M																																										
36-2, 65-67*	B																																											
36-2, 128-130*	B																																											
37-3, 88-90*	B																																											
37-3, 90	B																																											
37-4, 90	A	P																																9										
38-1, 75	R	P																															25	67										
38-3, 138	A	G																																										
38-5, 27-29*	R	P																																62										
38-5, 100	F	P																																60										
38-5, 125-127*	C	M																																										
38-6, 15-18*	A	G																				17																						
38-6, 65-67*	F	P																																67										
38-6, 140-142*	C	P																																20										
38, CC	B																																											
39-2, 42	B																																											
39-3, 101	A	M																																										
39-3, 102	C	M																				R																						
39, CC	C	M																																31										
40-4, 57-59*	F	M																																13										
40-4, 96	F	P																																26										
40-5, 79-81*	A	G																																										
41-1, 110-112*	C	M																																										
41-3, 50	A	M																																3										
41-4, 61	A	M																																										
41-4, 86-88*	A	M																																										
41-5, 141, 5	A	G																																										
41-6, 4-6*	A	M																																										
41-6, 144-146*	C	M																																										
42-1, 90	A	M																				3																						
42-4, 40	C	M																				6																						
42-4, 67-69*	C	M																				R																		>0				
42-4, 73	A	G																				6																						
42-5, 6-8*	C	G																																										
42-6, 93	A	G																				3												5										
43-1, 49-51*	C	M																																>0										
43-2, 80	A	G																																										
43-2, 81	C	G																																										
43-3, 145-147*	A	G																																										
43-4, 56	A	G																																										
44-2, 26	A	M																															1	1										
44-2, 44-46*	C	G																																										
44-2, 69	C	M																																										
44-4, 63-65*	A	M																																										
45-1, 47-49*	A	G																																										
45-3, 45-47*	A	G																				9																						
45-3, 123-125*	A	G																																1										
45-4, 94-96*	C	M																				2												3						1				
45-5, 60-62	C	M																																										
45-6, 77-79*	C	M																																						1				

TABLE 3–*Continued*

Melosira distans	*Melosira distans (curvata)*	*Melosira islandica*	*Melosira granulata* var. ang. f. *curvata*	*Melosira islandica* var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Rhopalodia gibberula*	*Skeletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus - Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus hantzschii* (B)	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis* (plicate)	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus* spores (Pl. 1, Figs. 2-4)	*Stephanodiscus carconensis* g	*Surirella costata*	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	A	B	C
																3													19												641.60
	25	51		20																									2										0.00	0.50	645.75
4		2	84	3																									7										0.00	0.50	649.91
4		3	73	2																									18										0.00	0.50	651.01
5		1	1																					2	13				69										0.00	1.06	670.40
1		4		1												2																							0.00	0.50	675.25
34			15																		17	9		13	7				5										0.00	0.96	678.88
9		7														2	4				>0	13		2					1										0.00	0.64	680.78
9		3	1	1																		3		9					14										0.00	1.89	681.50
	13	8	15																		11	12		7					34										0.00	1.80	681.76
3		3	9	1																	16	18		21	3				9										0.00	2.93	682.17
3		2																				18		10															0.00	3.71	682.66
13		6	5																			34		18					4										0.00	3.11	683.41
14		40		5																	10	17		2	2				10										0.00	1.55	688.01
40		36		7																	1	10		1	3				2										0.00	1.01	688.02
15		16														3						2		12					21										0.00	1.37	693.25
36		16		4																	>0	6		2					9		14								0.00	1.00	698.58
45		24																				1		3					1										0.00	0.94	698.96
54		5		1																	1			1							38								0.00	0.54	700.30
																					3	1		3							93								0.00	3.50	704.11
17		23		23																		2		15					7	1	9								0.00	1.08	706.50
40		16		5																	5			4	1				1		28								0.00	0.65	708.10
35		29		9																	8			2							17								0.00	0.57	708.36
17		7		5																	10										61								0.00	0.50	710.41
23		18		7																	10			4							39								0.00	0.69	710.55
48		8		3																	2			8							31								0.00	0.80	711.95
55		11																			2					2		27											0.00	0.50	713.40
40		30		5																	4					2		13											0.00	0.50	717.40
39		15		5														3			1			6				26			5								0.00	0.83	717.68
26		7														1					3							57											0.00	0.50	717.73
20		7		5																4	9			55															0.00	2.12	718.57
18		4														>0					9							64								>0			0.00	0.50	720.93
61		11		4												>0					1			16				7											0.00	0.94	722.50
1		3																94						1				1								>0			0.00	2.90	724.30
2																		90										8											0.00	2.95	724.31
2		2		13													1	51										26								5			0.00	2.35	726.46
1		12		2												1		66										18								R			0.00	2.54	727.06
45		15														3		9						5				1											0.00	0.97	733.26
13		29																	38					1		1											18		0.00	1.70	733.45
51		1																										48											0.00	0.50	733.69
19	24	33	20	3																				1															0.00	0.53	736.64
31		20		1																	4			1				37										6	0.00	0.55	741.48
6		4																			4			1		R		76											0.00	0.73	744.48
39		5		12																	10			20				13											0.00	1.16	745.24
37		21		6																	5			18				7											0.00	1.05	746.45
25		10		12												>0					4			4				15											0.00	0.70	747.61
39		5		5																				27				23											0.00	1.39	749.25

TABLE 3 – *Continued*

Hole 380A Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphiprora* aff. *palludosa*	*Amphora proteus*	*Biddulphia pulchella*	*Biddulphia tuomeyi*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus daemilianus*	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Cocconeis quarnerensis*	*Cocconeis scutellum*	*Coscinodiscus obscurus*	*Coscinodiscus* spp. (huge)	*Coscinodiscus stokesianus* ?	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Melosira undulata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha crux*	*Dictyocha fibula*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma acuminatum*	*Gyrosigma kützing* and sp. 1	*Hermesinum adriaticum*	*Mastogloia braunii*	*Melosira arenaria*
46-2, 75-76*	C	G																																	1									
46-3, 75-76*	C	M																																	2									
46-4, 75-76*	C	M																																<1	3									
46-5, 75-77*	A	M																																										
47-1, 75-77*	C	G																																	3						>0			
47-2, 75-77*	C	G																																	2									
47-3, 75-77*	C	G																																	2						1			
47-5, 50	C	M																																										
47-5, 137	C	P																											>0															
48-4, 35	C	M																												R					1									
48-4, 36	T	P																																	37									
48-4, 80	B																																											
48-4, 145	C	M																																										
48-5, 100	R	P																																7	34									
48-5, 100-102	C	M																																										
48-6, 59-61*	C	M																																										
48-6, 148	B																																											
48-6, 150	B																																											
49-1, 77	C	M			1	1																													>0									
49-1, 80	T	P																																										
49-4, 83	A	M															R																											
49-4, 97-99*	F	M																													R				R									
49-4, 99	R	P																																	5									
49-5, 26-28*	C	M																												2					2									
49-5, 93	F	P			2																																	R						
49-5, 96	B																																											
50-1, 133	T	P																																										
50-2, 14	R	M																																										
50-2, 15	R	M																																	1									
50-2, 20	A	M																																										
50-2, 28	C	M																																										
50-2, 58-60*	C	M			R																																							R
51-1, 53	C	M																																										
51-1, 73	R	M																				2																						
51-3, 66-68*	A	G			27																			15						12	3													
51-3, 76	T	P											3									23													8									
51-4, 68-70*	C	M																				50																						
51-6, 68-70*	C	M																				33									R													
51-6, 85	C	M																				24					3				2				8									
52-2, 30	B																																											
52-2, 82-84*	C	M																				7									4				1									
52-6, 4, 5	B																																											
52-6, 44-46*	F	M																				10									1				1									
52-6, 94-96*	C	G			R																	9					1				R			1	1									
53-1, 116	F	M																				23					2				3			1	2									1
53-2, 68-70*	B																																											
53-2, 84-86*	F	M			1																	52					9				4													
53-2, 93	B																																											
53-3, 54	C	P			2																	24					25							5	4									
53-3, 114-116*	C	M			1																	17					9								1									
54-1, 5	C	M																				62													1									
54-1, 58-60*	F	M			3																	3					13																	
55-3, 30	C	M			90																														3							4		
55-3, 70-72*	F	P			84																													R	R							6		
55-4, 74-76*	A	M			77																			1										9	1							3		
55-4, 83	C	M			71								7																					3	5		R		R			7		R
56-1, 76-78*	A	G			6																			75										1	R							17	1	
56-3, 40	C	M			13								32																					1								10		
56-3, 56-58*	C	M			38																													3	2							5		
56-4, 46	R	P			78								14																						8									
56-4, 81	C	M			64		5			R			5																					5	9							5		
56-4, 128	C	M			16								1											50										5	2							22		

TABLE 3 – *Continued*

Melosira distans	*Melosira dtstans (curvata)*	*Melosira islandica*	*Melosira granulata var. ang. f. curvata*	*Melosira islandica var. angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Rhopalodia gibberula*	*Sceletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus binderianus - Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus hantzschii* (B)	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis* (plicate)	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus* spores (Pl. 1, Figs. 24)	*Stephanodiscus carconensis* g	*Surirella costata*	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	A	B	C
3		2		3													44						1				42								4			0.00	2.62	752.75
4		18		3												3	>0	42						1				11							2	10		0.00	2.08	754.25
19		59		7												3		1										6								1			0.00	0.53	755.75
26		48		19														<1						<1				6											0.00	0.53	757.26
9		21		3														2		55									1										6	0.00	2.03	760.75
2		12		5														1		69									3										6	0.00	2.44	762.25
		37		6													2			35						3															14	0.00	1.67	763.75
20		50		12													7								6																0.00	0.67	766.50
38		52		2													1	2						5																0.00	0.63	767.37
11		49		6													4	10				1	2		16																0.00	1.02	773.85
2		40		3													8									9																1	0.00	0.91	773.86
9		45		13													9	7						17																0.00	0.97	774.95
		43		4													10	2																								0.00	0.50	776.00
		71		4													6	3						16																0.00	0.93	776.01
		89		8														3																								0.00	0.50	777.10
1		82		5													4	3						3																0.35	1.30	779.27
		89														11																											0.00	0.50	779.30
		82		16													2																									0.00	0.50	783.83
		77		17														6																								0.00	0.50	783.98
		82		10													3																									0.00	0.50	783.99
		83		13																																					0.00	0.59	784.77
		82		9													7																									0.00	5.65	785.43
		80		20																																					0.00	0.50	789.64
		85		14																																					0.00	0.50	789.65
		85		15																																					0.00	0.50	789.70
		74		25													1																									0.00	0.50	789.78
		98		2																																					0.00	0.50	790.09
2		90		8																																					0.00	0.50	798.03
		98																																								0.00	0.50	798.23
																											43															9.37	23.42	801.17
		61														5																									0.14	2.12	801.26
		35																	9								6															0.00	1.01	802.69
		8														7		47								5															0.00	2.64	805.69
		19														2		40								2															0.00	2.67	805.85
		13																	72								3															0.00	3.40	809.83
		11														1		71								5															0.00	2.87	815.45
		5														R		83								R															0.00	2.83	815.95
		57														7		2								2															0.00	1.48	818.16
		6														5		20								2									1						0.83	5.31	819.35
		29														3		7								1															0.54	1.87	820.54
		8														1		62								1															0.21	2.87	821.15
		37																																								0.00	0.50	826.55
		10														3	2	63								3															0.56	3.37	827.09
																											3															17.00	35.00	839.30
																10																									17.00	35.00	839.71
							R									10																									22.74	34.40	841.25
							R									7																									15.85	35.00	841.33
										>0																															7.74	21.87	846.27
										44																															0.88	35.00	848.90
									R	52																															17.00	35.00	849.07
																																								14.87	35.00	850.46
					1				R	6																															15.95	35.00	850.81
										2																2															10.10	25.45	851.28

TABLE 3 – *Continued*

Hole 380A Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphiprora* aff. *palludosa*	*Amphora proteus*	*Biddulphia pulchella*	*Biddulphia tuomeyi*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus daemilianus*	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Cocconeis quarnerensis*	*Cocconeis scutellum*	*Coscinodiscus obscurus*	*Coscinodiscus* spp. (huge)	*Coscinodiscus stokesianus* ?	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Melosira undulata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Dictyocha crux*	*Dictyocha fibula*	*Chrysophyta cysts B*	*Chrysophyta cysts A*	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma acuminatum*	*Gyrosigma kützingii* and sp. I	*Hermesinum adriaticum*	*Mastogloia braunii*	*Melosira arenaria*
56-4, 138-140*	C	P			13								6											5										2	41							7		
56-4, 138	B																																											
57-1, 30*	T	P											R																						C									
57-1, 65	B																																											
57-1, 85	R	P																																										
57-2, 118-120*	B																																											
57-3, 81*	T	P	R																																R									
57-6, 105	B																																											
58-3, 55	F	P	2		12								77																						9									
58, CC	T	P																																										
60-1, 35	B																																											
60-1, 36	B																																											
60-2, 46	B																																											
60-3, 78-80*	B																																											
60-3, 97	T	P	F																																									
60-4, 61-63*	R	P	F																																									
61-2, 50	R	P	R						R																																			
61-2, 52	T	P	R																																									
62-2, 72	B																																											
62-2, 118-120*	R	P	F										R																															
62-2, 130	B																																											
62-3, 15	T	P	R						R																																			
62-3, 33	B																																											
63-3, 46	C	M	F																																				R	R				
63-3, 119	T	P																																										
63-4, 4	T	P																																										
64-2, 96*	T	P	R					R																																				
64-4, 116*	F	P						R																											F					R				
65-1, 69-71*	T	P	R																																									
65-2, 44*	T	P	T																																				T					
66-1, 56-58*	T	P																																										
67-1, 81*	R	P	T		T													T	T																				R					
69-3, 66-68*	B																																											
69-4, 52-54*	B																																											
70-2, 106-108*	B																																											
70-5, 106-108*	B																																											
71-2, 30-32*	B																																											
71-3, 74-76*	B																																											
73-1, 96-98*	B																																											
73-2, 56-58*	B																																											
73-3, 78-80*	B																																											
74-2, 56-58*	B																																											
75-2, 56-58*	B																																											
76-2, 76-78*	B																																											
76-4, 104-106*	B																																											
77-2, 56-58*	B																																											
79-1, 76*	F	P			T														R													T	F						F					
79-2, 66*	T	P																																										

Core 3 has common to abundant marine diatoms, moderately to well preserved.

Unit VI (Cores 4-13) consists of greenish gray muds, dolomitic marls commonly interbedded in the muds, and sandy silt turbidite layers. Anozher type is a laminated clay which appears to be typical of varved type sediments. The varves are 1 to 2 mm thick and were laid down at an estimated rate of 1 to 2 m/1000 years (Shipboard Scientific Party, this volume). Characteristically laminated micrite (*seekreide*) with an indication of a cyclic pattern occurs in Core 12 and farther downward. All samples examined are barren of opal skeletons.

Unit VII (Cores 13-34): The upper boundary of this unit was defined at that level where the predominantly calcitic sedimentation gave way to a dolomitic sedimentation. The dominant lithology of this formation consists of muds, marls, and calcareous oozes. A cyclic pattern of sedimentation with cycles of 2 to 8 cm thickness is present. The upper part of the calcareous ooze is horizontally oriented, whereas the rest of the unit includes one or more large slump masses. The

TABLE 3 – *Continued*

Melosira distans	*Melosira distans (curvata)*	*Melosira islandica*	*Melosira granulata* var. ang. f. *curvata*	*Melosira islandica* var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Rhopalodia gibberula*	*Sceletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus* - *Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus hantzschii* (B)	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis* (plicate)	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus* spores (Pl. 1, Figs. 2-4)	*Stephanodiscus carconensis* g	*Surirella costata*	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	A	B	C
										8																							18						14.06	33.27	851.39
																F																									
																																							4.79	34.89	868.05
13		75														8															4								0.00	0.50	873.75
																R																									
																R																									
					F	R							R																												
		R														F																									
							R							F		F							R																		
													R			R																									
														R		R																T									
																T																T									
																R																									
					R	R								F		R																R									
		T				F						T				F	T																								
																R	R																								

calcareous oozes are interpreted as *seekreide*. Below 540 meters sub-bottom (Cores 23-34), carbonate varves occur instead of *seekreide*. They consist of light olive-gray calcareous ooze alternating with greenish gray clays or marls rich in organic matter. All samples except four are barren of opal skeletons. The upper part of Core 17 has an abundant diatom assemblage, moderately preserved to well-preserved, containing a great abundance of *Melosira undulata* and *Stephanodiscus hantzschii* and minor amounts of *Melosira granulata* and *Stephanodiscus astraea*. This assemblage suggests a rather shallow, warm, freshwater environment. The same composition but with fewer specimens was observed in Sample 17-2, 50 cm. Sample 32-4, 100 cm, contains a poorly preserved assemblage with trace amounts of freshwater species: *Melosira islandica*, *Stephanodiscus carconensis* (triangulate), *S. dubius*, and common Chrysophyta cysts. All other samples contain rare brown plant fragments and opal phytoliths and single occurrences of *Melosira islandica*, which is so scarce that whether they are autochthonous or allochthonous cannot definitely be determined.

TABLE 4
Per Cent Diatoms, Ebridiaceae, Silicoflagellatae, and Chrysophyta at Site 381 (legend compare Table 2)

Site 381 Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphora proteus*	*Biddulphia puchella*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Coscinodiscus obscurus*	*Coscinodiscus stokesianus* (?)	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kutzingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma kutzingii* and sp. I*	*Hermesimum adriaticum*	*Mastagloia braunii*	*Melosira arenaria*	*Melosira distans*	*Melosira islandica*	*Melosira granulata* var. ang. f. *curvata*
1-1, 60	T	P																																			
1-1, 64-66*	F	G			1						11							17								9										1	
1-1, 130	R	M																	3	16			10			16											
1-2, 60	B																																				
1-2, 74-76*	B																																				
1-2, 130	B																																				
1-3, 20	C	P																							1												
1-3, 74-76*	C	M				49									25			6								1						17					
1-3, 80	C	G				31					<1				5			37								1						24					
1, CC	C	G				70					1															6						18					
2-1, 27	F	M																	4	17			16			15											
2-1, 74-76*	F	M				1													19				25			23		4						1		<1	
2-1, 140	B																																				
2-2, 74-76*	B																																				
3-1, 74-76*	B																																				
3-1, 113	B																																				
3-2, 60	B																																				
3-3, 74-76*	B																																				
3-3, 130	C	G				4					3																										
4-2, 84-86*	B																																				
4-2, 100	B																																				
4-3, 74-76*	B																																				
4-3, 120	B																																				
5-2, 84-86*	B																																				
5-2, 120	B																																				
5-3, 29	B																																				
5-3, 74-76*	B																																				
5-4, 74-76*	B																																				
5, CC	B																																				
6-2, 74-76*	B																																				
6-2, 85	B																																				
6-3, 74-76*	B																																				
6-5, 86-88*	B																																				
6-5, 123	B																																				
7-3, 74-76*	B																																				
7-4, 74-76*	B																																				
7-5, 75	B																																				
7-5, 138	B																																				
8-1, 70	B																																				
8-1, 74-76*	B																																				
8-1, 130	B																																				
8-3, 74-76*	B																																				
8-5, 84-86*	B																																				
8, CC	B																																				
9-1, 80	B																																				
9-1, 96-98*	B																																				
9-1, 149	B																																				
9-3, 85	B																																				
9-3, 84-86*	B																																				
9-5, 79-81*	B																																				
10-1, 74-76*	B																																				
10-1, 90	B																																				
10-4, 84-87*	B																																				
10-5, 99	B																																				
10-6, 74-76*	B																																				

TABLE 4–*Continued*

Melosira islandica var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Skeletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus - Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis (plicate)*	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus carconensis* g	*Stephanodiscus* spp. (spores, Pl. 1, Figs. 2-4)	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	*Stephanodiscus hantzschii*	A	B	C
	5						7			5		25														11	5	2					6.32	20.66	0.6
												55																					0.00	1.16	0.65
												99																					0.00	0.50	3.20
											2																						7.67	21.32	3.75
											<1																						6.97	20.60	3.80
												5																					3.29	14.54	9.25
												48																					0.00	1.56	9.77
												24																1			1		0.22	3.03	10.25
												87													4						1	1	0.09	2.07	23.30

TABLE 4–*Continued*

Site 381

Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphora proteus*	*Biddulphia pulchella*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Coscinodiscus obscurus*	*Coscinodiscus stokesianus* (?)	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kützingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma kutzingii* and sp. I*	*Hermesinum adriaticum*	*Mastagloia braunii*	*Melosira arenaria*	*Melosira distans*	*Melosira islandica*	*Melosira granulata* var. ang. f. *curvata*
11-1, 128	B																																				
11-2, 12	B																																				
11-2, 74-76*	B																																				
12-1, 74-76*	B																																				
12-1, 77	B																																				
12-2, 31	B																																				
12-2, 74-76*	B																																				
12-2, 80	B																																				
12-5, 74-76*	B																																				
12, CC	B																																				
13-1, 13	B																																				
13-1, 75	B																																				
13-3, 74-76*	B																																				
13, CC	B																																				
14-1, 74-76*	B																																				
14-3, 74-76*	B																																				
14-4, 72	B																																				
14-5, 74-76*	B																																				
15-2, 90	T	M																																		100	
15-5, 74-76*	B																																				
15-6, 46	B																																				
15-6, 94-96*	B																																				
15-6, 113	B																																				
16-1, 130	B																																				
16-4, 74-76*	B																																				
16-6, 112	B																																				
16-6, 125	B																																				
16-6, 112-114*	B																																				
17-1, 90	B																																				
17-3, 74-76*	B																																				
17-3, 74-76*	B																																				
17-6, 76-78	B																																				
17-6, 74-76*	B																																				
17-6, 80	B																																				
18-2, 54-56*	B																																				
18-2, 30	B																																				
18-3, 116	B																																				
18-5, 74-76*	B																																				
18-5, 80	B																																				
19-1, 5	B																																				
19-1, 74-76*	B																																				
19-2, 8	T	M																																	13	68	
19-2, 40	B																																				
19-2, 50	B																																				
19-2, 120	B																																				
19-3, 45	B																																				
19-3, 66-68*	B																																				
19-4, 10	B																																				
19-4, 45	B																																				
19-5, 82-84*	B																																				
19-6, 84-86*	B																																				
20, CC	B																																				
22-1, 74-76*	T	M																								10									2	22	
22-1, 80	R	P																							23	22										29	

TABLE 4–*Continued*

Melosira islandica var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Skeletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus - Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis (plicate)*	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus carconensis* g	*Stephanodiscus* spp. (spores, Pl. 1, Figs. 2-4)	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	*Stephanodiscus hantzschii*	A	B	C
																																	0.00	0.50	135.40
9											5	5																					0.00	0.50	172.58
4											26					35	<1																0.00	3.00	195.75
2											24																						0.00	0.50	195.80

TABLE 4–*Continued*

Site 381 Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphora proteus*	*Biddulphia pulchella*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Coscinodiscus obscurus*	*Coscinodiscus stokesianus* (?)	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kutzingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma kutzingii* and sp. I*	*Hermesinum adriaticum*	*Mastagloia braunii*	*Melosira arenaria*	*Melosira distans*	*Melosira islandica*	*Melosira granulata* var. ang. f. *curvata*
22-3, 74-76*	A	G																													2*				13	21	26
22-3, 123	A	G																													1				24	3	27
23-1, 35	C	M																																	24	1	7
23-1, 90	A	M																																	51	10	
23-2, 52	A	G																																	35	20	
23-2, 145	A	G																								1									7	4	
23-3, 74-76*	C	M																								7								1		13	
23-4, 25	F	M																								6									39	4	
23-4, 74-76*	F	M																								8										88	
24-1, 74-76*	C	M																								3					2*				13	26	
25-2, 74-76*	R	P																								6									6	37	
25-2, 72	F	P																								16									22	2	
25-3, 75	F	P																								24										33	
25-4, 84-86*	C	M																																	17	26	
26-2, 75	F	M																																	50	36	
26-3, 104-106*	A	G																																	6	26	
26-5, 39	C	M																																	1		
26-5, 84-86*	A	G																													>0*						
27-3, 106-108*	C	M																								1									33	31	
27-3, 114	A	M																																	45	14	
28-2, 75	A	M																																	36		
28-3, 39-41*	C	M															11									1					>0*				42	13	
28-4, 75	A	M																																	38	6	
28-5, 56-58*	C	M																																	23	22	
28-6, 134	C	M																																	44	13	
29-1, 118-120*	C	M																								<1									13	30	
29-1, 130	A	M																																	5	14	
29-2, 30-32*	A	G																								1									15	9	
29-4, 55	F	M																																	60	9	
29-4, 64-66*	C	M																													4				5	42	
29-5, 32-34*	C	M																													2				7	42	
29-6, 50-52*	C	M																													R				6	42	
30-1, 138	B																																				
30-2, 135	C	M																																	11	19	
30-2, 136-138*	A	G																																	17	17	
31-2, 75	A	G																																		>0	
31-2, 86-88*	A	G																																		2	
31-2, 118	F	G																																	>0	18	
31-3, 42-44*	A	G																													1				2	20	
32-1, 61-63*	C	G																								2									3	24	
32-1, 66	A	G																																		35	
32-1, 118	B																																				
32-1, 120	T	M			2																					3										66	
32-2, 64	R	M			1																															94	
32-2, 73	F	M																						<1	>0											86	
32-2, 72-74*	C	M																						1												92	
32-3, 132	R	M			>1																					2										81	
32-4, 91	R	M			2											<2										<2						1				78	
33-2, 74-76*	C	M			1											61								5											5	25	
33-2, 74-76*	C	M			3						2					37					12			4		1									3	28	
33-3, 120	A	G														7					66														1		
33-4, 79	C	G														5										>0										77	
33-4, 82-84*	C	M														2																			<1	71	
34-1, 74	F	M			1																20					10											
34-3, 74-76*	C	G														<2					5			2													

TABLE 4–*Continued*

Melosira islandica var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Sceletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* b	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus* - *Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis* (*plicate*)	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus carconensis* g	*Stephanodiscus* spp. (spores, Pl. 1, Figs. 2-4)	*Thalassionema nitzschioides*	*Thalassiosira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. b	*Melosira granulata*	*Stephanodiscus hantzschii*	A	B	C
												1					9	12				1	15										0.00	1.36	198.75
																3	9	13	9				11										0.00	1.46	199.23
											1					29	8	10	8				12										0.00	1.72	199.85
6												6				1	15	6	1				4										0.00	1.38	200.40
2																2	15	11	15						R								0.00	1.65	201.52
10																3	19	36	5				15										0.00	2.81	202.45
											1					5	14	5	13	41													0.00	2.79	203.25
											7							13	12			1	18										0.00	1.08	204.25
																	2	2															0.00	0.65	204.75
													19			1	21		15														0.00	2.30	209.75
											22						28	1															0.00	2.29	220.74
											3							1	13				43										0.00	0.60	220.72
2																		8	7			2	19	5									0.00	0.97	222.25
13												1				7	15	2	5			1	9									4	0.00	1.92	223.85
															6			1	3				4										0.00	0.69	230.25
3															22	12	3	8	6				14										0.00	1.80	232.04
													1			>0		2	21				2	74									0.00	2.38	234.39
																3		4	8				2	82									0.00	3.00	234.85
6																2		7					1	19									0.00	0.54	void
1																		9				2	4	24									0.00	0.83	void
19												1	2			5						1	3	29								4	0.00	1.19	249.25
4													5			3		>1	1			4		15									0.00	0.73	void
>0													5			1		8				16		26									0.00	1.07	void
3													27			5		13				2		5									0.00	1.64	253.57
4													7			3		7				22											0.00	0.97	255.84
20											1		14					2				19											0.00	1.01	257.69
32													15			<1						33											0.00	1.07	257.80
5													7			2		7				54							R				0.00	1.31	258.31
2											1		1									26											0.00	0.54	261.55
											2											46											0.00	0.50	261.65
											3							6				39											0.00	0.77	262.83
											3							9				40											0.00	0.90	264.51
3														28				7				32							R				0.00	1.79	268.85
5													35					4				19							3				0.00	1.85	268.87
												>0		97			1				>1												0.00	3.17	277.75
														94			4																0.00	3.03	277.87
1											1	4		68			5				2												0.00	2.51	278.18
>0											>0			61			8				7												0.00	2.57	278.93
9														50			5	1			6												0.00	2.13	285.62
23											>0	9		23			5				5												0.00	1.34	285.66
2											27																						0.49	1.49	286.20
2											3																						0.18	0.86	287.14
6											2		4																				0.00	0.80	287.23
6											<1																						0.00	0.70	287.23
5											8		2																				0.19	0.94	289.32
4											9		3																				0.39	1.76	290.41
											2							1															0.46	4.14	296.75
											5		3							2													1.04	5.19	296.75
													26																				0.00	1.20	298.70
6											>0		10							2													0.00	0.77	299.79
26											1																						0.00	0.50	299.83
13											>2		25																				0.20	1.62	304.74
											>2		89							<1													0.00	3.22	307.75

TABLE 4–*Continued*

Site 381 Sample (Interval in cm)	Abundance of Diatoms	Preservation of Diatoms	*Achnanthes brevipes*	*Achnanthes* spp. (marine)	*Actinocyclus ehrenbergii*	*Actinocyclus normannii*	*Actinoptychus undulatus*	*Amphora proteus*	*Biddulphia pulchella*	*Chaetoceros* spp. (bristles)	*Chaetoceros* spp. (spores)	*Campylodiscus* spp. (marine)	*Cocconeis distans*	*Cocconeis* spp. (marine)	*Coscinodiscus obscurus*	*Coscinodiscus stokesianus* (?)	*Stephanodiscus niagarae*	*Cyclotella caspia*	*Cyclotella kutzingiana*	*Cyclotella ocellata*	*Cyclotella operculata*	*Cymatopleura elliptica*	*Cymatopleura solea*	*Diatoma elongatum*	*Chrysophyta* cysts B	*Chrysophyta* cysts A	*Distephanus speculum*	*Epithemia zebra*	*Grammatophora arcuata*	*Grammatophora oceanica*	*Gyrosigma kutzingii* and sp. I*	*Hermesinum adriaticum*	*Mastagloia braunii*	*Melosira arenaria*	*Melosira distans*	*Melosira islandica*	*Melosira granulata* var. ang. f. *curvata*
34-6, 50	C	M			53													2							2	<1		<2				1		<2			
35-3, 40	A	G			60																																
35-4, 38	C	G			19													4							25	10						36					
35-5, 35	R	P			52																				7	5						11					
35-5, 61-63*	C	G			29						10				>0											<2						12					
35-2, 30	C	M			89																				>0	6											
35-2, 74-76*	C	P			97																					2						1					
36-1, 40	C	M			42																				7	12						19		<2			
36-1, 70	C	M			32																				27	3						32					
36-2, 54-56*	F	M			17										>0										27	10						42					
37-1, 50	A	G			64																				11	5						14					
37-1, 58	C	G			46						<1														15	4						27		3			
37-1, 128	R	M			58		>1				9															22						6				1	
37-2, 114-116*	C	G									14				10											30						24					
37-5, 55	R	M			51						15															16						12				6	
37-5, 114-116*	F	P			25						16														5	39						15					
39-1, 50	T	P																																		100	
40-1, 112	R	P			49																				18							16					
41, CC	T	G			63																					5						12				12	
43-1, 10	B																																				
48-2, 38-40	B																																				
48-4, 28-30	B																																				
48-5, 20	B																																				
48-5, 80	T	P			3																															90	
48-5, 80	T	M																								16									9	75	
48-6, 128-130	B																																				
49-1, 78-80	B																																				
49-3, 136-138	B																																				
49-5, 106-108	B																																				
49-5, 106-108	B																																				
51-3, 22	B																																				
51-3, 35	T	P																																		100	
51-3, 57-59	B																																				
51-3, 64-66	B																																				
51-3, 92-94	B																																				
51-3, 120-122	B																																				
51-4, 9	B																																				
51-4, 45	B																																				
51-5, 22	B																																				
51-5, 96	B																																				
51-6, 3	B																																				
51-6, 90-92	B																																				
51-6, 100	B																																				
51-6, 120	B																																				
52-2, 56-58	B																																				
52-2, 62-63	B																																				
52-2, 65	B																																				
52-2, 123	B																																				
52-2, 149	B																																				
53-3, 112-114	B																																				
54-1, 49, 4	B																																				
54-3, 138	T	P																																		100	
54-4, 120-122	B																																				
54-5, 105	T	P																																		98	
54-6, 60-62	B																																				
54-6, 60-62	B																																				

TABLE 4–*Continued*

Melosira islandica var. *angustissima*	*Melosira sulcata*	*Navicula lyra*	*Nitzschia punctata*	*Pleurosigma angulatum*	*Rhabdonema adriaticum*	*Synedra indica*	*Rhizosolenia calcaravis*	*Rhizosolenia styliformis*	*Rhoicosphenia curvata*	*Sceletonema costatum*	Sponge spicules	*Stephanodiscus astraea*	*Stephanodiscus binderianus* bSte	*Stephanodiscus binderianus* a	*Stephanodiscus binderianus* c (Pl. 12, Figs. 19, 22)	*Stephanodiscus - Cyclotella*	*Stephanodiscus dubius*	*Stephanodiscus carconensis* a	*Stephanodiscus omarensis (plicate)*	*Stephanodiscus transylvanicus*	*Stephanodiscus* sp. C	*Stephanodiscus niagarae*	*Stephanodiscus omarensis*	*Stephanodiscus carconensis* g	*Stephanodiscus* spp. (spores, Pl. 1, Figs. 2-4)	*Thalassionema nitzschioides*	*Thalassoisira eccentrica*	*Thalassiosira oestrupii*	*Thalassiosira* aff. *lineatus*	*Thalassiosira* sp. B	*Melosira granulata*	*Stephanodiscus hantzschii*	A	B	C
											<2		35							<1													9.77	21.60	312.00
													36							4													10.63	23.00	316.90
											2									4													16.19	33.85	318.38
											24									<1													17.00	35.00	319.85
						47																											14.26	35.00	320.12
																				5													17.00	35.00	315.30
																																	19.78	47.14	315.75
											17																						16.46	33.91	323.40
											6						>0																17.00	35.00	323.70
											4																						17.00	35.00	325.05
						<1							5							<1													15.98	33.07	333.00
	>0																																16.16	33.66	333.08
	2																																14.78	34.55	333.78
				5		15					2																						12.91	35.00	335.15
																																	13.29	37.54	339.05
																																	13.00	35.00	339.65
																																	0.00	0.50	352.00
											17																						17.00	35.00	void
																	4			4													14.01	29.13	379.75
																								7									0.55	1.61	443.80
																																	0.00	0.50	443.80
																																	0.00	0.50	468.85
																																	0.00	0.50	498.38
												2																					0.00	0.50	501.05

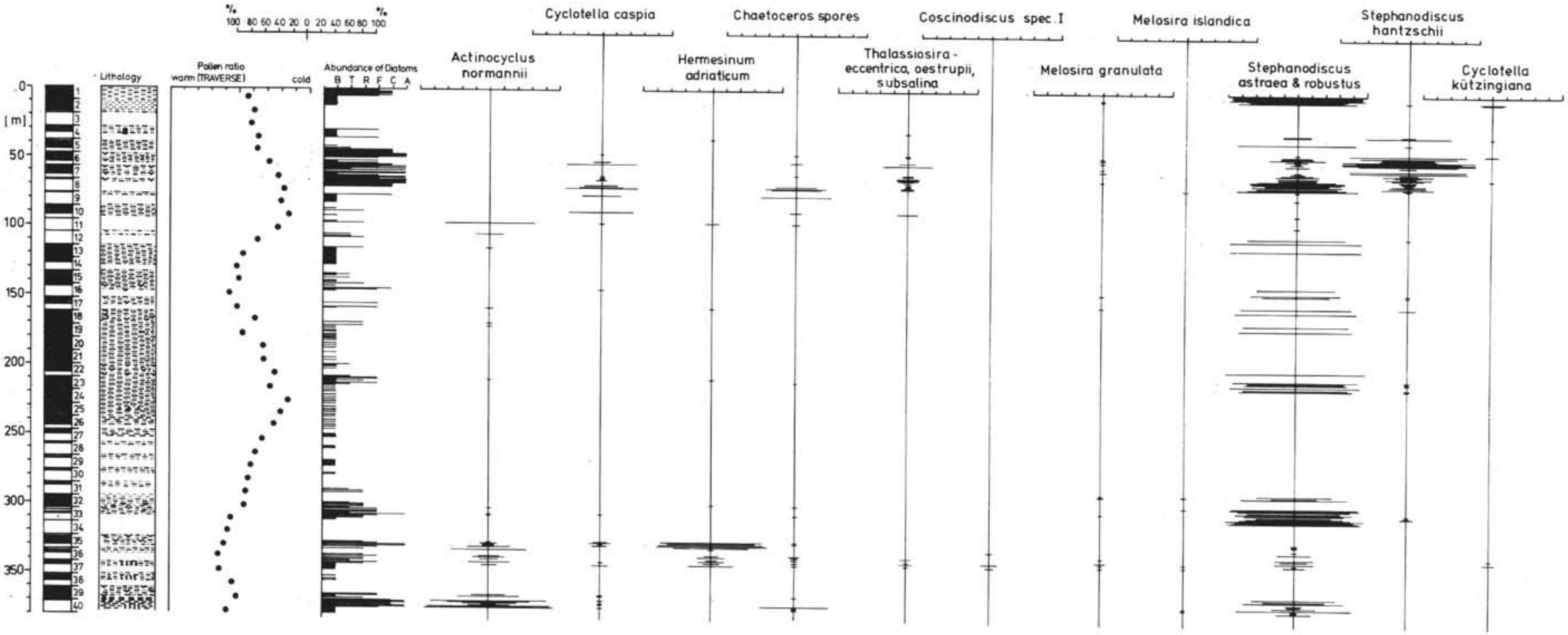


Figure 6. *Site 380, legend see Figure 4.*

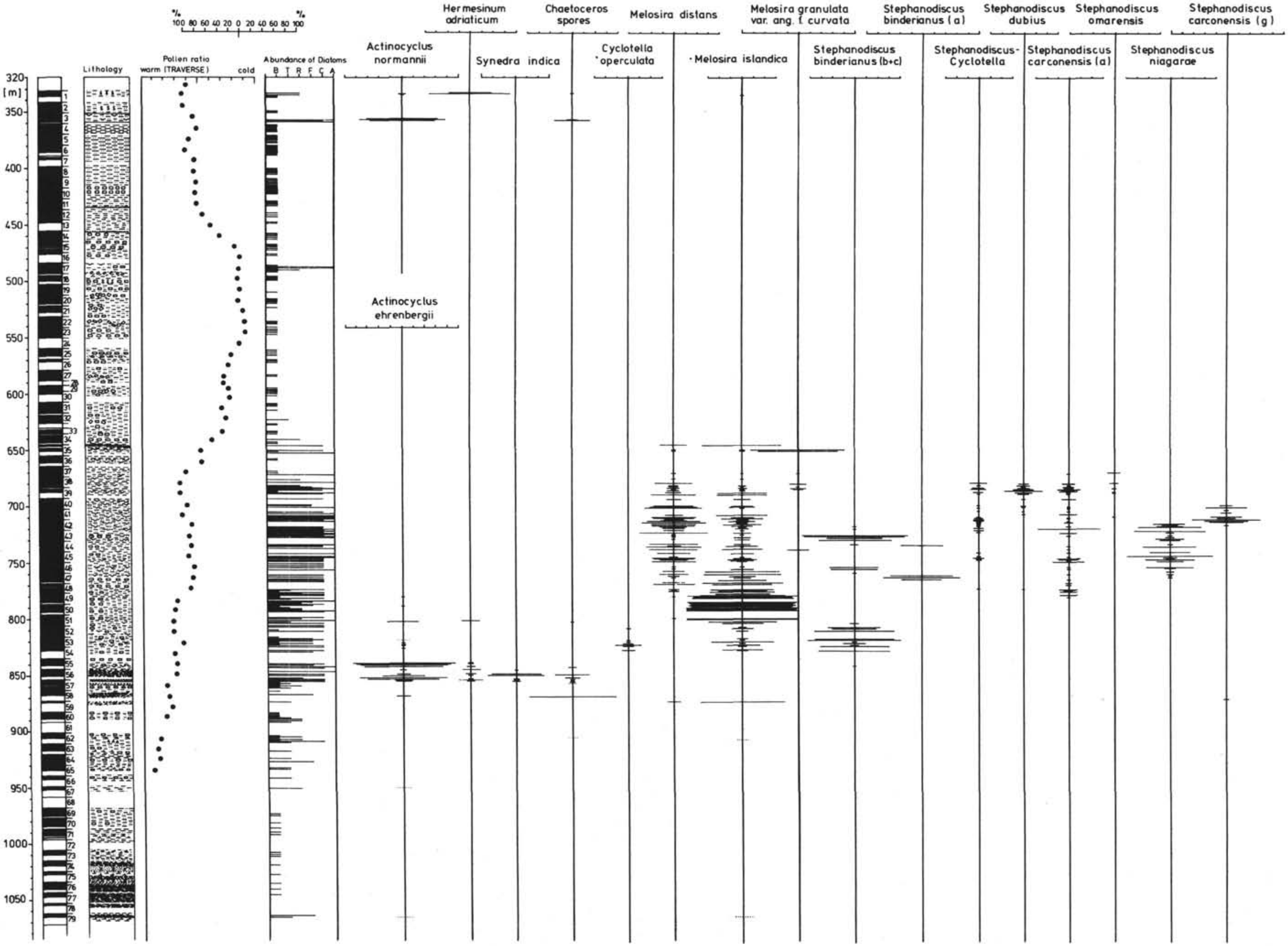


Figure 7. *Site 380, Hole 380A, legend see Figure 4.*

TABLE 5
Diatoms, Silicoflagellates, Chrysophyta Cysts, Ebridians and Sponge Spicules in "Recent" Black Sea Sediments

	1		2		3		4		
	1461-23 PG		1436-7 PG		1476-33 GC		1466-2 PG		Salinity-Tolerance
		%		%		%		%	
Distephanus speculum	6	2.7	75	42.4	15	36.6	127	31.6	10->35
Actinocyclus ehrenbergii			2	1.1			2	0.5	17->35
Hermesinum adriaticum	7	3.2					4	1	17->35 (?)
Coscinodiscus radiatus	1	0.5	8	4.5					17->35
Chaetoceros spores	38	17.4	9	5.1	17	41.5	59	14.7	3->35
Cyclotella caspia			8	4.5	6	14.6	81	20.2	5-14.3
Thalassiothrix frauenfeldii	65	29.7	37	20.9			32	8	17->35
Thalassionema nitzschioides	16	7.3					4	1	1.2->35
Thalassiosira oestrupii			31	17.5			85	21.1	17->35
Thalassiosira spp.	3	1.4							–
Melosira sulcata	43	19.6	5	2.8			8	2	5->35
*Melosira islandica**	3	1.4	2	1.1					0-0.5
*Stephanodiscus robustus**	1	0.5							0-0.5
Chrysophyceae cysts	9	4.1							?
Sponge spicules	20	9.1			3	7.3			?
Diploneis crabro	1	0.5							?
Diploneis smithii	2	0.9							3->35
Nitzschia punctata	4	1.8							10->35
Total	219		177		41		402		

Note: Asterisk indicates allochthonous freshwater species.

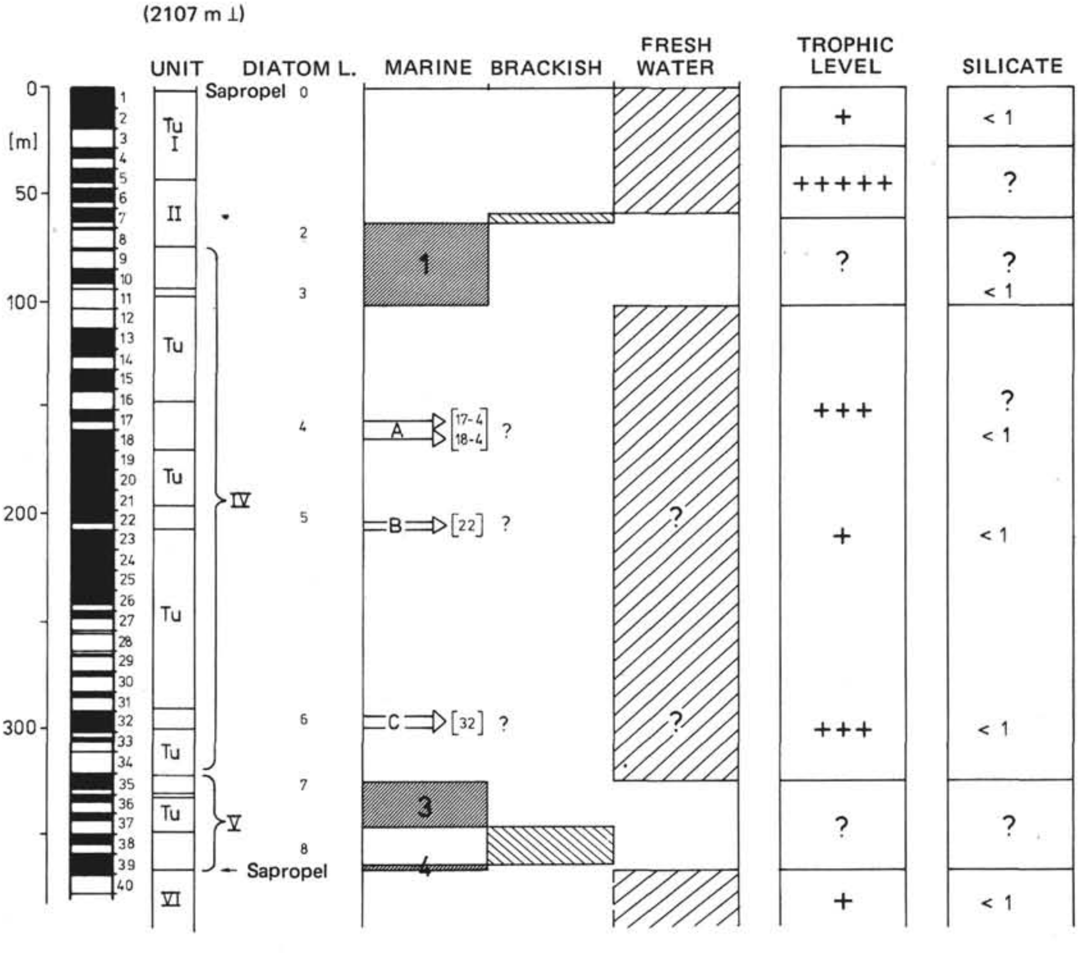


Figure 8a. *Summary figure of important findings at Site 380, legend see Figure 5.*

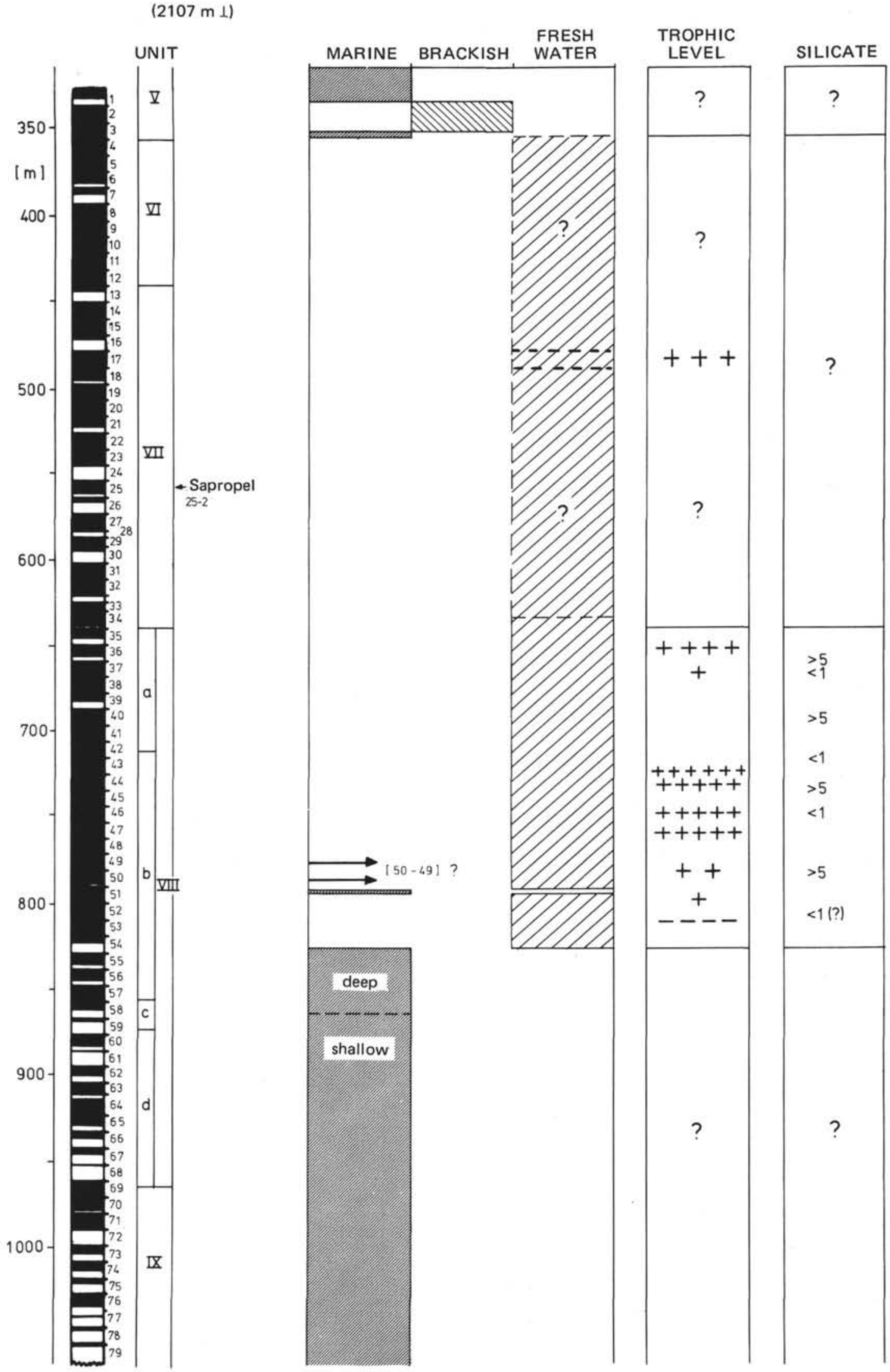


Figure 8b. *Summary figure of important findings at Site 380, Hole 380A, legend see Figure 5.*

Unit VIII (Cores 35-69): The top of this unit is a siderite layer at Sample 34-5, 110 cm (644 m sub-bottom), and the base is placed at that level where black shales become dominant (969 m sub-bottom). This unit is characterized by diatoms as sediment builders (proportion of diatoms ranges from 5% to 65%, smear-slide determination, of the total sediment); they are present down to Core 67, Section 1. Four subdivisions have been made within Unit VIII; they are elaborated below (Shipboard Scientific Party, this volume).

Subunit VIIIa (Cores 35-42) consists of finely laminated diatomaceous clays. The varves are about 1 mm thick; diatom content is 15 to 60 per cent (smear-slide determination) in the diatomaceous layers. Two layers of light olive-gray calcareous ooze or marl are present near the top of this subunit. Two tuff laminae were found in Section 37-5 and in Section 41-3. Siderite is a characteristic sediment component of this subunit, and is present in Cores 34, 36, 37, 39, 40, 41, and 42. Diatom occurrences range from barren to abundant, with poorly preserved to well-preserved assemblages. The various assemblages contain freshwater diatom species; *Melosira granulata* var. *angustissima* f. *curvata* is abundant near to top of this subunit, *Melosira distans* and *M. islandica* are abundant in the lower part, and *Stephanodiscus carconensis* (triangulate) is abundant near the bottom. *Melosira ambigua* (present in Cores 41-42, *Stephanodiscus - Cyclotella, Stephanodiscus dubius, S. carconensis* (type a), *S. omarensis, S. niagarae,* together with abundant *Chrysophyta* cyst type A, form the minor constituents of the diatom assemblages. Most remarkable are the mass occurrences of *Melosira granulata* var. *angustissima* f. *curvata, Stephanodiscus carconensis* (triangulate), and *Melosira ambigua*. No meso- or polyhaline diatom species were observed.

Subunit VIIIb (Cores 42-57): The top of this subunit is marked by a siderite layer and the base by the top of an underlying turbidite. The dominant lithology comprises diatomaceous muds and diatomite varves. Diatoms are present as sediment builders and range from a few to 45 per cent (smear-slide determination). Siderite is absent. Partly laminated black shales which form the dominant lithology of subunit VIIId are present in the lowest part of this subunit (Cores 55, 56, 57). Laminated carbonates and structureless marls are common, especially in the lower part. The occurrence of diatoms ranges from barren to abundant, with poorly preserved to well-preserved assemblages. The most common diatom species are *Melosira distans, M. islandica, Stephanodiscus binderianus,* which has a peak abundance of type a in Cores 44 and 47, *Stephanodiscus carconensis,* and minor components are *S. astraea, Stephanodiscus-Cyclotella,* and *Thalassiosira* aff. *lineata* in the upper part of this subunit. A floral change occurs between Samples 380A-51-1, 73 cm, and 380A-51-3, 66-68 cm. This middle part ranges from 51-3, 66 cm, to 55-3, 30 cm, at which level another floral assemblage change occurs. The middle part is characterized by abundant *Coscinodiscus* (?) *stokesianus, Melosira islandica,* and *Stephanodiscus binderianus. Actinocyclus ehrenbergii* is rare in the lower part. Since no salinity tolerances are known for *Coscinodiscus* (?) *stokesianus,* the calculated ones may be too low and the assemblage should be interpreted rather to indicate mesohalobous environments.

The lower part of this subunit is characterized by great abundances of *Actinocyclus ehrenbergii, Cyclotella caspia*, and *Synedra indica* (in the lowermost part); minor elements are *Chaetoceros* spores, *Hermesinum adriaticum,* Chrysophyta cysts, and *Stephanodiscus transsylvanicus* down to Sample 56-4, 138 cm. About 99 per cent of this assemblage consists of planktonic diatom species. Abundance and preservation change drastically in Sample 56-4, 138 cm to barren-rare and poor. Dominant species are *Achnanthes brevipes*, an epiphytic species indicating a rather shallow-water environment at the time of deposition, if it is autochthonous.

Subunit VIIIc (Cores 58-59) consists of coarse clastics and pebble mudstones; breccias and turbidites constitute the dominant lithology. Diatoms are barren to few and preservation is poor. Sample 58-3, 55 cm, contains a similar shallow-water marine diatom assemblage first observed in the lowermost part of Subunit VII-b. Sample 58, CC, contains a freshwater assemblage with *Melosira islandica* and *Stephanodiscus carconensis* (triangulate) and is interpreted as downhole contamination, since *S. carconensis* (triangulate) was observed in similar proportions only in Cores 42 through 49. All other remaining samples are barren of opal skeletons (including smear-slide samples not included in Table 3).

Subunit VIIId (Cores 60-69): This subunit consists of interbeds of three distinct types of sediments with sporadic dolomite intercalations: (1) laminated marls or shales, (2) carbonate varves, and (3) marls. Diatoms are absent to common with moderately to poorly preserved tests present. The observed assemblages contain few *Achnanthes brevipes, Amphiprora* aff. *palludosa, Grammatophora* species, *Melosira sulcata*, and other meso- to polyhaline benthic species. All these species and the paucity of marine-planktonic species suggest a rather shallow (less than 100 m water depth) environment during deposition.

A few individuals of *Stephanodiscus kanitzii* Pantocsek were observed as a single finding in Sample 380A-67-1, 81 cm; this species seems to have been restricted to the late Miocene in the Paratethys (Hajos, 1968), and is interpreted as a "fossile, sehr veränderliche Brack- und Meerwasserform" (Hajos, 1968). Associated with this species are *Licmophora* spp. (large forms) and *Cocconeis quarnerensis*. As a result of strong mechanical deformation, exact taxonomic identification is difficult.

Unit IX (Cores 69-80) consists of black shales with zeolitic sandstones and dolomite. The black shales are greenish black and fissile, consist of clays rich in organic matter, and may contain up to 20 per cent quartz and feldspars and 10 per cent pyrite. The black shales and associated sediments were deposited in a marine environment, as indicated by the presence of a small unidentified benthic foraminifer (Shipboard Scientific Party, this volume).

Diatoms were observed only in Core 79 in traces to few and with poor preservation. The diatom assemblage consists of common *Stephanodiscus* (?) *kanitzii*, few *Navicula lyra, Grammatophora* species, *Cocconeis scutellum*, and trace *Rhizosolenia styliformis* and *Actinocyclus ehrenbergii*. Associated are few *Dictyocha fibula, D. crux*, and a few sponge spicules. A tentative date of late Miocene can be assigned on the basis of occurrence of *Stephanodiscus* (?) *kanitzii* Pantocsek. Because of strong mechanical and chemical (dissolution) deformation of opal skeletons, no further taxonomic identification was possible. All the above-mentioned species point to a rather shallow (less than 100 m water depth) environment during deposition. Sample 380A-79-2, 66 cm contains trace freshwater diatoms, poorly preserved, and this occurrence is interpreted as downhole contamination.

Floral composition, with relative percent abundance, total abundance, preservation, and calculated minimum and maximum salinity ranges, have been tabulated in Table 3, and are partly illustrated in Figure 7. A more detailed paleoecological interpretation of the different levels will be found later in this chapter.

Figures 8a and 8b provide a generalized summary of important paleoecological interpretations, and show three marine episodes and three minor episodes tentatively interpreted as marine in Hole 380, and three marine episodes at Hole 380A. These episodes do not correlate with the pollen ratio curve (Traverse, this volume).

Sapropels were observed at the following levels: (1) Sapropel, Samples 380-1, 0 cm to 380-2, 50 cm, rich freshwater diatom assemblage; (2) sapropelic mud, Samples 380-4 to 380-5, sparse freshwater diatom assemblage in Samples 4-1, 36 cm, and 4-4, 108 cm; (3) sapropel, Sample 380-39-6, 50 cm, few diatoms *Actinocyclus normannii, Chaetoceros* spores, and Chrysophyta cysts, revealing a surface-water salinity range of 0.5 to 10‰ at the time of deposition; (4) clay rich in organic matter, Sample 380A-9-1, 100 cm, no diatoms present; (5) clay rich in organic matter, Sample 380A-16-1, 115 cm, no diatoms present; (6) sapropel, Samples 380A-25-2, 37 cm to 380A-25-2, 46 cm, no diatoms present; (7) clay rich in organic matter, Cores 380A-35 to 380A-36; a few samples with a freshwater diatom assemblage; (8) clay rich in organic matter, Core 380A-45, abundant freshwater diatom assemblage; (9) black shales, Core 380A-71 to bottom of Hole 380A; only one sample with a marine, primarily benthic diatom assemblage.

Site 381 (Figures 9 and 10)

Site 381 lies upslope of Site 380 in the southwest Black Sea (Figure 1), and was drilled at an actual water depth of 1728 meters to a total penetration of 503.5 meters.

On the basis of sediment structure, composition, and micropaleontological evidence, nine lithological units were distinguished, and were in part adjusted to the same unit subdivisions that have been used at Site 380, Holes 380A and 380.

Unit I (Cores 1-18) is a medium bluish gray to greenish black terrigenous mud to clay. The presence of occasional turbidites is indicated by graded bedding. Diatoms are absent to common in the uppermost Sections 1-3; *Actinocyclus normannii* is abundant, and minor components of *Hermesinum adriaticum, Cyclotella caspia* and polyhalobous *Thalassiosira* species occur in the interval from Sample 381-1-3, 74 cm to Sample 381-1, CC. Above and below, *Stephanodiscus astraea* is abundant in the tops of Cores 1 and 2; minor amounts of *Cyclotella kützingiana, Cymatopleura solea*, and Chryosphyta cysts are present. Section 3-3 contains common and well-preserved freshwater diatoms, including abundant *Stephanodiscus astraea* and in Section 15-2 traces of *Melosira islandica* occur. All other samples examined are barren of diatoms.

Unit II (Core 19) is a laminated micrite (*seekreide*) with an indication of a cyclic pattern. This unit may be comparable to the sediment section of Core 34, Hole 380A (base of Unit VII). Freshwater diatoms (*Melosira islandica* and *Melosira distans*) occur in Sample 381-19-2, 8 cm, in trace amounts. All other samples are barren of diatoms.

This unit is separated from the following one by approximately 25 meters of greenish gray terrigenous clay, but recovery over this interval was rather poor, so it is difficult to specify the contact between Units II and III.

Unit III (Cores 22-32) is a diatomaceous-sapropelic mud. The characteristic patterns are alternating sequences of dark greenish gray to olive-gray diatomaceous muds rich in organic matter and light olive-gray to grayish yellow carbonate-rich muds. Two lithified carbonate layers, 3 to 5 cm thick, were found in Cores 26 and 27, and are interpreted to be comparable to the two siderite layers in Hole 380A, Cores 40 and 41. Diatom occurrences range from barren to abundant with poorly preserved to well-preserved assemblages. The various freshwater assemblages contain abundant *Melosira islandica* and *M. distans*; the three most characteristic sequences are *Melosira granulata* var. *angustissima* .f. *curvata* Samples 22-3, 74 cm to 23-1, 35 cm), *Stephanodiscus carconensis* (triangulate) (Samples 25-3, 75 cm to 28-5, 56 cm), and *Stephanodiscus binderianus* type a, (Samples 30-2, 135 cm to 32-1, 66 cm). Minor elements within this unit are Chrysophyta-cysts, *Gyrosigma* sp. 1, *Stephanodiscus-Cyclotella, Stephanodiscus dubius, S. carconensis* type a, *S. omarensis, S. niagarae*, and *Melosira ambigua* in Core 31 (not included on Table 4). No meso- or polyhaline diatom species were observed.

Unit IV (Cores 32-34) is a pale olive diatomaceous micrite (*seekreide*) distinguished from the previous unit principally by the larger amounts of calcite, which occurs in a finely laminated pattern. Laminations range from 1 mm to 10 mm thick, and are partly disturbed by burrowed interbeds. Bedding of 4 cm was additionally observed. The base of this unit is defined between Samples 34-3, 74-76 cm and 36-6, 50 cm by the last great abundance of *Actinocyclus ehrenbergii*. Diatoms are absent to abundant with moderately preserved to well-preserved assemblages. The most common diatom species are *Melosira islandica, Coscinodiscus* (?) *stokesianus* (most common in Core 33), *Cyclotella operculata* (most common in Cores 33 and 34 and in mass abundance in Sample 33-3, 120 cm). Minor elements are traces of *Actinocyclus ehrenbergii, Diatoma elongatum*, Chrysophyta-cysts, *Melosira distans* (not included in Table 4), *Stephanodiscus binderianus*, and *S. transylvanicus*. Since no salinity tolerances are known for *Coscinodiscus* (?) *stokesianus*, the calculated ranges may be too narrow. The assemblage found in Cores 33 and 34 should be interpreted as indicating mesohalobous surface water environment. At the same time, the salinity ranges for *Cyclotella operculata* obtained from the literature (Hustedt, 1930; Stoermer and Yang, 1970) are 0 to 0.5‰ and indicate an oligohalobous surface water environment. The trace occurrence of the polyhalobous *Actinocyclus ehrenbergii* suggests short marine spills if these occurrences are autochthonous. This unit corresponds to Unit VIIIb of Hole 380A where a rather similar succession of species was observed (Figure 7).

Unit V [Cores 34 (lower part)-38] is an aragonite-rich diatomaceous clay. Aragonite occurs as needle-shaped crystals and is concentrated in fine layers mixed with clays, diatoms, and detrital carbonates in massive beds. Diatoms

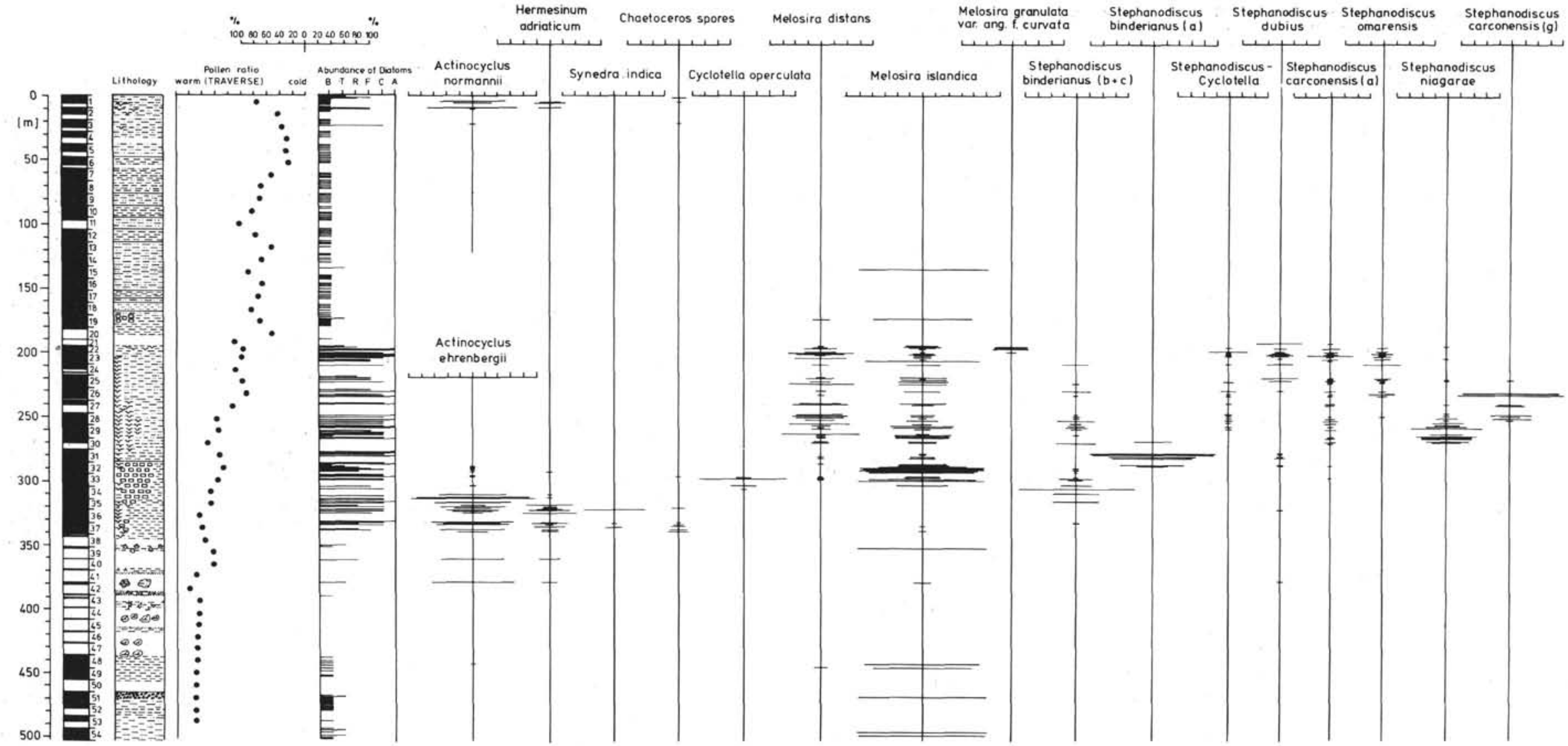


Figure 9. *Site 381, legend see Figure 4.*

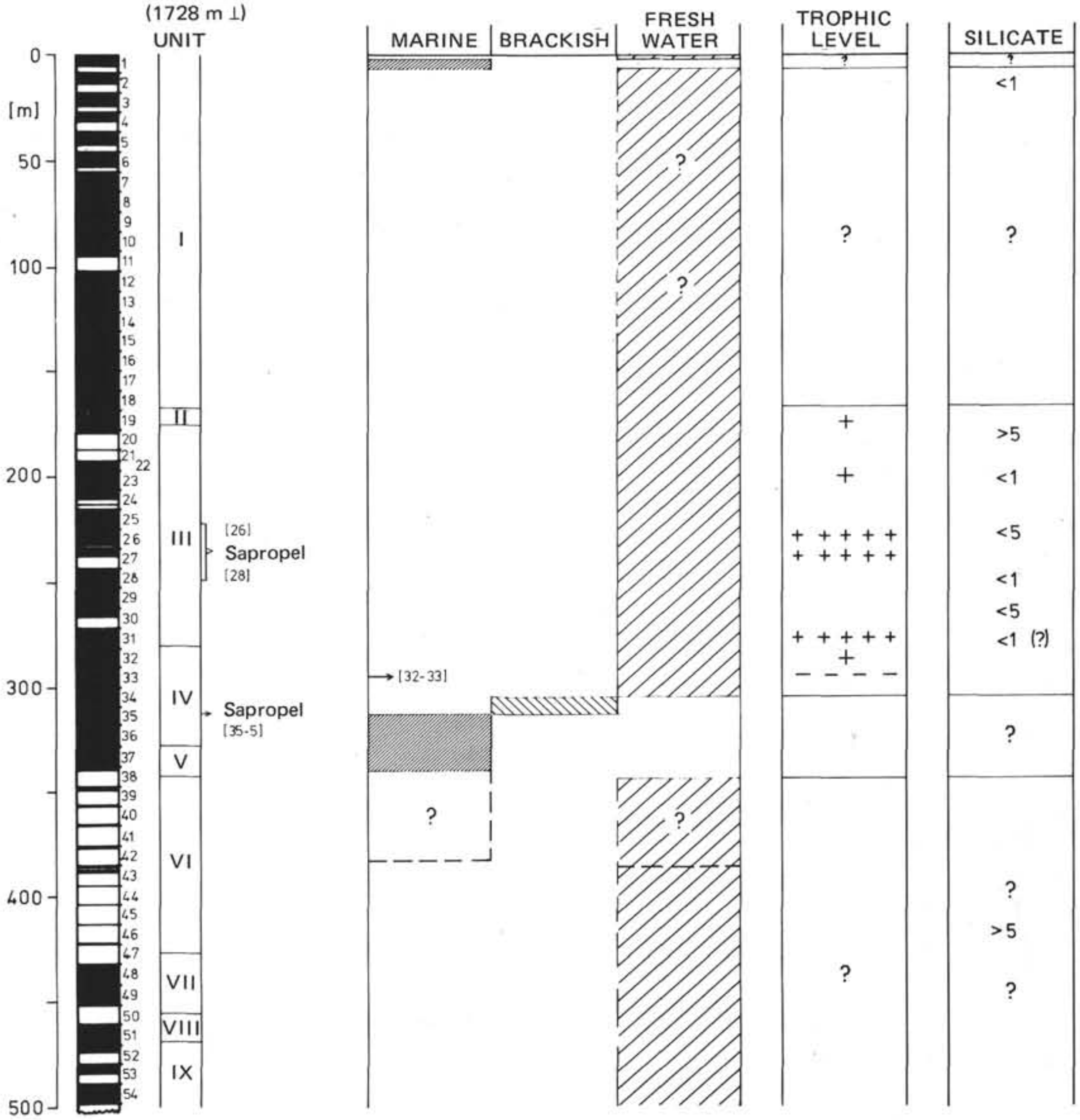


Figure 10. *Summary figure of important findings at Site 381, legend see Figure 5.*

are rare to abundant and poorly preserved to well-preserved. The assemblage consists primarily of marine planktonic species, *Actinocyclus ehrenbergii* and *Hermesinum adriaticum*; associated species are Chrysophyta cysts, *Synedra indica, Stephanodiscus transylvanicus*, and *Pleurosigma angulatum*. This unit corresponds to Subunit VIIIb, lowermost part of Hole 380A (Figure 7).

Unit VI (Cores 39-47) consists of pebbly mudstone, breccia, and sand. The upper part is unconsolidated and consists of a mixture of sand, gravels, mollusc shells, and mud; the lower part is a consolidated breccia. Diatoms are absent to rare in this rather poorly recovered interval and are poorly preserved to well preserved. In Sample 39-1, 50 cm, the assemblages contain high percentages of *Melosira islandica*, and in Samples 40-1, 112 cm and 41, CC, high percentages of *Actinocyclus ehrenbergii*. Whether these occurrences are autochthonous or a result of displacement by coring could not be readily determined. I would interpret the occurrence of *Melosira islandica* in Sample 39-1, 50 cm as allochthonous (displaced by coring). Thus the interval from Section 37-5 to Sample 41, CC would still represent marine depositional environments.

Unit VII (Cores 47-49) is a finely black laminated shale with sandy layers. A cyclic pattern appears to be present with sands to silts at the base and a clay, rich in organic matter, at the top. Only two samples contain traces of *Melosira islandica* and *Melosira distans*. These occurrences suggest a freshwater depositional environment. All other samples are barren of opal skeletons.

Unit VIII (Cores 49-51) consists principally of quartz and clay. Freshwater diatoms occur only in one sample, in traces and poorly preserved; all other samples are barren of opal skeletons.

Unit IX (Cores 51-54) is mainly a dark greenish gray to olive-gray finely laminated clayey siltstone with abundant quartz and feldspar. Freshwater diatoms occur only in two samples in Core 54, as traces of *Melosira islandica*.

Floral content, with relative abundance, total abundance, preservation, and calculated minimum and maximum salinity ranges are tabulated in Table 4 and partly illustrated in

Figure 9. A detailed paleoecological interpretation of the different levels will be found later in this chapter.

Figure 10 is a generalized summary figure of important paleoecological derivations demonstrating two marine episodes. These episodes do not correlate with the pollen ratio curve (Traverse, this volume). Information regarding correlation with the other sites will be found in the next section.

Sapropels and sections rich in organic matter occur at the following levels: (1) diatomaceous mud rich in organic matter, Cores 381-26 to 381-28; abundant freshwater diatom assemblage; (2) sapropel, Sections 381-35-5 to 381-35-6; abundant marine planktonic diatom assemblages.

CORRELATION BETWEEN SITES (Figure 11)

Correlation between Sites 379, 380, and 381 is done primarily on the basis of opal phytoplankton paleontological data—such as first and last occurrences of species (not evolutionary but controlled by the changing ecological parameters), peak abundances, changes in floral composition, and presence or absence of opal skeletons—under the assumption that essentially uniform sediment deposition and no changes in the autecology of species have occurred in the Black Sea over the time interval under discussion. Correlation lines are numbered 1 through 18 and are defined below (Figure 11). Additionally, sedimentological data are also used for correlation, and were taken from the individual site chapters (Shipboard Scientific Party, this volume).

Correlation lines are listed from bottom (oldest sediments) to top (youngest sediments):

a) **Correlation line 18:** last common occurrence of *Actinocyclus ehrenbergii*, slightly below common occurrence of *Synedra indica*; correlation of Hole 380A, Core 55 (:top) with Hole 381, Core 35 (top).

b) **Correlation line 17:** first common occurrence of *Stephanodiscus binderianus* type a, between lines 17 and 18 also the range of *Coscinodiscus* (?) *stokesianus* in Hole 380A (Cores 54 to 51) and in Hole 381 (Cores 34 to 32), the range of *Cyclotella operculata*; correlation of Hole 380A, Core 47 with Hole 381, Core 32 (bottom).

c) **Correlation line 16:** last common occurrence of *Stephanodiscus binderianus* type a. Scarce *Thalassiosira* aff. *lineata* occurs in sediments between correlation lines 17 and 16; correlation of Hole 380A, Core 44 with Hole 381, Core 30.

d) **Correlation line 15:** first common occurrence of *Stephanodiscus carconensis* (triangulate type); correlation of Hole 380A, Core 42 with Hole 381, Core 28 (middle part).

e) **Correlation line 14:** last common occurrence of *Stephanodiscus carconensis* (triangulate type); correlation of Hole 380A, Core 40 with Hole 381, Core 26.

f) **Correlation line 13:** abundance peak within the range of *Melosira granulata* var. *angustissima* f. *curvata*, between lines 14 and 13 occurrence of *Stephanodiscus omarensis* and *Stephanodiscus-Cyclotella* support this correlation of Hole 380A, Core 38 with Hole 381, Core 22.

g) **Correlation line 12:** last occurrence of freshwater diatoms in the lower Black Sea section; correlation of Hole 380A, Cores 32 or 34 with Hole 381, Core 10. If the *trace* occurrence of freshwater species in Sample 380A-32-4, 100 cm is used for drawing this line, the upper limit in Figure 11 must be used, and if the last common occurrence is used in Sample 34 the lower line should be used.

The common occurrence of *Melosira undulata* in Hole 380A, Core 17 does not correlate with Hole 381, because no diatoms were found over the corresponding interval. This may be owing to a shallower position and its not being covered by fresh water, and/or because of no recovery by drilling.

h) **Correlation line 11:** abundance peak of *Actinocyclus normanii* and no *Hermesinum adriaticum*; correlation of Hole 380, Core 39 with Hole 379A, Core 29. This horizon was not observed at Site 381, where recovery was rather poor in the topmost 50 meters, but was observed at Hole 380A, Core 3(?); because of its tentative character, this correlation line is not included between Hole 380A and Hole 381 in Figure 11.

i) **Correlation line 10:** decrease in abundance of *Actinocyclus normannii*, increased *Stephanodiscus astraea* and its varieties (inclusive of *S. hantzschii*), associated with small amounts of *Cymatopleura solea*; correlation of Hole 379A, Core 29 with Hole 380, Core 39, with Hole 380A, Core 3 with Hole 381, Core 3. The occurrence of sapropels and layers rich in organic matter additionally supports this correlation.

j) **Correlation line 9:** first abundant occurrence of *Actinocyclus normannii*, associated with *Hermesinum adriaticum*; correlation of Hole 379A, Core 25 with Hole 380, Core 36 with Hole 380A, Core 1 with Hole 381, Core 1, Section 3.

k) **Correlation line 8:** last abundant occurrence of *Actinocyclus normannii*, associated with *Hermesinum adriaticum*; correlation of Hole 379A, Core 24 with Hole 380, Core 35 (top).

l) **Correlation line 7:** abundance peak of *Stephanodiscus astraea* and *S. robustus*; correlation of Hole 379A, Core 22 (top) with Hole 380, Core 31.

m) **Correlation line 6:** abundance peak of *Stephanodiscus astraea* and varieties and *S. robustus* and one abundance peak of *Actinocyclus normannii* and *Cyclotella caspia* at Hole 379A, Core 18, whose counterpart was not observed in Hole 380. Thus the correlation of Hole 379A, Core 18 with Hole 380, Core 23 is tentative, and there may be an even better correlation with the rather poorly recovered interval between Cores 25 and 30 of Hole 380, assuming uniform sedimentation rates.

n) **Correlation line 5:** decrease in abundance of *Stephanodiscus astraea* and varieties and *S. robustus*; correlation of Hole 379A, Core 16 with Hole 380, Core 15.

o) **Correlation line 4:** peak abundance of *Cyclotella caspia*, associated with *Thalassiosira* marine species; *Chaetoceros* species; absence of *Hermesinum adriaticum*; correlation of Hole 379A, Core 11 with Hole 380, Core 10(?).

p) **Correlation line 3:** increase in abundance of *Stephanodiscus hantzschii*; correlation of Hole 379A, Core 9 with Hole 380, Core 8.

q) **Correlation line 2:** abrupt decrease in abundance of *Stephanodiscus hantzschii*; correlation of Hole 379A, Core 4 with Hole 380, Core 4.

r) **Correlation line 1:** abundance peak of *Stephanodiscus astraea*; correlation impossible because it is not found

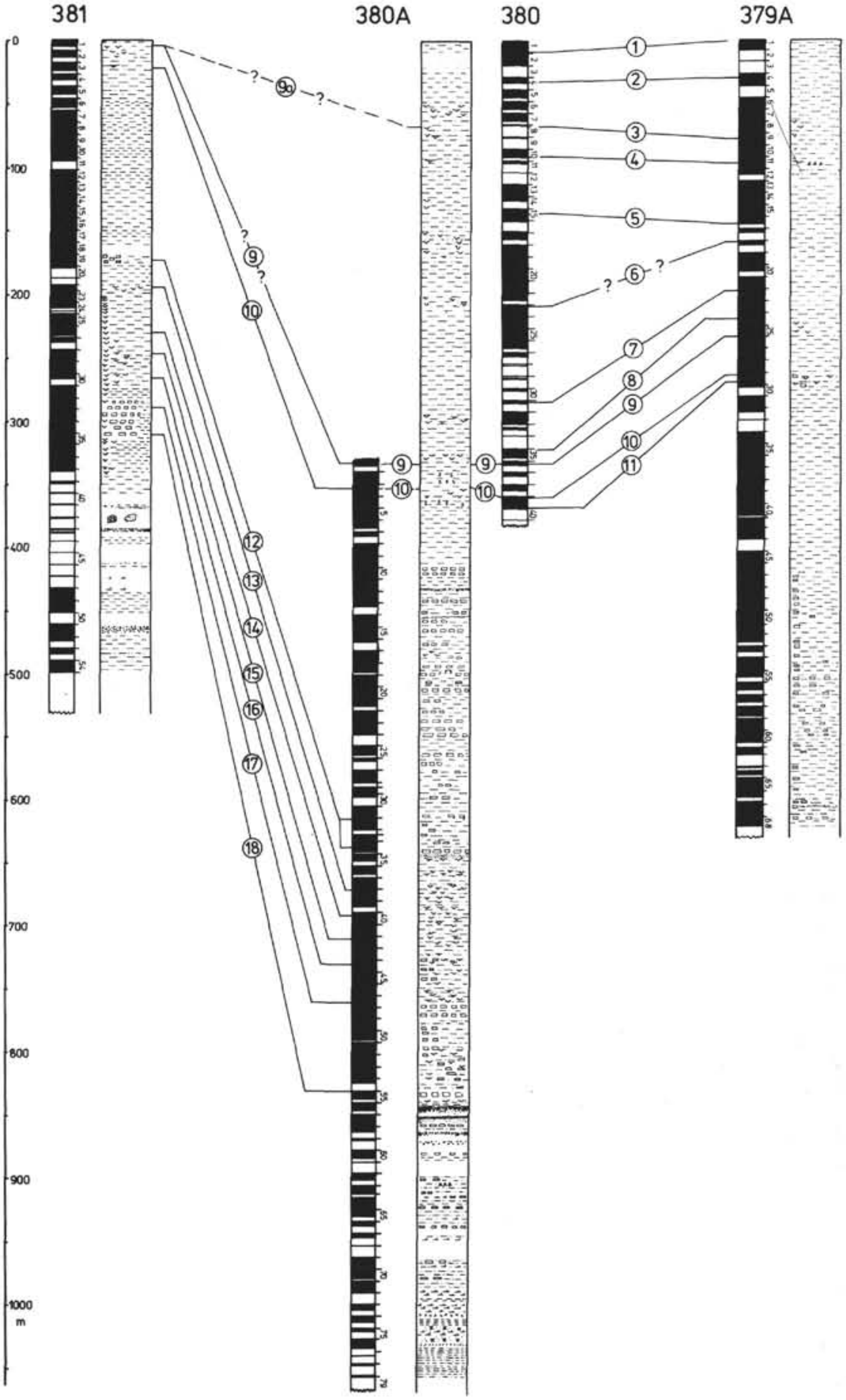


Figure 11. *Correlation between DSDP Leg 42B sites, based on diatom investigation (details see text).*

in Hole 379A, and is only present at Hole 380, Core 1. It is most probably correlative to Unit 2 as it was found in most of the Black Sea piston cores (Ross et al., 1970).

DIATOMACEOUS LAYERS (Figure 12)

The defined correlation was used to subdivide and number those intervals which have abundant diatoms. The diatomaceous intervals are numbered in descending order from youngest to oldest. A total of 10 diatomaceous intervals was defined; the longest and most extensive one was subdivided into three sub-units (A, B, and C). Added to these sections is a zero section which was not recovered during Leg 42B, but was observed in almost all *Atlantis* II expedition cores.

Since within each layer a great variation in assemblages occurs and no general pattern of uniformity within one unit was observed, a detailed description is not made within this chapter, but will be found under each site description. A generalized composed section is shown on the right of Figure 12: black bars and black arrows indicate a marine influx as

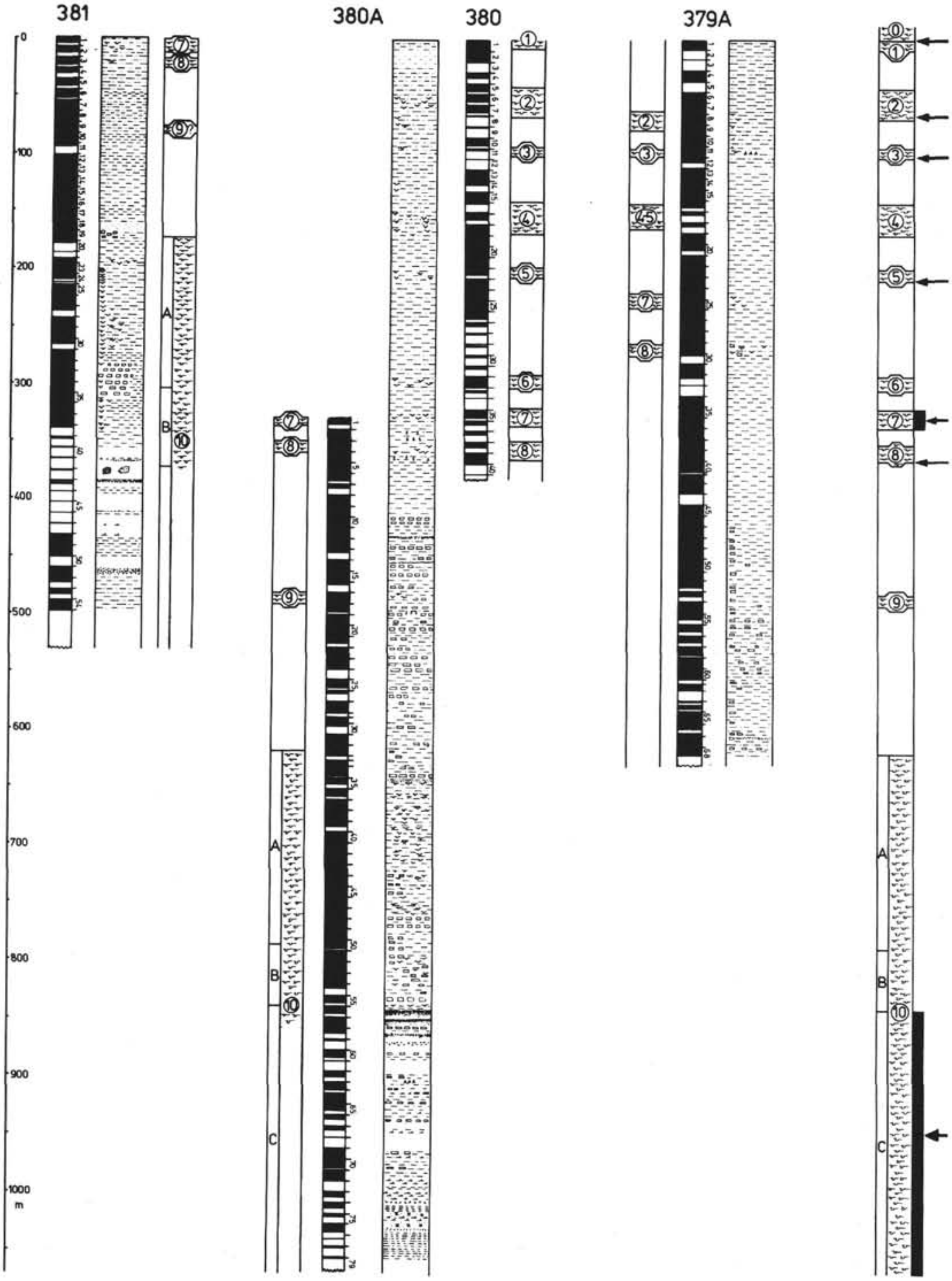


Figure 12. *Diatomaceous layers at DSDP Leg 42B sites. Correlative intervals have the same numbers. At right, a composed sequence with arrows indicating intervals with marine diatom assemblages.*

deduced from the occurrence of polyhaline diatom assemblages. The following describes and illustrates some outstanding opal microfossil assemblages recovered during Leg 42B.

Mass occurrences of Chrysophyta cysts were found within several diatomaceous layers (Table 6). According to Dahm (1956), mass occurrences of these cysts always indicate periodic desiccation of a freshwater environment. This interpretation cannot be used here; instead they suggest restricted, in total volume, Black Sea conditions (Figure 13).

Mass occurrence of polyhaline *Hermesinum adriaticum* (Figure 14) in Section 380-35-3 may also indicate rather restricted environmental conditions at the termination of a marine phase during the Holsteinian.

As an example of a sapropel being formed under freshwater conditions, Hole 380, Core 1 may serve with its abun-

TABLE 6
Mass Occurrence of Chrysophyta Opal Cysts, Types A and B at Leg 42B Drill Sites With Over 50% of the Total Opal Phytoplankton Fraction

Sample (Interval in cm)	A	B
Hole 379A		
10-1, 100	–	57
18-2, 137-139	4	47
19-3, 112	59	–
24-2, 100	72	–
24-4, 141	56	–
Hole 380		
3, CC	70	–
6-4, 77	71	–
6, CC	83	–
16-1, 110	45	–
31-2, 102	48	–
Hole 380A		
34-4, 60	77	1
38-1, 75	67	25
38-5, 27	62	–
38-5, 100	60	–
38-6, 65	67	–
48-5, 100	34	7
56-4, 138	41	2
Site 381		
22-1, 80	22	23
37-5, 114	39	5

dant *Stephanodiscus* and organic plant fragments (Figure 15). Other mass occurrences were found at Section 379A-29-4 with *Actinocyclus normannii* (Figure 16).

Within the ''chemical phase'' (defined elsewhere in this volume) sedimentation, various outstanding assemblages were observed:

1) in Core 380A-17 an abundant *Melosira undulata* assemblage (Figure 17);

2) in Core 380A-35 an abundant assemblage of *Melosira granulata* var. *angustissima* forma *curvata* and other curvate freshwater *Melosirae* (Figure 18);

3) in Core 380A-41 an aberrant diatom flora with eccentric and triangulate *Stephanodiscus* species (Figure 19). In Core 381-26 a similar assemblage (Figure 20), but with better preservation of tests;

4) in Core 381-31 an eutrophic diatom assemblage with abundant *Stephanodiscus binderianus* (Figure 21); and

5) in Core 381-35 a polyhaline *Actinocyclus ehrenbergii* assemblage (Figure 22).

PRESERVATION OF OPAL SKELETONS (compare Figures 13-22)

The major uncertainty in interpreting past ecological shifts in the Black Sea by opal phytoplankton shell assemblages is the presence and the state of preservation of diatom frustules in the sediments. Various sections are completely barren of opal skeletons, others do contain trace amounts, and others only contain high abundances of heavily silicified microshells. These differences in content and state of preservation may be attributed to displacement of shallow-water sediment material, to resuspension and to changes in the production of

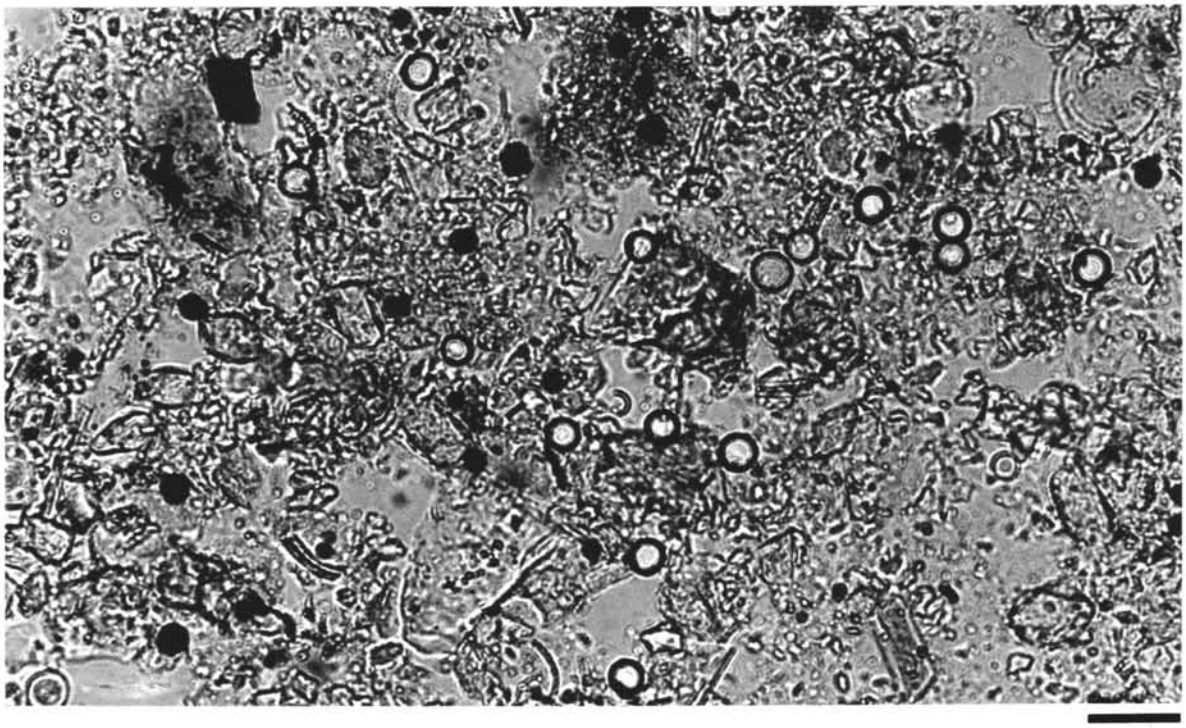


Figure 13. *Sample 380-6, CC, with floods of* Chrysophyta *cysts and corroded diatoms (upper right corner). Bar equals 20 µm. Smear slide.*

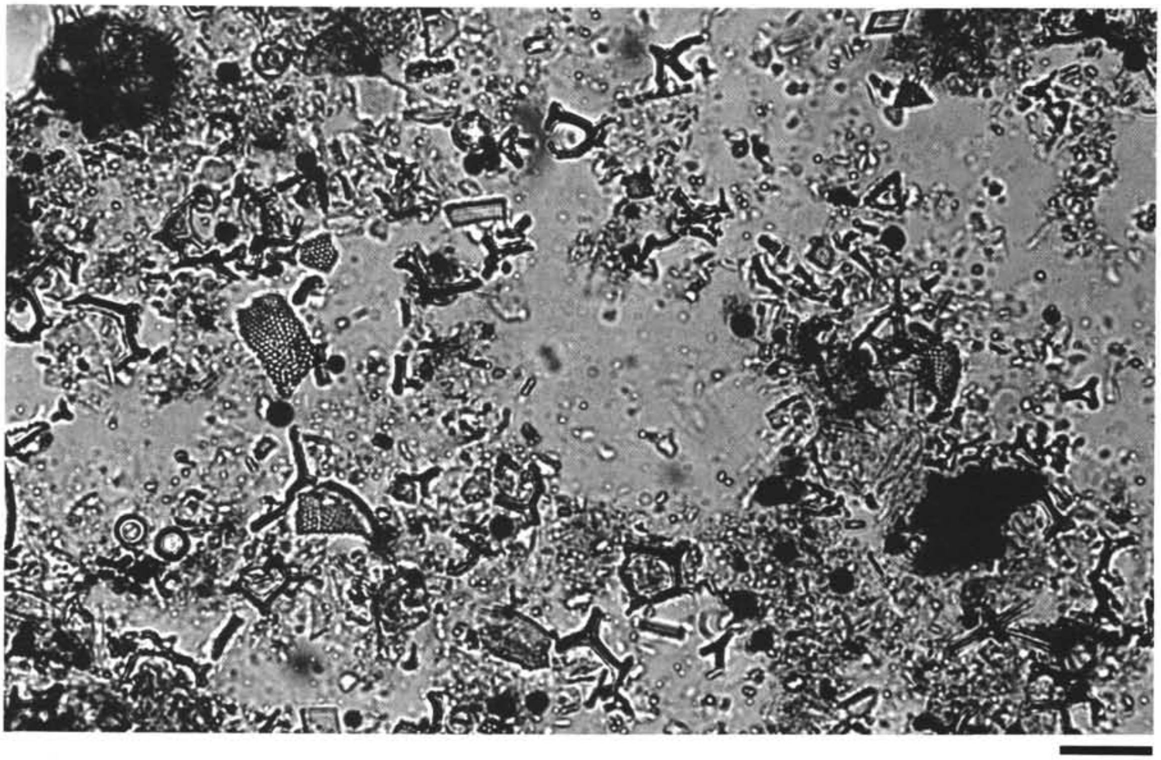


Figure 14. *Sample 380-35-3, 21 cm. Floods of* Hermesinum adriaticum *partly broken into pieces. Preservation good. Bar equals 20 µm. Smear slide.*

Figure 15. *Sapropel at 380-1-1, 10 cm. Bar equals 20 µm. Black = wood fragment, others* Stephanodiscus astraea. *Smear slide.*

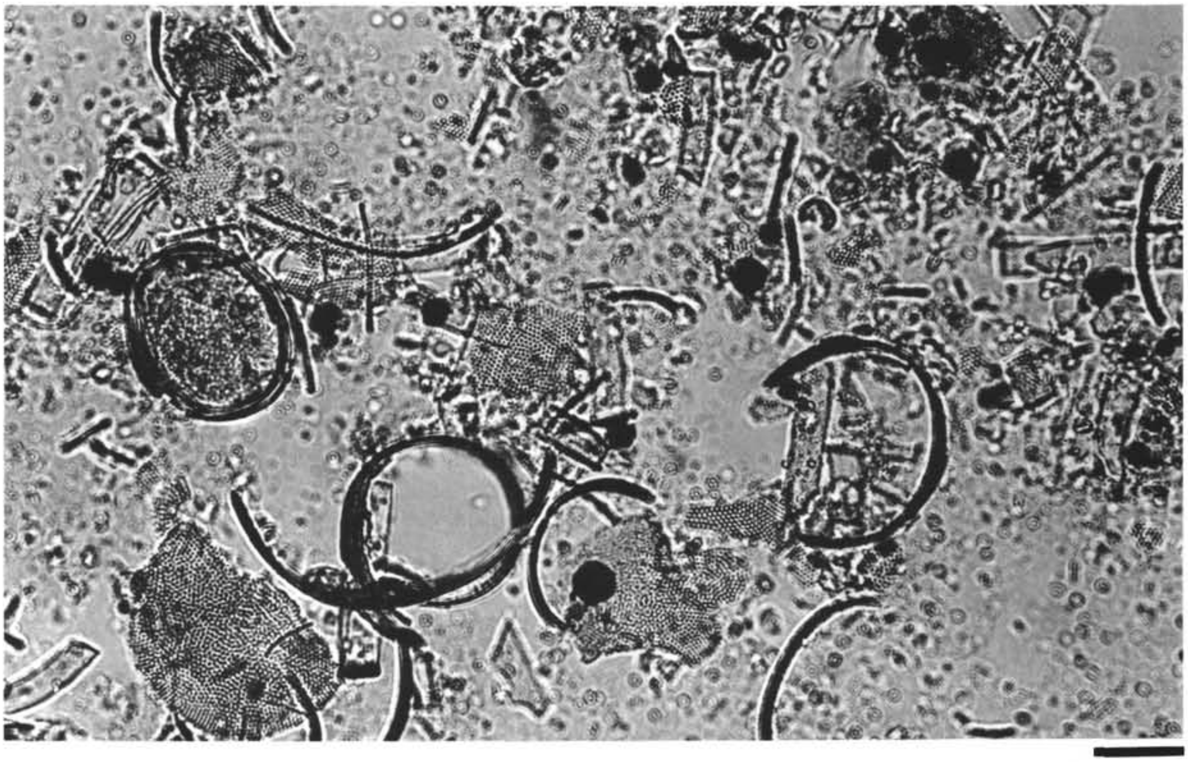


Figure 16. *Sample 379-29-4, 64 cm. Floods of* Actinocyclus normannii *mostly girdle bands. Bar equals 20 µm. Smear slide. Preservation good.*

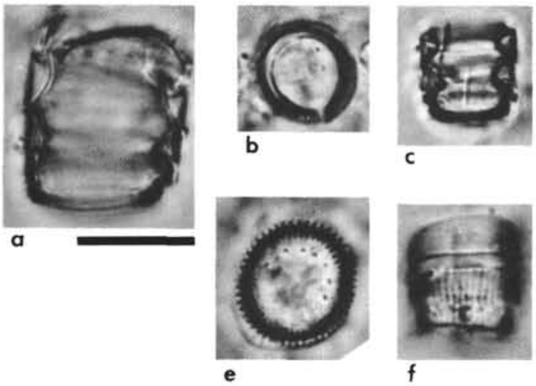


Figure 17. Melosira undulata *from Sample 380A-17-1, 89 cm, smear slide. Bar equals 10 µm. a, c, f = girdle view, b = valve view of girdle, e = valve view of valve.*

opal microshells in the productive zone, and to changes in the sediment accumulation rates.

Controlling factors of the rate of opal dissolution are still ill understood. Holdship (1976) discusses two influences upon diatom preservation in freshwater environments; he says that (1) lack of dissolved oxygen below the chemocline favors well-preserved opal assemblages, and that (2) high silicate concentration in the bottom-water interface retards frustule dissolution, not mentioned in Holdship, but still an influence, is depth of deposition.

In general, the comparable diatom assemblages at Site 381 and Hole 380A are significantly different in their state of preservation of opal tests. Assemblages are much better (qualitatively) preserved at Site 381 than at 380A. The sites are geographically close to each other, but differ in water depth. Site 380 lies at an actual water depth of 2107 meters, and Site 381 lies at 1728 meters (379 m difference); correlative intervals at Site 380 lie approximately 465 meters apart from those at Site 381. The total depth difference of comparable horizons is approximately 850 meters today, and assuming that both sites have subsided at equal rates, if they subsided at all, this difference in depth was established during all the time span already discussed. This is quantitatively supported by the better state of preservation of all opal microtests in diatom horizon 10 (Figure 12) at Site 381, compared with Hole 380A.

As demonstrated in Foged (1962), it should be possible on the basis of the quotient Centrales: Pennales to make an estimate of the order of magnitude and conditions of depth of a lake basin. The present material does not permit an estimate of this quotient, since all samples are overwhelmed with Centrales.

Only the polyhalobous assemblages in Cores 381-35 through 381-41 show an increase in Pennales such as *Pleurosigma* sp.

Sites 380 and 379 show no significant difference in opal preservation: both sites currently lie at approximately the same depth. The excellent preservation of the weakly silicified *Stephanodiscus hantzschii* at both Sites 380 and 379 can only be explained by rather lowered sea level stands and/or mass production.

DIVERSITY (Figure 23)

A number of diversity indexes have been proposed. Here the Shannon-Wiener diversity index was used; it has been

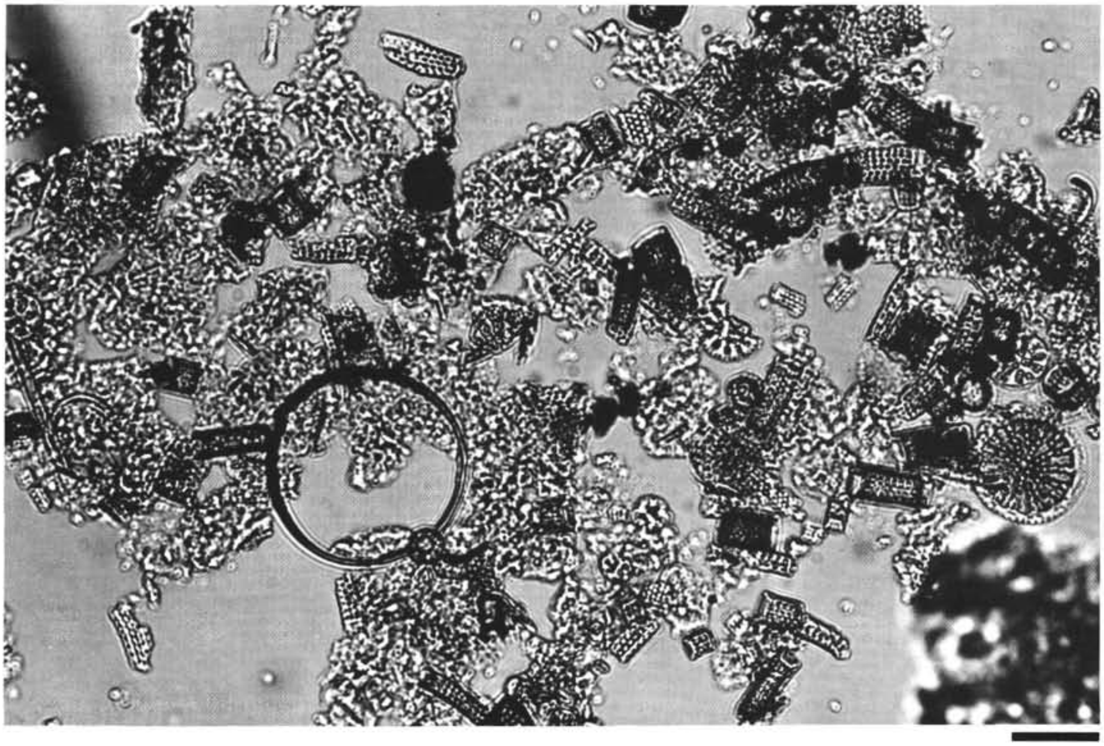


Figure 18. *Sample 380A-35-4, 50-52 cm, with common* Melosira granulata *var.* angustissima *f.* curvata. *Smear slide. Bar equals 20 µm.*

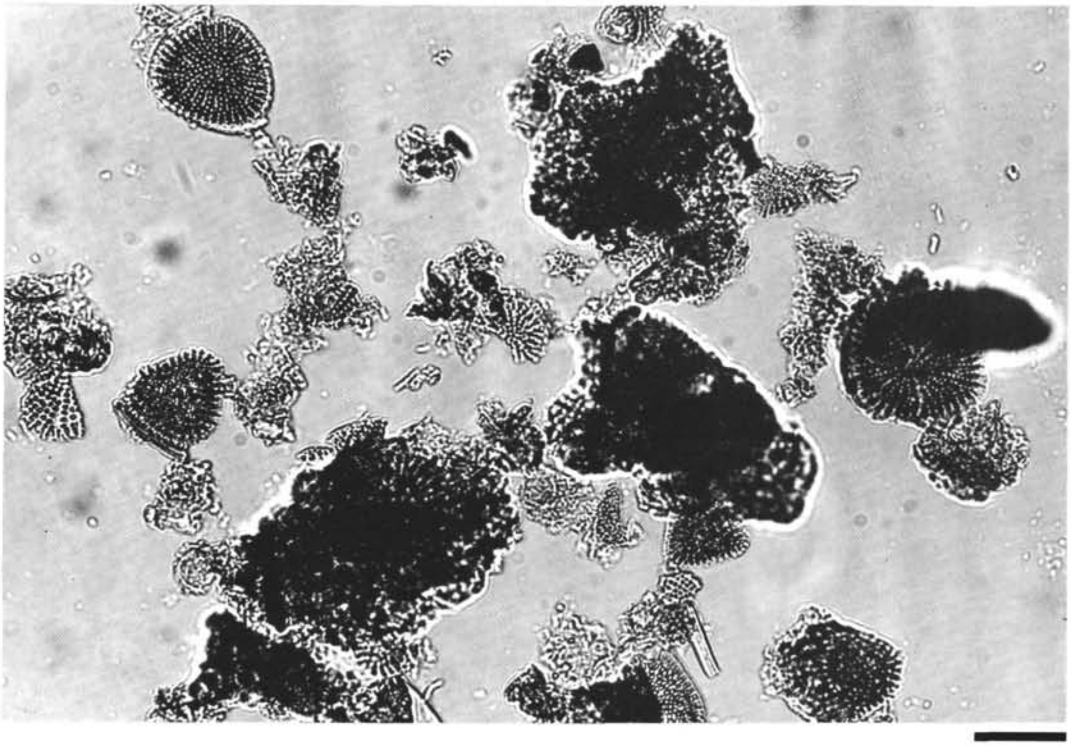


Figure 19. *Sample 380A-41-1, 110-112 cm, with common aberrant* Stephanodiscus *species, assemblage moderately well preserved. Cleaned sample. Bar equals 20 µm.*

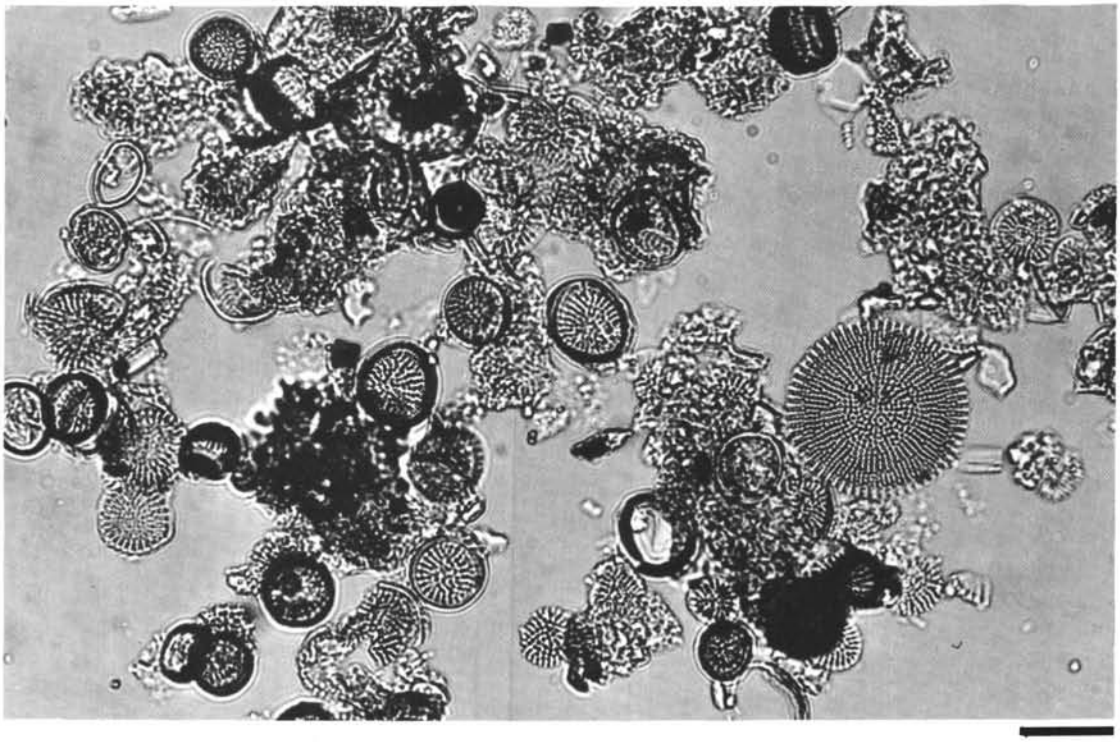


Figure 20. *Sample 381-26-5, 84-86 cm, with abundant aberrant* Stephanodiscus *species, assemblage well preserved. Cleaned sample. Bar equals 20 μm.*

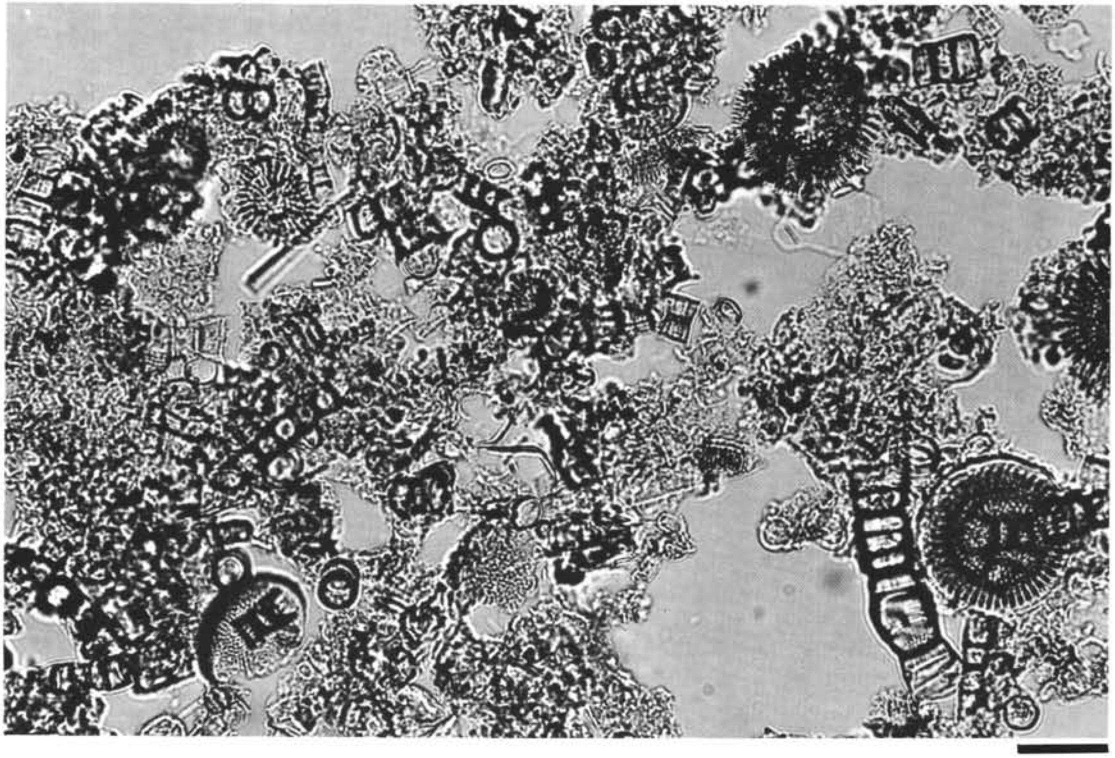


Figure 21. *Site 381, Core 31. Abundant barrel-shaped* Stephanodiscus binderianus *chains. Preservation good. Smear slide. Bar equals 20 μm.*

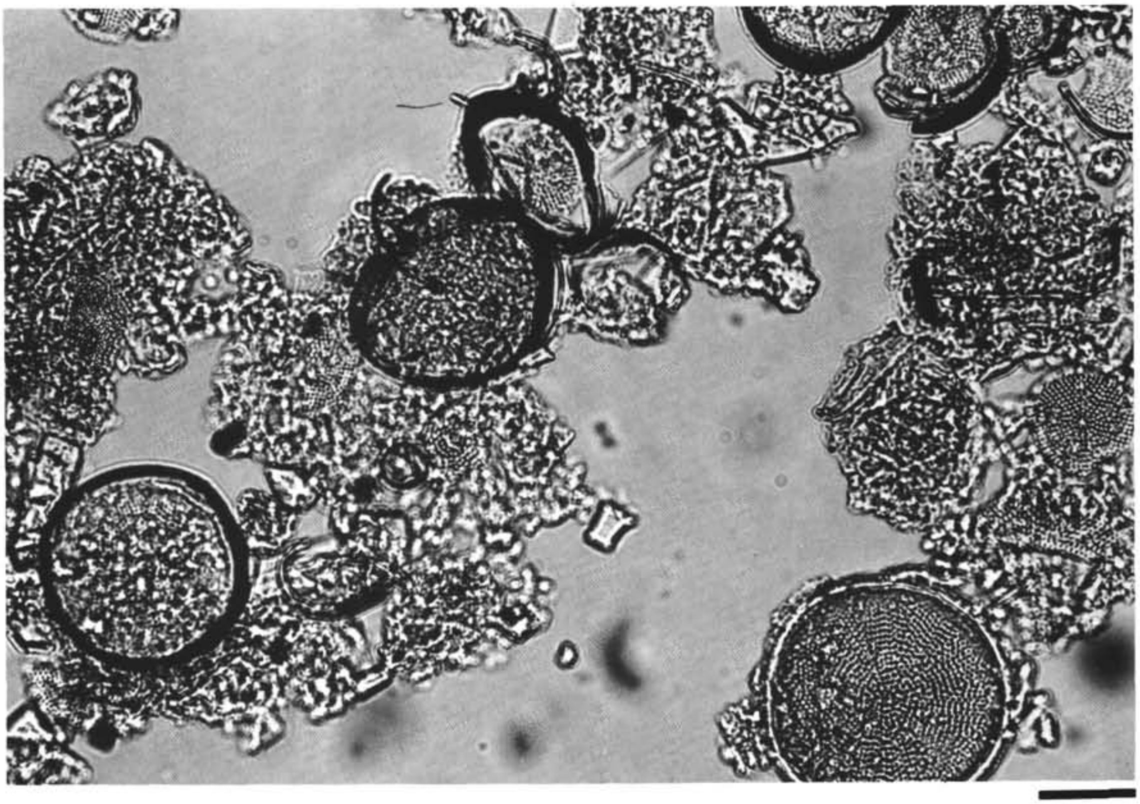


Figure 22. *Sample 381-35-2, 74-76 cm. Common* Actinocyclus ehrenbergii *partly dissolved and girdle bands. Preservation poor. Cleaned sample. Bar equals 20 μm.*

applied to fossil assemblages by Stockner and Benson (1967), and is particularly suited to minimizing the effect of relatively low percentages of many rare and very rare species (Stoermer and Yang, 1968).

Diversity values were calculated using the formula (Berger and Parker, 1970)

$$D_H = -\sum_{1}^{s} p_i \cdot \ln p_i$$

wherein *pi* is the per cent proportion of the individual species, taking *all* observed different opal skeletal species into account. Reduction in diversiy is usually considered an indication of disturbance in an environment (Margalef, 1964). It would thus appear that profound disturbances occurred around the time of deposition of intervals where diversity values are lower than 1 (Figure 23).

No diversity values have been calculated for the cored interval of Hole 280A below Core 58 or of Hole 381 below Core 40.

Diversity values are generally rather low for all Black Sea opal assemblages. This can partly be explained in the case of the oligohalobous assemblages by strong eutrophication and restriction of total water volume during glacial periods. Additionally, diversity values are smaller in fossil assemblages because of loss of part of the lesser silicified frustules during sedimentation.

Diversity indexes reach values of 2 in Core 380A-36; all other values are below 2. Extremely low values occur in Cores 379A-10, 380-13, 380-33, 380A-41, 380A-43, 380A-48 through 380A-51, 381-14, 381-30 through 381-32, and 381-34.

At the following levels very low diversity values were observed:

1) Hole 379A, Core 10: mass occurrence of *Cyclotella caspia*.

2) Hole 380, Core 13: mass occurrence of *Stephanodiscus astraea* and *S. robustus*.

3) Hole 380, Core 33: mass occurrence of *Stephanodiscus astraea* and *S. robustus*.

4) Hole 380A, Core 41: mass occurrence of triangulated forms of *Stephanodiscus-Cyclotella* and *Stephanodiscus carconensis*.

5) Hole 380A, Core 43: mass occurrence of *Stephanodiscus binderianus*.

6) Hole 380A, Cores 49-51: mass occurrence of *Melosira islandica*.

7) Hole 381, Core 15: mass occurrence of *Melosira islandica*.

8) Hole 381, Cores 30-31: mass occurrence of *Stephanodiscus binderianus*.

9) Hole 381, Core 32: mass occurrence of *Melosira islandica*.

10) Hole 381, Core 34: mass occurrence of *Stephanodiscus binderianus*.

The proposed theory that oligotrophy, expressed here as highly diverse assemblage, should succeed eutrophy and not precede it (Margalef, 1975) cannot adequately be tested with the present material, because of the long sampling intervals.

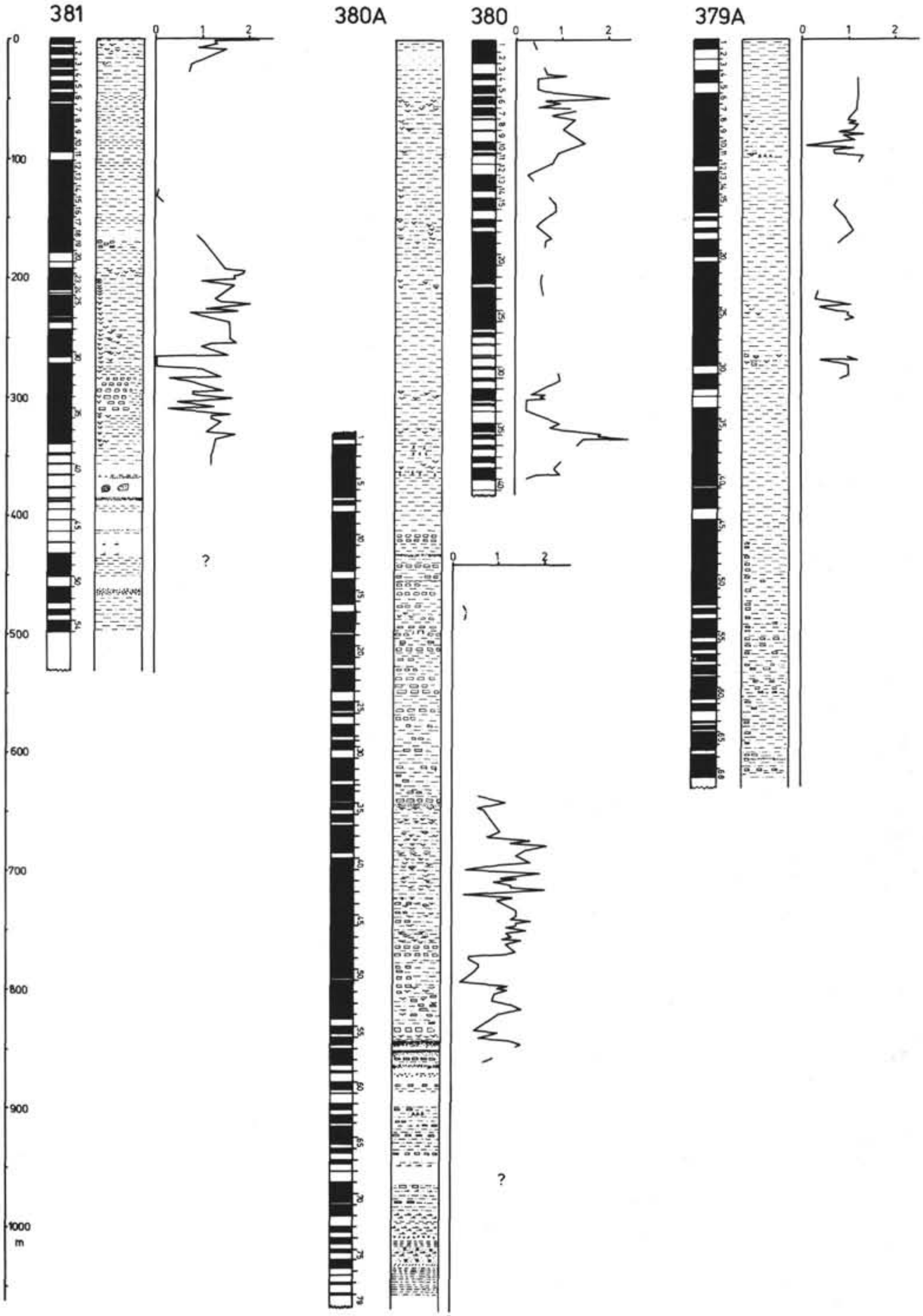


Figure 23. *Shannon-Wiener diversity index.* $D_H = -\sum_{1}^{s} p_i \cdot \ln p_i$ *of all occurring opal skeletons.*

Assemblage successions from *Stephanodiscus binderianus* to *Cyclotella operculata* to *Stephanodiscus binderianus* might, however, substantiate this theory of succession.

CHANGES IN TROPHIC STATUS

Most of the Black Sea diatomaceous sequences were deposited under lacustrine conditions. Changes in the trophic status, expressed in differing primary production and changes in the composition of assemblages, should reveal indications of the steady state of nutrient availability and its changes through time. An environment highly diluted through high influx of fresh water should trigger the production of oligotrophic assemblages, and the reduction of volume, which may have occurred several times through excess evaporation and limited inflow from the hinterland, has caused changes in primary production. Changes from eutrophy to oligotrophy (Naumann, 1919) can be defined by the presence of oligotrophic-mesotrophic-eutrophic diatom species.

Three grades of trophic status are defined: oligotrophic, mesotrophic, and eutrophic (compare also Caspers and

Schulz, 1960); they are dependent upon the availability of minerals, organic substances, and plant nutrients in an environment. On the basis of data available in the literature (U. S. Dept. of the Interior, 1966), an attempt has been made to identify oligotrophic, mesotrophic, and eutrophic lake episodes. This identification could serve as a factor in the calculation of the restriction and expansion of the Black Sea as a whole. Since most diatom species are mesotrophic (Hustedt, 1959), those intervals with diatoms, not mentioned below, should be grouped into this category. All the following interpretations are made solely for oligohalobous assemblages. The intervals at issue are discussed only for Site 380, which can easily be correlated (Figure 11) with the remaining horizons of Sites 379 and 381.

Melosira islandica (Figure 7) appears to be an indicator of oligotrophic to mesotrophic lakes, but favors the eutrophic end of the spectrum (Stoermer and Yang, 1968). This species is most commonly found in Cores 51 through 46, and is replaced in Cores 45 through 37 by *Melosira distans* (Figure 7), which is interpreted by Gasse (1975) as oligotrophic, but by present interpretation it should be grouped rather as mesotrophic to eutrophic; this interpretation is supported by the abundance of *Stephanodiscus dubius* (Figure 7)—a eutrophic indicator (Jarnefelt, 1952) in the same assemblages.

Shortly after the decrease of *Melosira islandica*, *Stephanodiscus binderianus* has a peak abundance (Figure 24). This species is considered by Stoermer et al. (1974) to be favored in growth by both eutrophic conditions and considerable enrichment in limiting nutrients (Huber-Pestalozzi, 1942). Thus intervals with high proportions of *Stephanodiscus binderianus* (all types, Figure 24) are indicative of eutrophic lake conditions in Cores 53 through 51, 47, 46, 44, and 43.

Cyclotella operculata (Figure 7; Figure 9, Site 381) is frequently found in Cores 53 and 54, and is interpreted by Stoermer and Yang (1970) as an oligotrophic species.

At Site 380 (Hole 380A) a general increase in the trophic status from oligotrophic (Cores 53, 54) to mesotrophic (Cores 53-47) to eutrophic (Cores 47-35) was observed. The gradual increase in *Stephanodiscus niagarae* and *Stephanodiscus carconensis* also points in this direction, as does the abnormal assemblage of eccentrically oriented and/or triangulate diatom species of all three *Stephanodiscus* species—*S. carconensis, S.-Cyclotella,* and *S. binderianus* (Cores 42-40)—all following the same trend. Since all levels of intermediate forms were also observed, as well as a gradual increase in abundance of abnormal forms, these individuals were treated as ecological modification and no new taxonomic entries were established.

The next level with abundant oligotrophic (Cleve-Euler, 1951-1955) *Melosira undulata* occurs in Core 17.

No conclusions regarding the opal-barren intervals between Cores 32 and 17 and 17 and 3 can be drawn, and the single occurrence in Core 17 cannot be connected with overlying or underlying assemblages.

The next common oligohalobous assemblages with abundant *Stephanodiscus astraea* occur in Hole 380, Cores 39, 33 through 31, 23 and 22, 18 through 15, 12 and 11, 7 through 4, and 1. Since taxonomy of *S. astraea* and its varieties is rather unsatisfactorily defined, and since there are considerable differences in the autecology, no more detailed trophic status interpretations are made here. Generally, this species does not occur in high numbers in oligotrophic environments (compare Cleve-Euler, 1951-1955 and Stoermer and Yang, 1970).

A sharp decrease in the abundance of *S. astraea* is noted in Cores 380-7 through 380-5, and *Stephanodiscus hantzschii* gradually increases in abundance (Figure 24). This species is favored by enrichment in limiting nutrients (Stoermer et al., 1974), and indicates strongly eutrophic waters.

All marine intervals which lead to the deposition and preservation of opal-rich sediments indicate high primary production, and should thus be indicative of relatively high nutrient content, and be comparable to modern situations.

DISSOLVED SILICATE CONCENTRATION

Kilham (1971) found a direct correlation between the maximum growth of the two freshwater planktonic species *Stephanodiscus astraea* and *Melosira granulata* (Figure 25) and the availability of dissolved silicate in the photic zone. Available field observation data show clearly that *Stephanodiscus astraea* is most likely to reach its greatest abundance in the phytoplankton of a eutrophic lake when the dissolved silicate concentration reaches values below 1 mg/l.

Ratios of the two species and closely related species were calculated to interpret past fluctuations of dissolved silicate availability in the trophogenic zone.

The ratio was calculated on the assumption that in silicate requirements the autecology of *Stephanodiscus robustus, S. carconensis, S. niagarae, S. omarensis*, and *S. transylvanicus* is similar to that of *S. astraea*, and that *Melosira islandica* and its varieties behave similarly to *Melosira granulata* with respect to silicate requirements.

Almost no changes in the silicate ratio (Figure 26) were observed in the freshwater horizons at Site 379 and in Hole 380 (compare also Figures 5 and 8a). Those horizons with moderately to poorly preserved low-diversity diatom assemblages in Cores 380-10 and 380-16 were not taken into consideration for formulation of the ratio.

Low values were observed in Hole 380A in Cores 17, 34 through 36, 39 through 42, 44, 46, and 48 through 51, and increased values (above 5, Figure 26) in Cores 37, 43, 45, 46 and 47. Similar patterns in ratio variations were observed at Site 381: with low values in Cores 19 through 22, 23 through 27, 30, and 32 through 34, and increased values in Cores 23, 28, and 29, and 31 (Figure 26). Variations on a much smaller scale are definitely present but could not be calculated because of a lack of continuously sampled sections.

Variations in the "opal ratio" might be used to reconstruct past fluctuations of the silica cycle. Increased silica supply to the trophogenic zone can be accomplished by increased supply from the hinterland (volcanic activities) and/or by changes in the recycling of dissolved silicate from bottom waters to surface waters, to mention a few sources. Since no drastic changes in the preservation of opal tests were observed over the interval under discussion, shifts in the recycling of opal have not played a major role. Thus the differing supply of dissolved silica and the increased content of dissolved silica during times of volume restriction may explain the variation in the "opal ratio." Thus intervals in Hole 380A, Cores 34 through 51 and Hole 381, Cores 19 through 34 represent restricted-volume phases (compare Paluska and

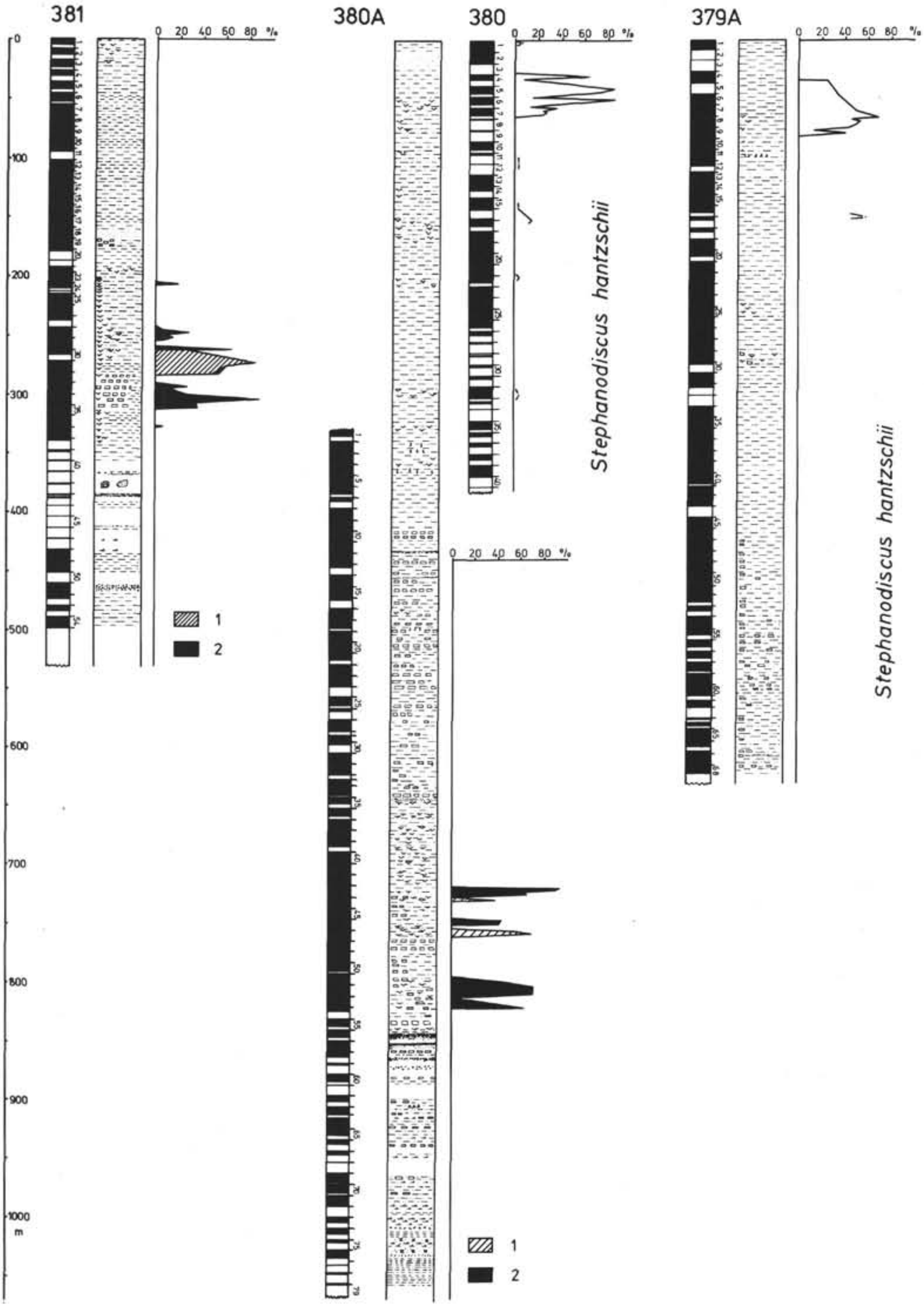


Figure 24. *Per cent of total opal skeletons of* Stephanodiscus hantzschii *(upper part of figure) and of* Stephanodiscus binderianus *type a (1) and types b + c (2) at all sites.*

Degens, this volume), where the total volume was reduced by at least one third. An increase in volume approximating the present-day situation may have occurred in Core 380A-37 (correlative to Core 381-23), Core 380A-43 (correlative to Core 381-28) and Core 380A-46 (correlative to Core 381-31). This increase in volume was definitely smaller than that of the present situation, and did not allow mixing of freshwater with marine waters.

pH OF SURFACE WATERS

The pH of natural waters is governed to a large extent by the interaction of H_+ ions arising from the dissociation of H_2CO_3 with OH_- ions resulting from the hydrolysis of bicarbonates. The pH of natural waters ranges from less than 2 to 12 (Wetzel, 1975). The pH range of a majority of open lakes is between 6 and 9, and most of these lakes are of the

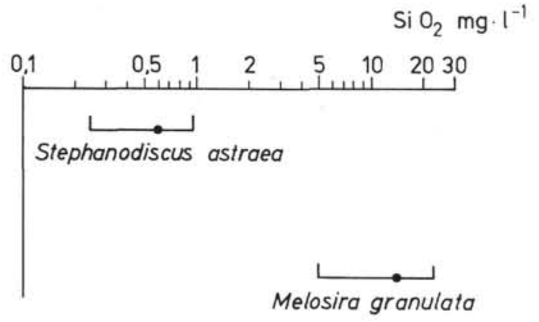


Figure 25. *Occurrence of abundant* Stephanodiscus astraea *and* Melosira granulata *at different availability of dissolved silicate (from Kilham, 1971).*

bicarbonate type. Optimum growth rates of diatom species may indicate the type of pH environment they thrived in. According to the literature (Foged, 1970; Gasse, 1975; and Cholnoky, 1968), the most common oligohalobous diatom species may be grouped into five categories (Table 7): (1) acidobiontic with pH values <7 and optima around 5, (2) acidophilous, with pH values <7, (3) neutral with pH values around 7, (4) alkaliphilous, with pH values $\geqslant 7 \leqslant$ and (5) alkalibiontic with pH values >7. Gasse (1975) did not differentiate between acidobiontic and acidophilous, and grouped both categories as acidophilous. Where pH ranges are listed in the literature, these values have been entered in Table 7.

All three authors group *Melosira distans* into the acidobiontic-acidophilous categories. Thus I infer that this species (at Hole 380A, Cores 47 through 38 and Site 381, Cores 29 through 22) was deposited in an environment with *p*H values less than 7 in the photic zone.

Melosira islandica is placed by Foged (1970) in the alkaliphilous category.

Melosira undulata belongs to the alkaliphilous (Foged, 1970) category.

Stephanodiscus astraea and *S. hantzschii* belong to the alkalibiontic category with *p*H values greater than 7 (Cholnoky, 1968, *p*H ~8).

Cyclotella operculata, most common in Core 381-33, belongs to the alkalibiontic category (Cholnoky, 1968, *p*H > 8).

Stephanodiscus carconesis and *S. niagarae* are grouped by Gasse (1975) into the neutral category, with *p*H values around 7.

Other species listed on Table 7 are too scarce in their occurrence to allow interpretation of past surface *p*H fluctuation.

SALINITY

Great confusion exists in the terminology of diatoms living in the various saline biotopes (cf. Caspers, 1959). The simplest scheme distinguished between marine, brackish-marine, brackish, and freshwater diatom species. A more sophisticated scheme, the halobous system, was established by Kolbe (1927 and 1932) and modified by Hustedt (1953). In this scheme diatoms are classified into polyhalobous, oligohalobous, and halophobous species and varieties, according to their optimal halobiotope.

Simonsen (1962) introduced the concept of salt tolerance of individual species and varieties occurring in the western Baltic, and his concept has been adopted here in an attempt to interpret "fossil" surface water salinity conditions.

The polyhalobous and mesohalobous euryhaline groups were subdivided by Simonsen (1962) into several categories according to their hypertonic resistance, for species of the western Baltic, and was enlarged for both benthic and planktonic diatoms species living today in the total Baltic by Pankow (1976). Since Simonsen (1962) and Pankow (1976) dealt primarily with brackish water assemblages, the definition of the highest salinity values in hypersaline waters and the resulting tolerance were not defined.

Ehrlich (1975) published an expanded halobous classification of diatoms according to their tolerance to salinity changes; it also included Simonsen's data (Figure 27). Ehrlich (1975) listed a few marine stenohaline species (30-40$^0/_{00}$ S), which were also found in the Black Sea: *Actinocyclus ehrenbergii* (this species does occur also in the Baltic, and should rather be classified as meioeuryhaline-polyhalobous), *Grammtophora oceanica (after Simonsen* [1962] mesoeuryhaline-polyhalobous!), *Melosira sulcata (after Simonsen* [1962] pleioeuryhaline-polyhalobous), *Thalassionema nitzschioides (after Proschkina-Lavrenko* [1952] and Simsonsen [1962], meso- or pleioeuryhaline-polyhalobous), *Thalassiothrix frauenfeldii* (found today in the Black Sea with salinities of about 18$^0/_{00}$).

Since data on polyhalobous benthic and planktonic diatom species are scant, no salinity interpretations were made with regard to maximum salinity values. All polyhalobous forms were computed with an upper salinity value of 35$^0/_{00}$; thus, ranges falling into this category may be higher than 35$^0/_{00}$.

The attempt to quantitatively describe paleosalinities from fossil Black Sea diatom assemblages basically uses salinity tolerances of modern species (Table 8), on the assumption that the autecology of fossil and modern taxa have not changed within the period of time under discussion. All available data from the literature were used in the calculation, and only a few entries could not be grouped because of lack of data (Table 8). Using the salinity tolerances of species, the maximum and minimum paleosalinities indicated by each fossil assemblage were computed by the formula (Lynts and Judd, 1971):

$$S = \frac{\Sigma p_i \cdot a_i}{\Sigma p_i}$$

with S = paleosalinity (maximum or minimum), p_i = the proportion of the i-th species of the assemblage, a_i = either the maximum or minimum salinity at which the i-th species occurs.

The resulting surface-water paleosalinities are plotted on Figure 28 for all sites with a log salinity scale, in order to resolve variations at the lower end, and in normal scale on Figure 29 for Sites 380 and 379. Each horizontal bar represents one sample. Minimum paleosalinities may in some instances be too low, since frequently oligohalobous species are allochthonous in assemblages characterizing poly- and mesohaline waters; no adjustment was made for this.

All paleosalinity values indicate salinities of surface waters during time of production and deposition of the respective

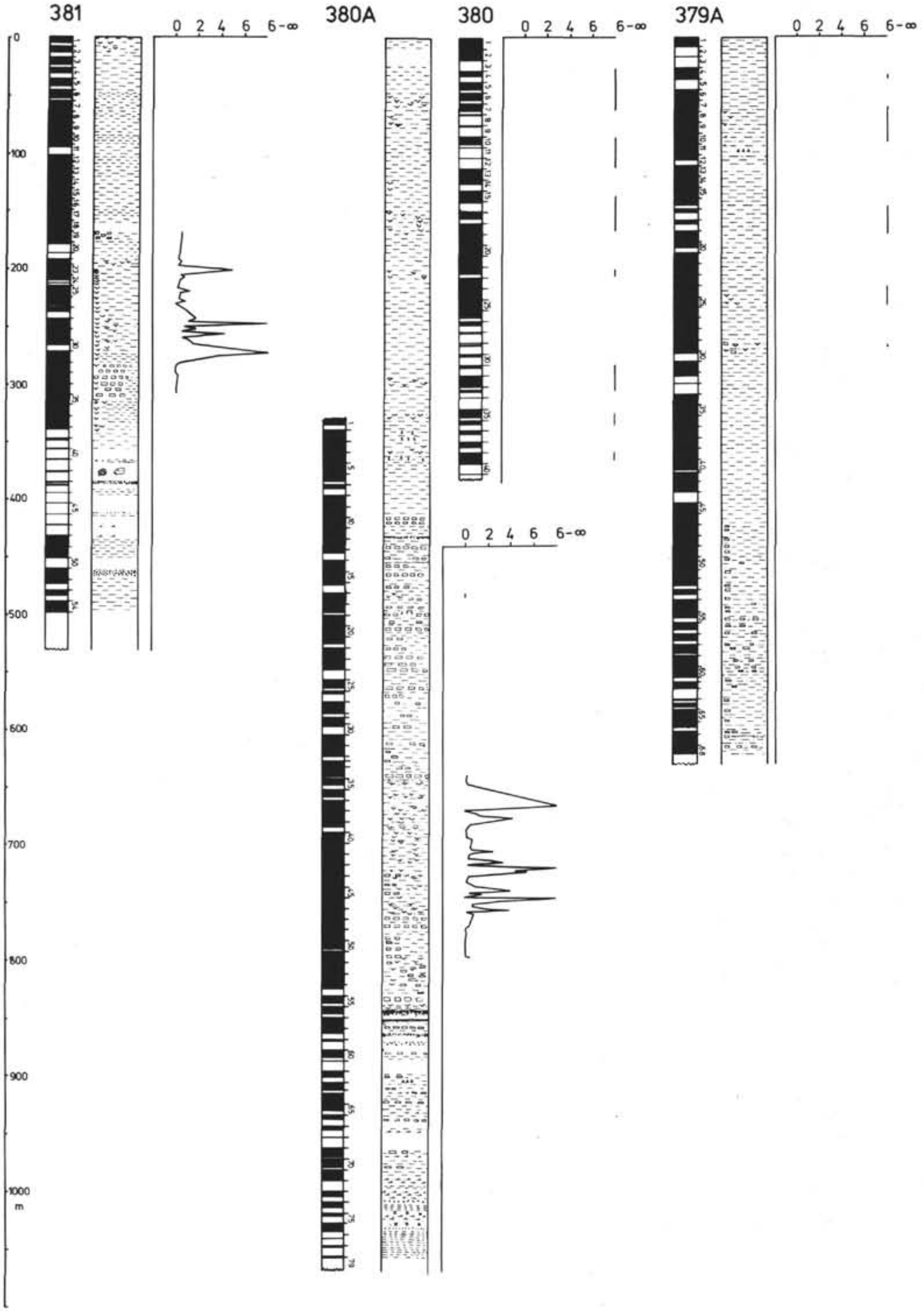


Figure 26. *Ratio of* Stephanodiscus *and* Melosira *species (see text); low values indicate high dissolved silicate and high values low dissolved silicate in surface waters.*

assemblages, since most reproducing diatoms are bound to the photic zone (approximately the upper 50 m of the water column), and do not allow direct salinity calculations of underlying waters. The present salinity flux varies between 18 and 19‰ at the surface and 22‰ at 2000 meters water depth (Kremling, 1974).

The four sediment surface samples from the *Atlantis* II cruise had a few polyhaline diatom, silicoflagellate, and Ebriaceae species (Table 5). The above-mentioned calculation yields a salinity range of about 6 to 35‰ (Figure 3). "Recent" sediment assemblages are dominated by *Distephanus speculum, Cyclotella caspia,* and *Thalassiothrix frauenfeldii*. This specific assemblage is not similar to any polyhalobous assemblage recovered during Leg 42B.

The following describes the fluctuating surface paleosalinities at Sites 379, 380, and 381, starting with the oldest sediment recovered and proceeding to the youngest. Oligohaline waters are defined to have salinities of 0 to 5‰,

TABLE 7
Diatom Species and *p*H of Surface Waters at Which Optimum Growth Occurs

	(1) acidobiontic $p_H < 7$ opt. ~ 5	(2) acidophilous $p_H < 7$	(3) indifferent p_H ~ 7 ~	(4) alkaliphilous $p_H \leqslant 7 \geqslant$	(5) alkalibiontic $p_H > 7$
Foged, 1970					
Ceratoneis arcus				+	
Cocconeis placentula				+	
Cocconeis quarnerensis				+	
Cyclotella comta			+		
Cyclotella kutzingiana			+		
Cymatopleura elliptica			+		
Diatoma elongatum			+		
Diploneis subovalis				+	
Epithemia turgida					
Epithemia zebra					+
Gyrosigma attenuatum					+
Mastogloia braunii				+	+
Melosira arenaria				+	
Melosira distans		+			
Melosira granulata				+	
Melosira islandica sp.				+	
Melosira undulata				+	
Meridion circulare				+	
Opephora martyi				+	
Rhopalodia gibberula				+	
Stephanodiscus astraea					+
Stephanodiscus dubius					+
Gasse, 1975		ac	I	Al	Ab
Melosira ambigua				+	
Melosira distans		+			
Melosira granulata					7.9-9
Melosira granulata f. *curv.*				+	
Cyclotella kutzingiana				+	
Cyclotella ocellata				+	
Cyclotella striata					+
Stephanodiscus astraea				+	
Stephanodiscus hantzschii			+		
Stephanodiscus niagarae			+		
Stephanodiscus carconensis			+		
Cocconeis pediculus					8.5
Rhoicosphenia curvata				+	
Mastogoia braunii				+	
Diploneis subovalis					7-8
Gyrosigma acuminatum					8
Gyrosigma kutzingii					8
Navicula scutelloides				+	
Nitzschia punctata				7.3	
Epitheria turgida					8
Epitheria zebra					8.3
Rhopalodia gibberula					8.2
Cymatopleura solea				+	
Cholnoky, 1968					
Cyclotella comta				+	
Cyclotella kutzingiana					+
Cyclotella ocellata					8.4-8.8
Cyclotella operculata					8
Melosira granulata					7.9-8.2
Melosira distans	+				
Melosira islandica		+			
Stephanodiscus astraea					8.3
Stephanodiscus hantzschii					8.2

Note: Data from Foged (1970), Gasse (1975), and Cholnoky (1968).

mesohaline waters to have salinities of 5 to 20‰, polyhaline waters to have salinities of 20 to 30‰, and mixoeuhaline waters to have salinities of 30‰ to more than 35‰ (Ehrlich, 1975). No complete opal-skeleton-bearing sequence was found in the Black Sea samples. Diatom occurrences were interrupted by turbidites, slumped deposit sequences, and non-opal sequences. The following discussion will attempt to use the defined diatom layers (Figure 12) and relate non-

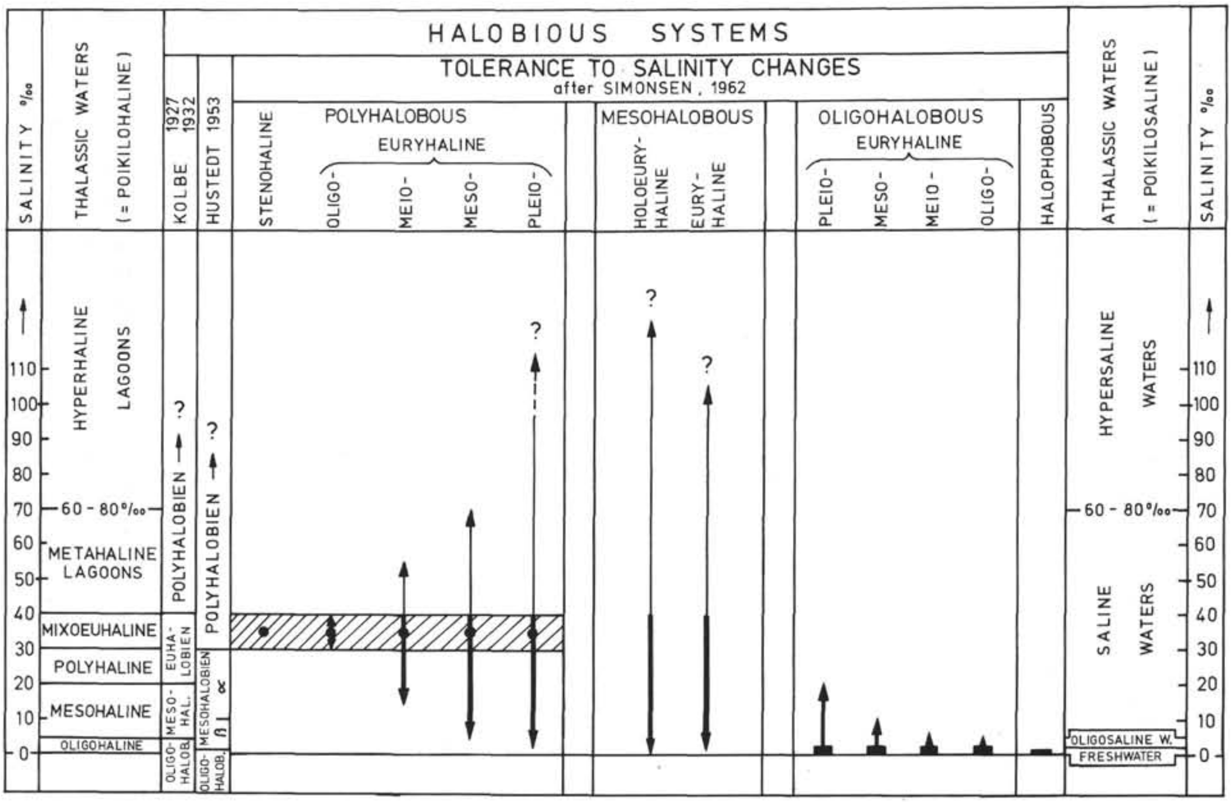


Figure 27. *Halobious classification of diatoms according to their tolerance to salinity changes (redrawn from Ehrlich, 1975).*

opal-bearing sequences either to the next upper or lower opal sequence in the case of allochthonous material (turbidites or slumped sequences).

Site 380 (Figure 29) serves as a standard profile into which missing paleosalinity values (because of sampling distance, poor recovery) are transferred from Sites 379 and/or 381.

Diatomaceous Unit 10, extending from Core 32 downward to the lowermost Core 79, has been subdivided on the basis of different diatom assemblages into three subunits, C, B, and A (cf. Figure 5).

Subunit 10-C (salinity interpretations not figured on Figure 28) contains, in Cores 57, 855 to 864.5 meters sub-bottom, and lower a shallow water (benthic) diatom assemblage characteristic of polyhaline-mixoeuryhaline *surface* and *bottom* waters (20 to 40‰S). That the correlative interval at Site 381 lies approximately 850 meters above the interval under discussion at Hole 380A (379 m difference of water depth and approximately 475 m difference in sub-bottom depth between Holes 380A and Site 381) explains why this level was not covered at Site 381 by polyhaline waters but was occasionally flooded by freshwater—either rainfall or river inflow—and did contain a few freshwater diatoms. Since the interval at Hole 381, Cores 38 through 54, was poorly recovered, there still remains the possibility of downhole displacement of these freshwater assemblages. The oligohalobous assemblage at Hole 380A, Sample 58, CC (compare Figure 7, Table 4, and Figure 28) is interpreted as downhole contamination and therefore not included in Figure 29.

Subunit 10-C contains in Cores 55 and 56 (836 to 855 m sub-bottom) a planktonic diatom assemblage characteristic of mixoeuryhaline waters (30 to 40‰S). This interpretation is supported by the high abundances of *Actinocyclus ehrenbergii* (stenohaline after Ehrlich, 1975; meioeuryhaline-polyhalobous after Pankow, 1976) and *Synedra indica,* which seems to be restricted today to the Indian Ocean and may have a salinity tolerance of 30 to 40‰ because of its geographical distribution. A similar diatom assemblage was observed at Site 381, but with higher proportions of marine-benthic species (*Pleurosigma* sp.), indicating that sea level may have been only about 50 to 100 meters above the depositional level of Cores 35 and 36 at Site 381.

Subunit 10-B contains in Core 55 (836 to 845 m sub-bottom) a planktonic diatom assemblage characteristic of mixoeuryhaline waters (30 to 40‰ salinities). A sharp boundary in the composition of diatom assemblages occurs between Cores 55 and 54, but is not well documented because of poor recovery over this interval. Cores 50 through 54 (788 to 836 m sub-bottom) contain a planktonic diatom assemblage characteristic of oligohaline waters, with salinities of less than 5‰ and commonly less than 0.5‰. One sample in Core 51 (51-3, 66-68 cm; 801.17 m sub-bottom) contains a planktonic diatom assemblage characteristic of mesohaline waters (10 to 25‰); since only one sample within a relatively short interval (798.23 m — oligohaline, 801.17 m — mesohaline, and 801.26 m — oligohaline) represents strongly increased salinities it was not included in Figure 29.

Subunit 10-A, extending from Core 32 through Core 50 (617.5 to 797.5 m sub-bottom), contains a planktonic diatom assemblage indicating deep to shallow water; it is characteristic of oligohaline waters with surface-water salinities of less

TABLE 8
Diatoms Species Observed in Black Sea Materials and Their Tolerance to Salinities[a]

Achnanthes brevipes	0.5	30	Simonsen, 1962
Actinocyclus ehrenbergii	17	>35	Simonsen, 1962
Actinocyclus normanii	0.5	10	Hustedt, 1957 (β mesohalob)
Actinoptychus undulatus	17	>35	Simonsen, 1962
Amphiprora palludosa	0.5	30	Simonsen, 1962
Amphora proteus	5	>35	Simonsen, 1962
Biddulphia pulchella	17	>35	Hustedt, 1930 (polyhalob), Pankow, 1976
Biddulphia tuomeyi	17 (?)	>35	Hustedt, 1930 (polyhalob)
Chaetoceros (bristles + spores)	3	>35	Proschkina-Lavrenko, 1955 (e.p.)
Cocconeis distans	20	>35	Simonsen, 1962
Cocconeis pediculus	0	10	Simonsen, 1962
Cocconeis quarnerensis	20	>35	Simonsen, 1962
Cocconeis scutellum	5	>35	Simonsen, 1962
Coscinodiscus divisus	17 (?)	>35	Hustedt, 1930 (polyhalob)
Coscinodiscus obscurus	17 (?)	>35	Hustedt, 1930 (polyhalob)
Cyclotella caspia	5	14.3	Proschkina-Lavrenko, 1963
Cyclotella comta	0	0.5	Simonsen, 1962; Hustedt, 1957 (oligohalob)
Cyclotella kutzingiana	0	0.5	Hustedt, 1957; Stoermer and Yang, 1970
Cyclotella ocellata	0	0.5	Hustedt, 1957; Stoermer and Yang, 1970
Cyclotella operulata	0	0.5	Hustedt, 1930; Stoermer and Yang, 1970
Cyclotella striata	0.5	10	Hustedt, 1957 (β mesoholob)
Cymatopleura elliptica	0	0.5	Hustedt, 1957 (oligahalob)
Cymatopleura solea	0	5	Simonsen, 1962
Diatoma elongatum	0	20	Simonsen, 1962
Dictyocha fibula	10	>35	Pankow, 1975
Distephanus speculum	10	>35	Pankow, 1975
Epithemia turgida	0	20	Simonsen, 1962
Epithemia zebra	0	10	Simonsen, 1962
Grammatophora arcuata	20	>35	Simonsen, 1962
Grammatophora oceanica	10	>35	Simonsen, 1962
Gyrosigma acuminatum	0	10	Simonsen, 1962
Hermesinum adriaticum	17	>35 (?)	Loeblich and Tappan, 1968
Mastogloia braunii	0.5	10	Simonsen, 1962
Melosira ambigua	0	0.5	Hustedt, 1957 (oligohalob)
Melosira arenaria	0	0.5	Hustedt, 1957 (oligohalob)
Melosira distans	0	0.5	Hustedt, 1957 (halophob)
Melosira granulata	0	0.5 (5)	Hustedt, 1957 (oligohalob), Simonsen 1962
Melosira islandica	0	0.5	Simonsen, 1962
Melosira sulcata	5	>35	Simonsen, 1962
Melosira undulata	0	0.5	Hustedt, 1926
Meridion circulare	0	0.5	Simonsen, 1962
Navicula lyra	20	>35	Simonsen, 1962
Navicula scutelloides	0	0.5	Simonsen, 1962 (oligohalob)
Nitzschia punctata	10	>35	Simonsen, 1962(oligohalob)
Opephora martyi	0	20	Simonsen, 1962 (oligohalob)
Rhabdonema adriaticum	20	>35	Simonsen, 1962 (oligohalob)
Rhizosolenia alata	10	>35	Pankow, 1976
Rhizosolenia bergonii	30	>35	Hustedt, 1930 (polyhalob)
Rhizosolenia calcar avis	20	>35	Hustedt, 1930 (polyhalob, occ. Baltic)
Rhizosolenia styliformis	17	>35	Pankow, 1976
Rhoicosphenia curvata	0	20	Simonsen, 1962
Rhopalodia gibberula	0	20	Simonsen, 1962
Sceletonema costatum	5 (2.54)	>35	Simonsen, 1962; Proschkina-Lavrenko, 1963
Stephanodiscus astraea	0	5	Pankow, 1976
Stephanodiscus binderianus	0	5 (?)	Round, 1975; Hustedt, 1930
Stephanodiscus carconensis	0	2	Gasse, 1975
Stephanodiscus dubius	0	5	Hustedt, 1957 (halophil)
Stephanodiscus hantzschii	0	10	Simonsen, 1962
Stephanodiscus niagarae	0	0.5	Gasse, 1975; Stoermer and Yang, 1970
Synedra indica	30	>35	Simonsen, 1974; Taylor, 1966
Thalassionema nitzschioides	1.2	>35	Proschkina-Lavrenko, 1936
Thalassiosira spp.	8	>35	

[a] References are listed on the right side.

than 3 to 5‰. The base of this subunit is defined by the last occurrence of *Actinocyclus ehrenbergii*. Within this interval several severe ecological changes occurred: drop of lake level, changes in alkalinity, changes in dissolved silicate, changes in stratification of the water column (indicated by changes of non-bioturbated varved sediments to highly bioturbated sediments), to mention a few. The corresponding interval at Site 381 extends from Core 19 through Core 34.

Unit 9, present in Core 17 at Hole 380A (485 m sub-bottom) and not observed at the other drill sites, contains an

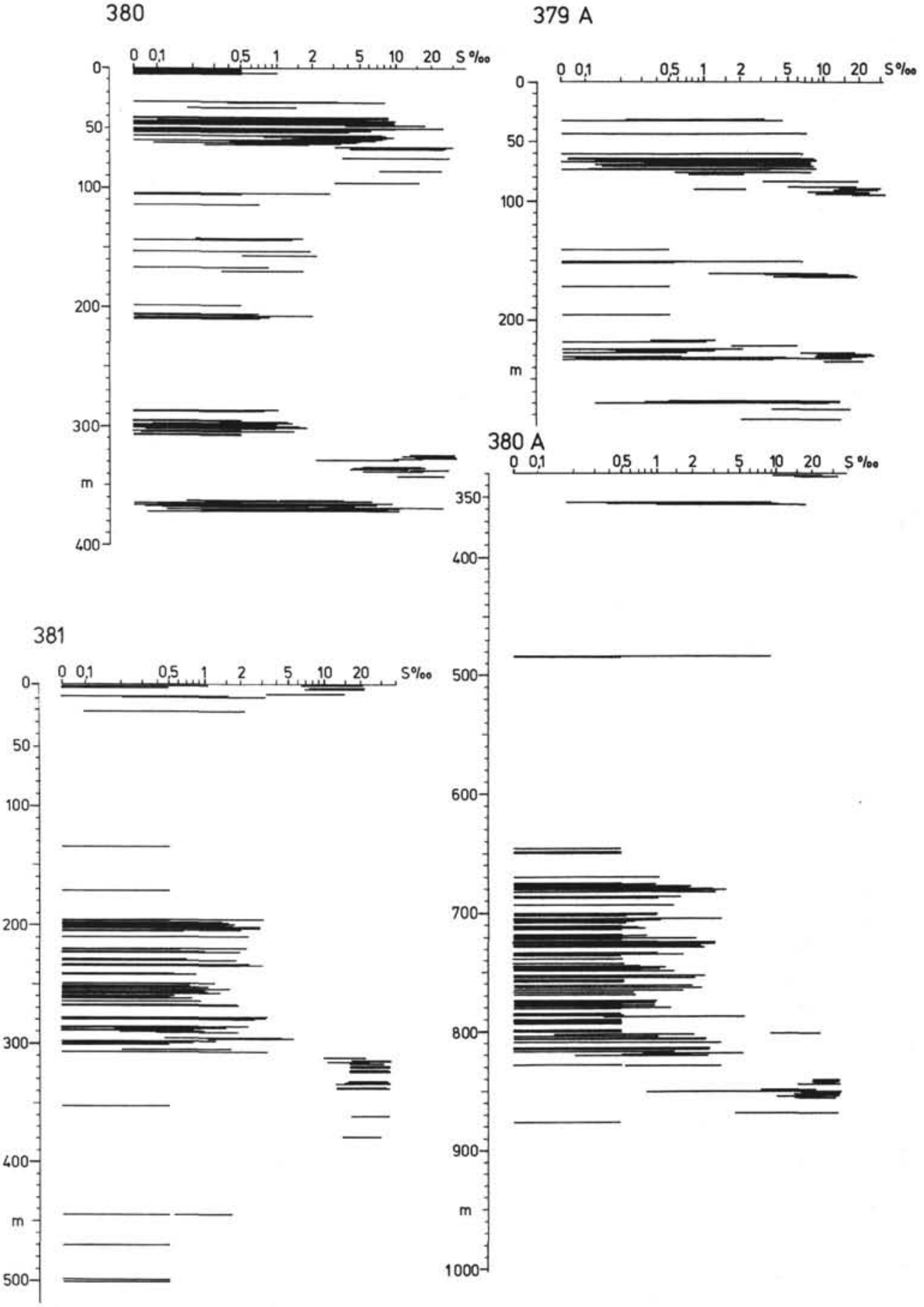


Figure 28. *Paleosalinity ranges of Leg 42B drill sites, as calculated from diatom assemblages. Each bar represents one sample. Note salinity is in log scale.*

almost monospecific freshwater diatom assemblage of *Melosira undulata* which includes minor admixtures of *M. granulata* cland *Stephanodiscus astraea* and its varieties; this assemblage places the unit in oligohaline waters with surface water salinities of less than 3‰. The position of this unit is tentatively placed at Core 381-9, assuming uniform sedimentation rates between the two holes. Different sediment composition can be explained by the depth difference between the two sites.

Unit 8 contains a planktonic diatom assemblage characteristic of mesohaline to oligohaline waters (5 to 20‰ and 0 to 5‰). It is present in Hole 380A, Core 3; Hole 380, Cores 38 and 39; Hole 381, Core 3; and Hole 379A, Cores 29 and 30. The most characteristic species are *Actinocyclus normannii, Cyclotella caspia, Chaetoceros* spores, and *Stephanodiscus* species.

Unit 7 contains a planktonic diatom assemblage characteristic of meso- to mixoeuryhaline waters, in ascending order. It occurs in Hole 380, Cores 24 and 25, with slightly lower salinity values than at Hole 380 (maximum salinity value 27‰ at Hole 379A and 31‰ at Hole 380) indicating that the marine inflow area was adjacent to Site 380. A

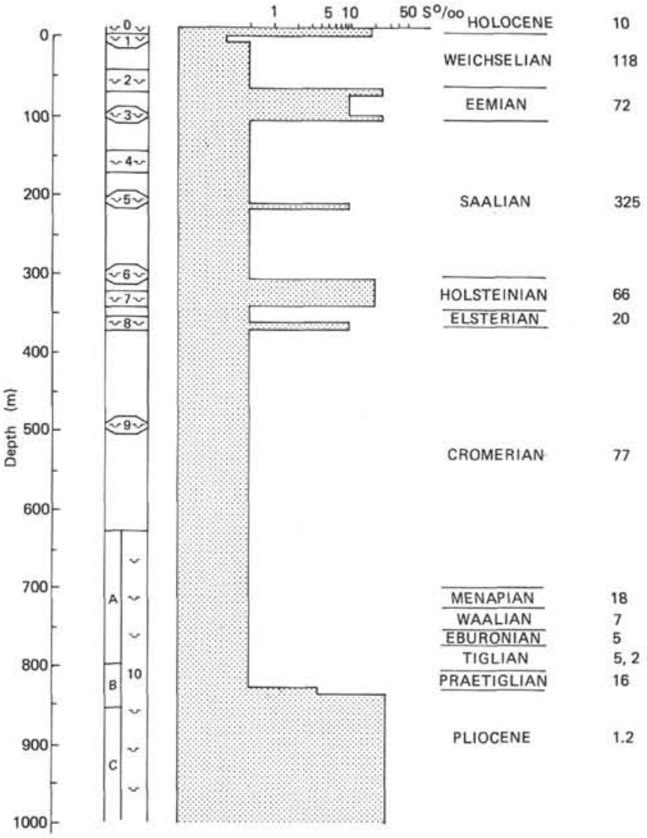


Figure 29. *Generalized interpretation of environmental conditions at diatomaceous intervals and intermediate units in % salinity and tentative glacial-interglacial correlation with sedimentation rates for each period in cm/1000 years at Site 380.*

similar difference in the maximum salinity is obtained by the floral assemblage interpretation of Recent sediments. Here (compare Figure 3) a gradational decrease of calculated maximum salinities of 34 to 33 to 29 and to 30‰ was observed over the west-east transect (note: there are almost no strong salinity changes observed in chemical measurements of surface waters, Kremling, 1974).

Unit 6 contains a planktonic diatom assemblage characteristic of oligohaline waters, and contains high proportions of *Stephanodiscus astraea* and *S. robustus*. The correlative interval occurs in Hole 379A, Core 24. In Hole 279A, Unit 6 is not separated from the underlying Unit 7 by a turbidite layer.

Units 4 and 5 contain a planktonic diatom assemblage characterizing oligohaline waters with salinities of less than 3‰. Because of poor recovery at Core 22, the short mesohaline interval observed in Hole 379A, Core 18, Section 2 may have not been recovered from Hole 380. Owing to poor recovery over this interval, the interpretations are tentative: Unit 5 is defined in Hole 380 at Core 22, Unit 4 in Hole 380, Cores 12 through 18, and both units in Hole 379A, Cores 16 through 18.

Unit 3 contains a planktonic diatom assemblage characteristic of mesohaline to polyhaline waters, in ascending order (salinity surface-water ranges from 3 to 30‰). In Hole 379A the correlative interval occurs at Cores 10 and 11. Since this unit was rather poorly recovered from Hole 380 (Cores 11 to 8), but better recovered from Hole 379A (Cores 10-11), a direct comparison is difficult.

Unit 2 is almost directly overlain by Unit 3, and contains a planktonic diatom assemblage characteristic of oligohaline and lower mesohaline waters with salinity values ranging from 0 to 10‰. The high proportion of *Stephanodiscus astraea*, an oligohalobous species (Simonsen, 1962) or a meioeuryhaline oligohalobous species (Pankow, 1976), indicates oligohaline surface-water conditions. The lower meso- or oligohaline characteristic depends upon whether *Stephanodiscus hantzschii* is interpreted as being mesoeuryhaline-oligohalobous (0-10‰, Simonsen, 1962) or as being α to β mesosaprobic (Caspers and Schulz, 1960). Its occurrence here is thought to be caused not only by increased salinities but by increased eutrophication, or by both (for more details see Section 8). This unit was observed in Cores 380-5 through 380-8 and Cores 379A-7 through 379A-9. One short upper mesohaline episode was documented in Section 380-6-3, whereas no such episode was found in Hole 379A.

Unit 1 contains a planktonic diatom assemblage characteristic of oligohaline waters, and contains high proportions of *Stephanodiscus astraea, S. robustus* and varieties. This unit was observed only in the topmost core of Hole 380 and was not found at any of the other sites. It correlates with "sedimentological Unit 2" as defined by Ross and Degens (1974) in Black Sea piston cores, and is a diatomaceous mud rich in organic matter.

Unit 0 was not found in any of the Leg 42B drill holes, but was frequently observed in Black Sea piston- and kastencores during the WHOI *Atlantis* II expedition. It contains a planktonic diatom assemblage with high proportions of polyhalobous species.

A direct correlation between paleosalinities of Holes 380 and 379A is presented in Figure 30. The calculated surface-water salinity ranges (maximum and minimum) were averaged for each section, and bars represent average ranges of each investigated section. Salinity values are plotted on a linear scale and demonstrate generally that maximum salinities of comparable units are higher in Hole 380 than in Hole 379A, specifically at levels with good recovery: Unit 2 and Unit 7. This may indicate that Site 380 was closer to the marine influx source than Site 379, and is analogous to present conditions.

Surface-water salinities should influence not only the composition of micro-floras and micro-faunas, but also levels deeper in the underlying water column, and should indirectly influence pore-water salinities in the sediments even in strongly meromictic lakes, because of the different densities. In order to test this indirect correlation, pore-water salinity data were taken from Manheim (this volume) and plotted (Figure 31) in the same depth frame as was done for Figure 28. Frequently the two different curves are not comparable and are divergent.

There is no explanation of the high pore-water salinities in Holes 380A and 381 at those levels where the floral composition points to freshwater conditions. Even in the case of a meromictic lake with strong stratification and dense highly saline water forming the monimolimnion overlain by less dense freshwater forming the mixolimnion, there should be

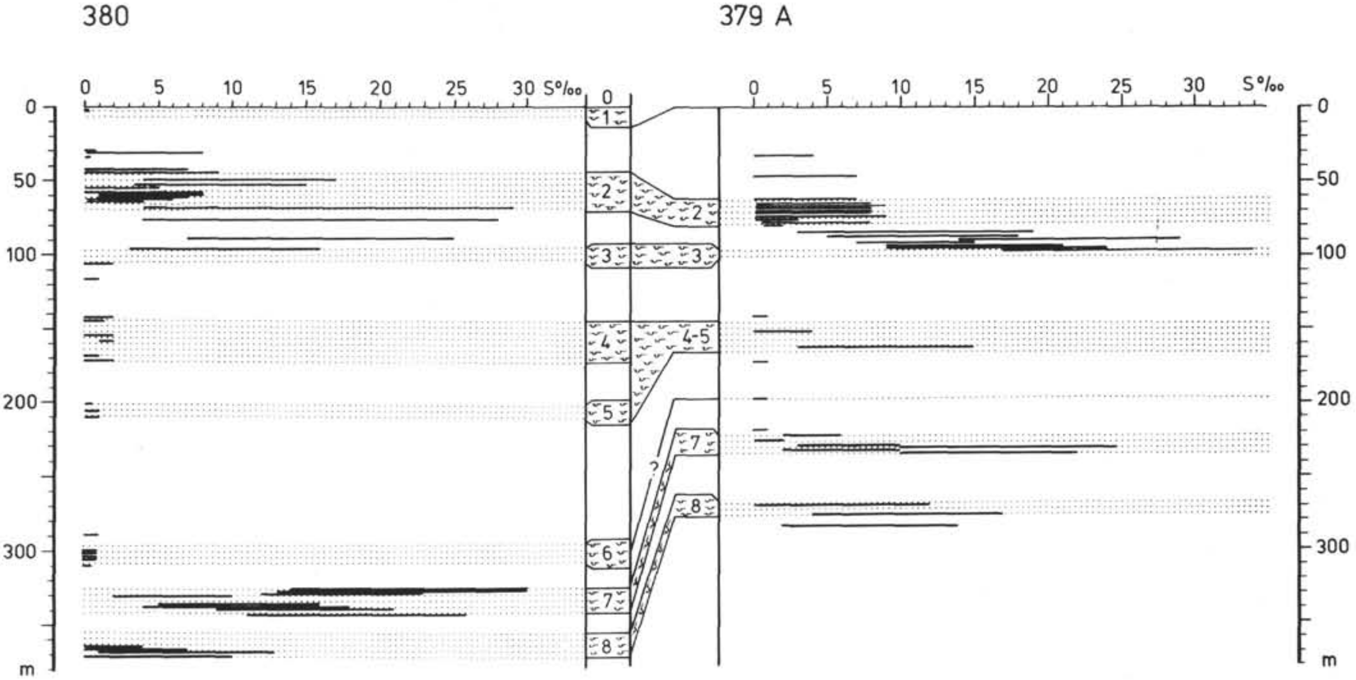


Figure 30. *Correlation of paleosalinities of Hole 379A and Site 380. Bars represent average ranges of salinities of all samples from one section. Stippled areas are diatomaceous layers 0-8, indicating the proposed correlation.*

some response of the biocoenoses inhabiting the mixolimnion similar to the response found in present interactions in the Black Sea. The slight increase in pore-water salinities in Hole 380A at 840 meters sub-bottom correlates well with the paleontological interpretation derived from floral evidence, as does the drop of pore-water salinities in Hole 381 at 340 meters sub-bottom, and would also indicate that the two polyhaline assemblages in Sample 381-40-1, 112 cm and Sample 41, CC are downhole contamination. The remaining curve for Hole 381 cannot be correlated with the surface-water salinities, and are even opposite (Core 1).

Two major marine episodes have been postulated at Hole 379A (Manheim, this volume) because of increased pore-water salinity values between 275 and 350 meters sub-bottom and between 50 and 100 meters sub-bottom. Polyhaline surface-water conditions were observed on the evidence of diatom assemblages, at 280 meters and not below, at 230 to 240 meters, at 160 meters, and at 90 to 100 meters sub-bottom. Diffusion in both directions may be one possible explanation of the phase-out of pore-water salinities at 300 meters and 75 meters sub-bottom.

Calvert and Batchelor (this volume) postulate three marine episodes in Hole 379A at 50 to 100 meters, at 150 to 180 meters, and at 200 to 290 meters sub-bottom; again there is little overlap between "biological" and pore-water chemistry interpretation. Below 350 meters in Hole 379A, a sharp increase in salinity is taken (Calvert and Batchelor, this volume) to indicate saline-evaporitic conditions; no biological evidence can be presented for this lower interval, as is true for the middle part of Hole 380 and the upper part of Hole 381.

TEMPERATURE

A general review is presented by Kalbe (1973), who followed Hustedt's (1957) interpretation that the majority of the diatom freshwater species are eurythermal and are able to thrive in environments which may be subjected to changes in temperatures over a 20°C span. Eustenothermal coldwater species are not yet found in freshwater environments (compare also discussion in Cholnoky, 1968). Simonsen (1957) discussed problems involved in the terminology *nordic-alpine* or *boreoalpine,* but primarily benthic species are listed. Solar insolation and temperatures are closely related considerations which may possibly explain the diatom phytoplankton periodicity (Kalbe, 1973; Nipkow, 1920; Jørgensen, 1957; Benda, 1974).

Stoermer and Ladewski (1976), on the other hand, have used statistical methods in relating a large number of phytoplankton observations in southern Lake Michigan to apparent optimal growth temperatures. They found that approximately 75 percent of the observed forms "reach their most significant abundance in a single relatively narrow temperature range." The limiting factor in using all presented data is the differing taxonomic interpretations of different authors, most relevant within the genus *Melosira* and *Stephanodiscus* (*S. alpinus*, *S. minutus*, *S. transylvanicus*, *S. subtilis*, *S. subsalsus*). The species listed below did occur in the Black Sea sediments in higher frequencies. Their predicted temperature range (Tm[°C]) was taken directly from Stoermer and Ladewski (1976, Table 1).

	Tm (°C)	
	Absolute Abundance	Relative Abundance
Melosira islandica	6.8	8.4
Stephanodiscus binderianus	8.9	8.0
Cyclotella kutzingiana	15.0	15.0
Melosira granulata var. *angustissima*	17.0	19.3
Melosira granulata	18.9	18.8
Cyclotella comta	19.8	19.3

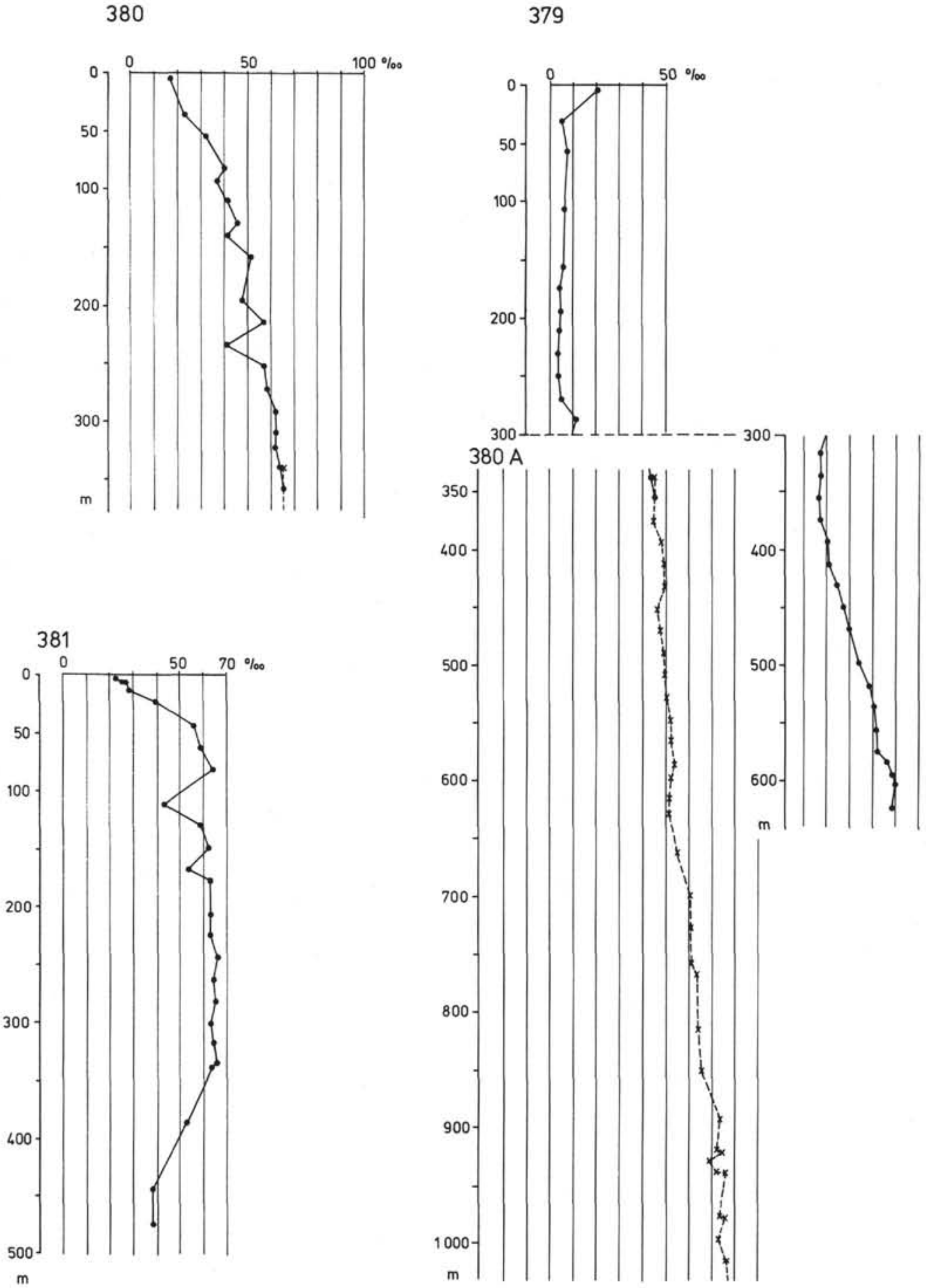


Figure 31. *Pore-water salinities of Leg 42B drill sites from Manheim (this volume).*

Species adapted to lower temperatures (less than 9°C) and lower solar insolation are *Melosira islandica, Melosira distans, Melosira ambigua,* and *Stephanodiscus binderianus* (Hustedt, 1926, 1957; Van Landingham, 1970; Stoermer and Ladewski, 1976; and R. Pattrick, personal communication, 1976). These species are most commonly found at the following levels of Hole 380 (from which correlations with the remaining sites can be drawn): *Stephanodiscus binderianus,* Cores 53 and 52 (380A); *Melosira islandica,* Cores 50 through 48 (380A); *Stephanodiscus binderianus* and *M. islandica,* Cores 47 and 46 (380A); *Stephanodiscus binderianus,* Core 48 (380A). *Melosira ambigua* was observed in Cores 380A-34 and 380A-38 and in Cores 381-28 through 381-31, and in the case where *Stephanodiscus hantzschii* has a temperature range similar*S. binderianus,* the interval from Core 380-7 through Core 380-5 might also be grouped into this category. All the above-listed assemblages may indicate surface-water temperatures of 6.8° to 8.9°C and thus represent colder climatic conditions.

Species adapted to higher (more than 9°C) temperatures and higher solar insolation are *Cyclotella kuetzingiana, Melosira granulata* and its varieties (compare also Kilham and Kilham, 1975), *Cyclotella comta,* and *Melosira undulata* (Hustedt, 1926; Stoermer and Ladewski, 1976; and R. Pattrick, personal communication, 1976). *Melosira granulata* and varieties occur in Core 380A-35 and in Core 279A-10.

All observed brackish to marine species are eurythermal, and except for *Synedra indica* (see below) no indirect surface water temperature interpretations can be made; instead, the presence of these floras has been used to interpret marine water flow into the Black Sea caused by raised eustatic sea level, which is compared with raised sea levels during interglacial periods on a worldwide scale.

Synedra indica (Figure 32) is frequently found today, particularly in the nearshore stations, and less abundantly in virtually all Indian Ocean stations with water temperatures around 22°C (Simonsen, 1974). Its Black Sea occurrence indicates that surface waters must have had temperatures around 20°C during the time of deposition of the sediment sequence in Core 380A-56 and Cores 381-35 and 381-37. Salinities of surface waters may have been as high as 35 or 36‰ (Indian Ocean oceanographic data from Dietrich and Kalle, 1965 and Indian Ocean Oceanographic Atlas).

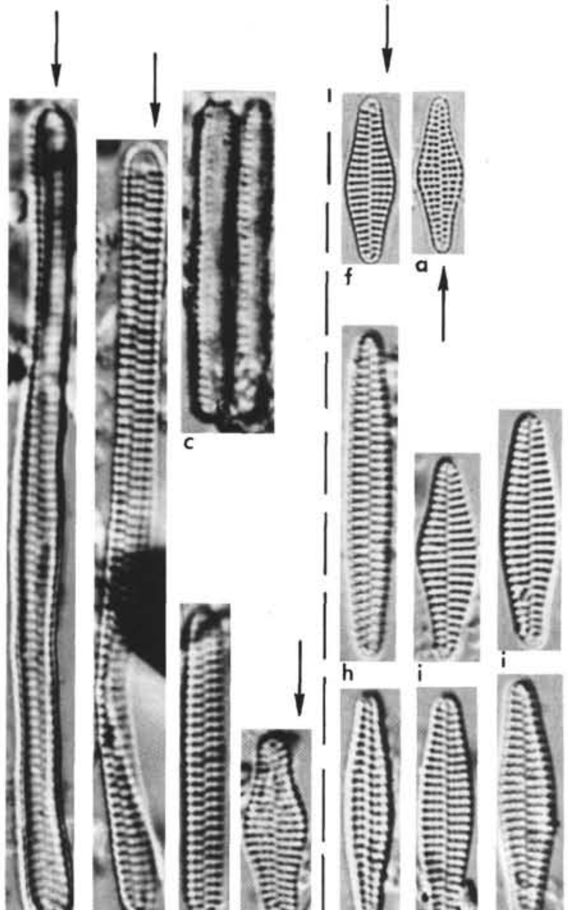


Figure 32. Synedra indica, *left side (a-e) fossil specimen from Sample 381-35-5, 61 cm, right side (f-m) recent individuals from phytoplankton Sample IOE 189. Arrows point to hyline apical field. a-b, d, h-m differential interference phase contrast; c, e, f-g normal plain through light.*

CORRELATION WITH GLACIAL AND PREGLACIAL EPISODES AND RESULTING SEDIMENTATION RATES (Figures 30, 33, and 34)

Only a very few marine planktonic diatom species were found in the Leg 42B material which could directly serve as biostratigraphic indicator species. It must be clearly pointed out that *no* freshwater diatom biostratigraphy has been established yet. Of stratigraphically useful species, "*Stephanodiscus kanitzii*" (which most probably belongs to the genus *Actinocyclus* because it possesses a clear pseudonodulus) was found at Site 380 (Hole 380A, Core 79, not mentioned in Table 4). A tentative assignment of upper Miocene (>5-<12 million years) can be given to this lower marine interval at Site 380.

An event occurred at Hole 380A, Hole 58, and at Site 381, Core 37, which is tentatively interpreted here as a tectonic event in which a subsiding Black Sea basin changed from shallow marine (diatom flora mostly composed of benthic species) to deep marine conditions (diatom flora composed of planktonic species). The shallow marine interval at Site 380 can be correlated with Site 381, Core 38 and deeper (Figure 33). The sediments representing the deep marine facies had abundant *Synedra indica* (Figures 32 and 33), a delicate species also found on Leg 13 at Sie 124, Core 13, Section 2 (Schrader and Gersonde, 1978a). This Leg 13 interval was dated on micropaleontological evidence as upper Miocene (Messinian; for more information compare *Initial Reports of the Deep Sea Drilling Project,* v. 13).

The "*Synedra indica* section" is correlated tentatively with the uppermost Messinian, and the subsequent section with common *Actinocyclus ehrenbergii* (Figure 33) and *Thalassiosira* aff. *lineata* (Figure 34) with the lower Pliocene. *Thalassiosira* aff. *lineata* was frequently observed in the Capo Rossello section (type Zanklian), where finely laminated marine diatomaceous sequences are exposed (Cita and Gartner, 1973; Schrader and Gersonde, 1978b). In the present material, *T.* aff. *lineata* occurs in Hole 380A, Core 46 (up to 4%) and Core 43 (up to 5%). Since no range of *T.* aff. *lineata* has yet been established, the event of drastic ecological change was used and correlated with the first strong northern hemisphere glacial period in the Neogene (the Praetiglian, 2.6 to 2.2 m.y.B.P.; cf. Figure 35 and Zagwijn, 1975).

Using these dates a tentative sediment accumulation rate of 1.2 cm/1000 years can be calculated for the marine interval of Hole 380. No such calculation can be made at Site 381.

Stratigraphic correlations and estimates of absolute ages of the Pliocene-Pleistocene interval in the Black Sea are difficult because the biogenic remains found give only facies and no time indication. The age assignment as well as the Pleistocene nomenclature refer to the recent chronology by Zagwijn (1975).

The first northern Neogene glacial episode, the Praetiglian, may be documented in the Black Sea by a sharp floral change from marine to freshwater at Site 380 (Hole 380A), Core 55 and at Site 381, Core 34.

Ecological conditions may have been restricted during this cold period by the closing off of the Black Sea from copious

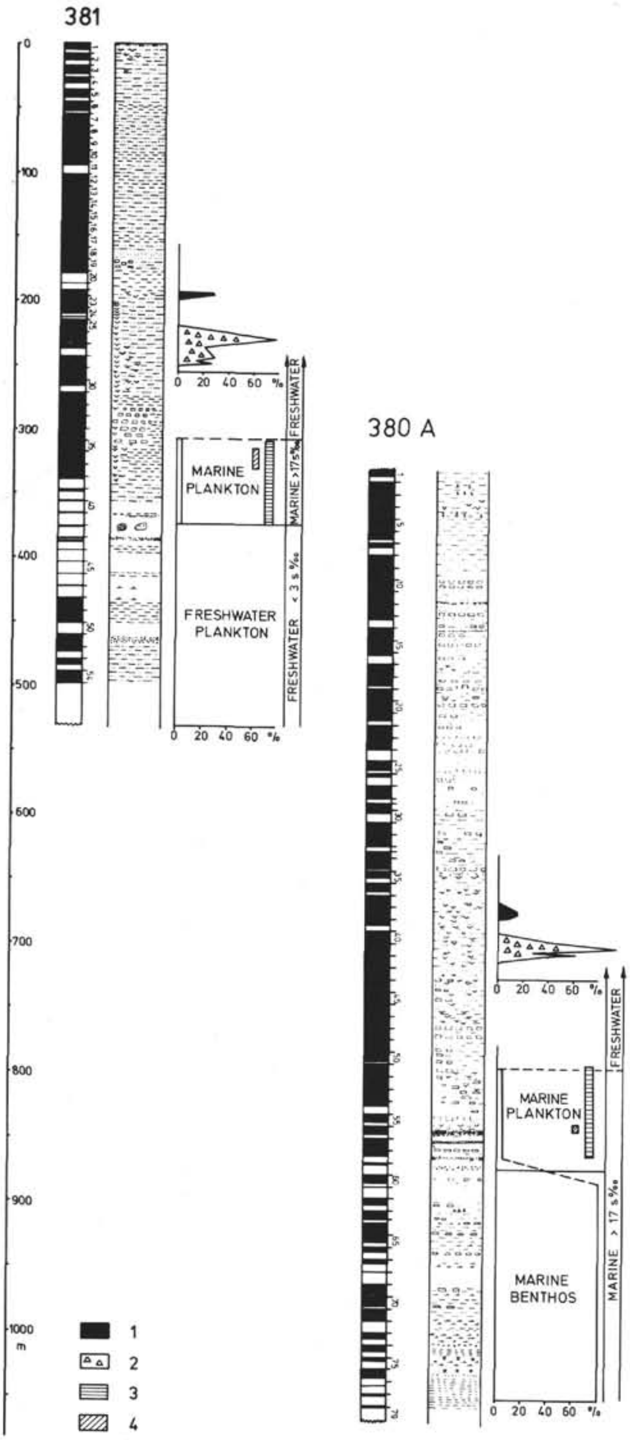


Figure 33. *Occurrence of diatom species* Actinocyclus ehrenbergii *(3),* Synedra indica *(4), and* Melosira granulata *var.* angustissima *f.* curvata *(1),* Stephanodiscus *aberrant triangulate forms (2) in per cent of total opal skeletons. Lower part indicates shift of predominantly marine benthic to predominantly marine planktonic diatom assemblage (% of total diatom count) in Hole 380A and shift of freshwater to marine habitat in Site 381.*

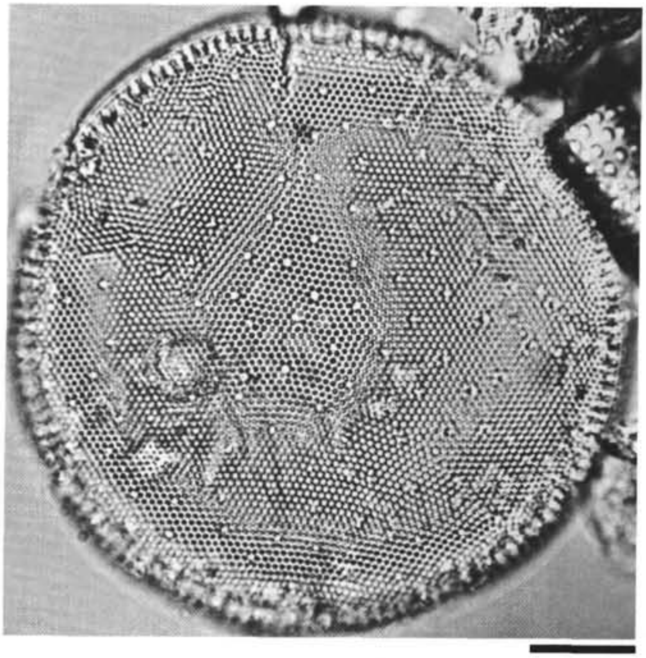


Figure 34. Thalassiosira *aff.* lineata, *normal plain through light, Sample 381-30-2, 136-138 cm.*

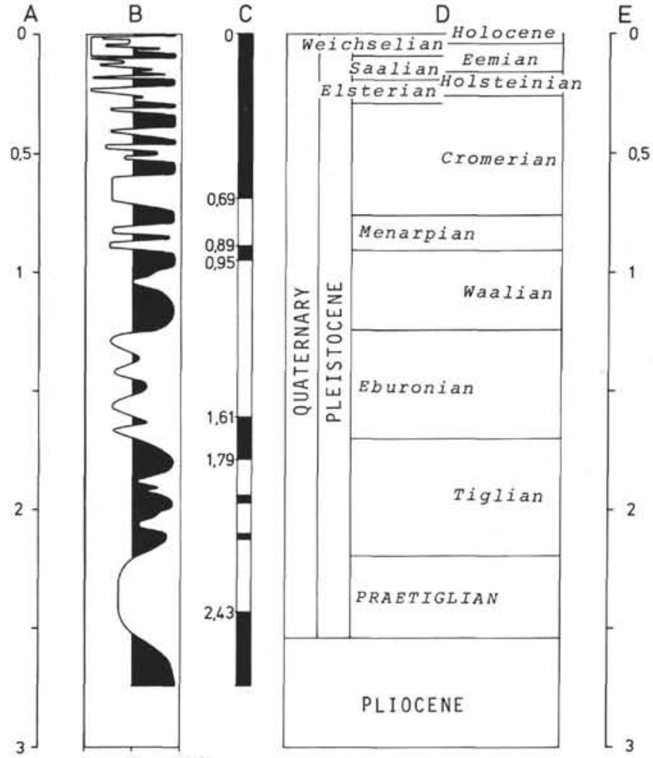


Figure 35. *Standard European glacial and interglacial zones (D), boundaries, correlation with the paleomagnetic stratigraphy (C), and to the absolute time scale (A). (B) demonstrates averaged July temperatures (after Zangwijn, 1975).*

fresh water supplied by rivers, and the consequent lowering of lake level which caused eutrophic conditions. The Praetiglian extends at Site 380 to Core 51 and at Site 381 to Core 32. Sedimentation rates would be on the order of 16 cm/1000 years.

No direct strong marine influx occurred until the termination of the Cromerian approximately 300,000 years ago. The intermediate interval is correlated tentatively with glacial and interglacial episodes, using both diatom floral composition and ecological changes which influence the diatom assemblages, i.e., changes in temperature, in dissolved silicate availability, and in predominance of ecological modification of species.

Starting from the Praetiglian the next warm period would be the Tiglian (2.2 to 1.7 m.y.B.P., Figure 35). Only very few polyhalobous indicator species (e.g., *Actinocyclus ehrenbergii*) invaded the Black Sea during this time interval; this indicates rather restricted communication between the Black Sea and the Mediterranean Sea. Predominant oligohalobous species are *Stephanodiscus carconensis* and *Melosira islandica* (Figure 7). Mean July temperatures in Northern Europe were over 15°C (Figure 35) on the Zagwijn (1975) scale; such temperatures would have led to even higher temperatures in the Black Sea area. These high temperatures are in contrast with the predicted maximum growth temperatures for *Melosira islandica* of 6.8° to 8.4°C (Stoermer and Ladewski, 1976). Three possible explanations can be offered: (1) the maximum growth of *M. islandica* occurred during colder periods within the Tiglian (Figure 35), (2) the temperature requirements of *M. islandica* have changed, (3) the occurring species is not properly identified and does not represent *M. islandica*. The most likely explanation may be the first. The Tiglian extends in Hole 380A to Core 48 and in Hole 381 to Core 30, revealing a sedimentation rate of about 5 cm/1000 years.

The steady increase in abundance of *Melosira distans* and *Melosira islandica* and the high abundance of *Stephanodiscus binderianus* (a) may prefigure the subsequent glacial period (Eburonian, 1.7 to 1.25 m.y.B.P., Figure 35). The resolution of the available samples is too rough to indicate precisely the climatic oscillations (Figure 35). The Eburonian extends in Hole 380A from Core 48 to Core 46 at that level where *Stephanodiscus niagarae* increases in relative abundance and *Thalassiosira* aff. *lineata* occurs for the first time. A tentative sediment accumulation rate of 5 cm/1000 years was calculated for the interval in Hole 380A.

The relatively warm Waalian (Figure 35), 1.25-0.9 m.y.B.P., with its one pronounced colder period, may be represented in Hole 380A, Cores 46 to 43. During the warmer periods only very minor exchanges between the Black Sea and the Mediterranean saline waters occurred, as indicated by the rather infrequent *Thalassiosira* aff. *lineata* in Cores 43 and 46. (Note that since no salinity ranges for this species together with *Thalassiosira* sp. b are known, they were not used for salinity recalculations, and thus this slightly brackish environment is not illustrated on Figures 28 and 29). This warm interval extends to that level where *Stephanodiscus carconensis* (triangulate) has its first occurrence. This upper level was found in Core 381-28. Sedimentation rates are on the order of 7 cm/1000 years.

A distinct change in environmental conditions is indicated in Hole 380A at Core 43, where triangulated forms of different circular *Stephanodiscus* species occur; they are interpreted as ecological modifications produced by restricted environmental conditions during a cold season.

The co-occurrence of *Melosira ambigua* (not included in tables), which has its growth optimum in colder waters, supports this interpretation, as does the sharp drop of lake level as interpreted and correlated with the Post Cauda-Menapian by Paluska and Degens (this volume) (Table 9). The Menapian (Figure 35) extended from 900,000 to 750,000 years B.P.; using the above-interpreted dates a sediment accumulation rate of 18 cm/1000 years can be calculated.

The Cromerian, with highly fluctuating climates, extended from 750,000 to 300,000 years B.P. and cover one of the rarely found longer Black Sea sediment intervals free of opal. The total interval extends in Hole 380A from Core 40 to Core 1, in Hole 381 from Core 26 to Core 1, in Hole 380 from bottom to Core 39, and in Hole 379A from the bottom to Core 29. The Black Sea was rather limited in volume at the beginning of the Cromerian (correlation with the cold period represented at the lower part of the Cromerian, Figure 35). Frequently changing lake level may have been reponsible for deposition of big slump deposits. Other intervals are barren of opal skeletons, which can only be explained by silicate-free environmental conditions, interrupted only once, at Hole 380A, Core 17, where an opal-rich (benthic?) *Melosira undulata* warm-water assemblage occurs, and/or by the allochthonous character of most of the sediment (unstable Seekreide, Unit II in Stoffers et al., this volume). Isotope data suggest deposition in a freshwater environment, and the pollen data (Traverse, this volume) indicate cold climate (Figure 7).

Diatom data suggest rather warm surface water conditions at the lower part of the section (common occurrence of *Melosira granulata* var. *angustissima,* which has optimum growth rates at 17° to 19.3°C). The Cromerian terminated with a rise in lake level around 300,000 years B.P.; sedimentation rates were on the order of 77 cm/1000 years.

The Elsterian, with freshwater conditions, and the Holsteinian, with marine conditions, follow. Sedimentation rates for the Elsterian were around 20 cm/1000 years (Figure 29).

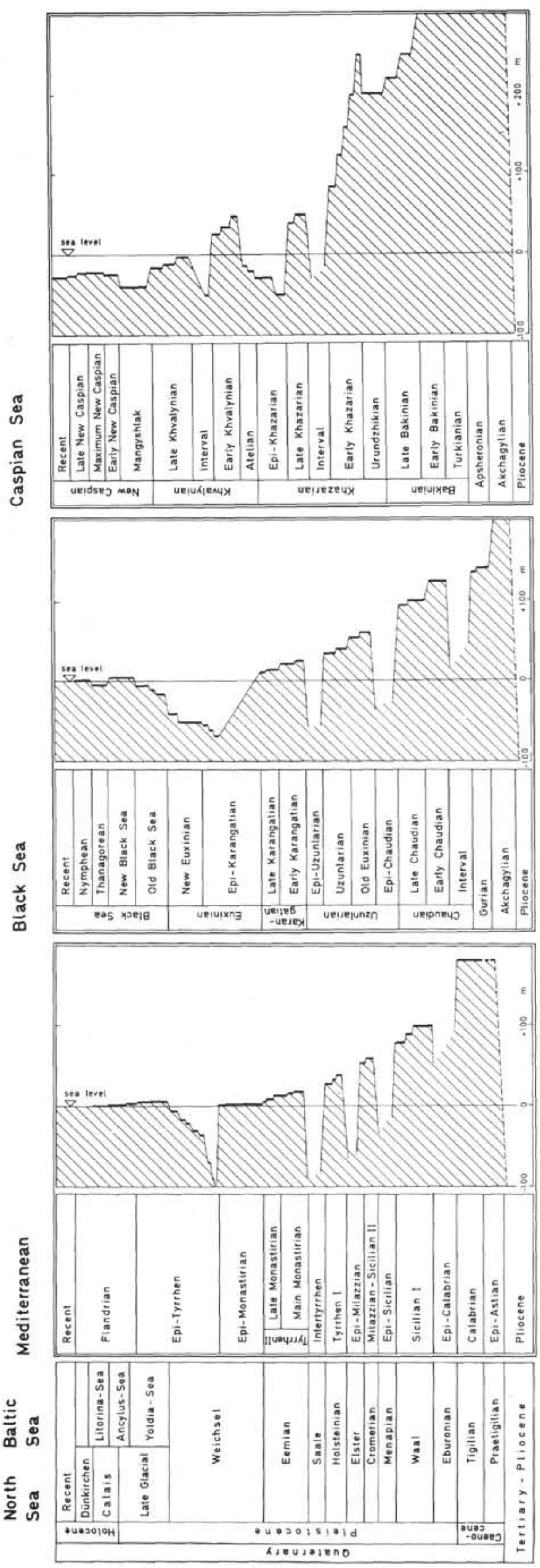
The following glacial (Saalian, Weichselian) and interglacial epochs (Eemian, Holocene) are tentatively defined by the occurrence of either brackish and/or marine assemblages (for interglacial periods) and by the occurrence of freshwater assemblages (for glacial periods). Sedimentation rates were on the order of 72 cm/1000 years for the Eemian, 10 cm/1000 years for the Holocene (Ross and Degens, 1974, revised by Degens et al., this volume, to 10 cm/1000 years for the sapropel unit [freshwater sediments] and 30 cm/1000 years for the coccolith unit [marine-brackish sediments] over the past 5000 years), 325 cm/1000 years for the Saalian, and 118 cm/1000 years for the Weichselian (Figure 29).

The varved interval at Site 380 (Hole 380A) between 646 and 717.5 meters sub-bottom indicates sedimentation rates of 7 to 18 cm/1000 years. These rates are comparable to those defined by Benda (1974), who found a similar type of sediment in the freshwater deposits of Lüneburger Heide, with a rate of 16 cm/1000 years.

The proposed correlation of the standard North European Pleistocene-Pliocene time scheme of Zagwijn (1975) with

TABLE 9

Stratigraphic Subdivision of the Quaternary (taken directly from Paluska and Degens, this volume) for the Mediterranean, the Black Sea, and the Caspian Sea



that of other workers in the Mediterranean Sea, Black Sea, and Caspian Sea can be seen in Table 9, which is from Paluska and Degens (this volume). For more details and discussions see also Frenzel (1968).

Sedimentation rates are not corrected for compaction. They are slightly higher at Hole 380A than at Hole 381. The correlation of the various diatom floras with cold and warm periods represents the best fit with the climatic standard North European scheme. Direct correlations by biostratigraphic indicator species were not possible at this time. On the other hand, the fit is sustained by known stratigraphic subdivisions and changes in sea level (compare Table 9). Up to now, no absolute dating methods have been applied to the Leg 42B materials.

DISCUSSION AND SUMMARY

Diatoms, together with less common silicoflagellates, chrysomonad cysts, and ebridians, constitute the main component of the hemipelagic to pelagic Black Sea sediments. Their composition leads to the following interpretations. The oldest sediments recovered at Site 380 are tentatively dated as upper Miocene (occurrence of *Coscinodiscus* (?) *stokesianus* and *Stephanodiscus kanitzii*). During the late Miocene diatom flora consisted of primarily meso- to polyhalobous benthic species. The great predominance of benthic species indicates a shallow (less than 50 m water depth) and polyhaline (30 to 40‰ salinity) environment. The comparable horizon at Site 381 contains only a few scattered freshwater assemblages, and lies approximately 900 meters above the one at Site 380A (Figure 36).

In this context the question arises as to which salinity crisis in the Mediterranean (late Messinian) is comparable to this shallow marine basin phase in the Black Sea. Did the Black Sea dry out in a manner similar to that suggested by the Mediterranean salinity crisis hypothesis? What was the relative position of the sea floor in comparison to sea level (NN)?

The Black Sea gains, and has gained, its marine waters since the latest Miocene from the Mediterranean Sea through a "channel" system similar to today's situation: Dardanelles—Sea of Marmara—Bosporus—Sakaria. In the case of a totally dried out deep Mediterranean basin and a depth pattern similar to that of today, it would have been impossible for marine waters and floras to enter the Black Sea from the Mediterranean Sea. Hypersaline floras were not

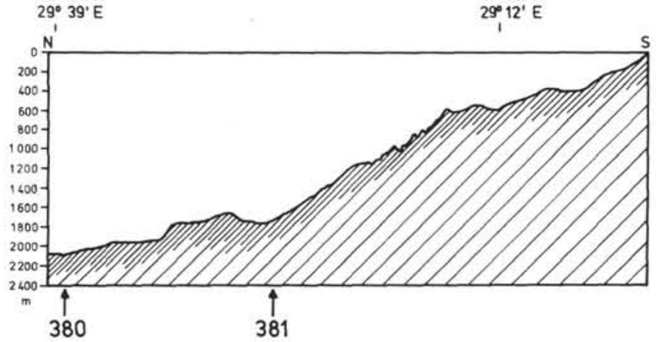


Figure 36 *Diagrammatic sketch of position of Holes 380 and 381.*

found over this interval; they should have been present if the Black Sea were partly or totally dried up.

If both sea floors were uplifted close to NN (range 100 m), an exchange of waters through the Mediterranean Sea into the Black Sea would have been possible. The flora indicating shallow water at Hole 380A supports this interpretation, since this horizon was close to NN during part of the late Miocene and subsided abruptly more than 1000 meters below NN during the early Pliocene (cf. also discussion in Paluska and Degens, this volume). Both horizons in Holes 380A and 381 subsided similarly over this interval. This change was completed rapidly, and normal pelagic sedimentation is indicated in the middle Pliocene. The increased opal skeleton content and increased amounts of autochthonous shallow-water benthic diatoms at Site 381 suggest that this interval was deposited in water about 50 meters deep. This would add up to an approximate water depth of 950 meters for the deep basins in the Black Sea. An additional subsidence must have occurred at a later date for it to have reached its present depth of 2200 meters.

The first indication of climatic deterioration in the northern hemisphere through the latest Pliocene-earliest Pleistocene (in the continental sense) is documented by a lowering of sea level which was responsible for the disconnection of the Mediterranean Sea from the Black Sea (Figure 37).

The Black Sea changed during early Praetiglian to a freshwater environment, restricted in volume by restricted freshwater influx (compare paleogeographic reconstruction of Akchagilian in Paluska and Degens, this volume), which resulted in a highly eutrophic environment.

By increased freshwater influx and/or by lowered evaporation, the basin filled up and changed into an oligotrophic lake, which again changed into a eutrophic freshwater stage during the Tiglian, with only minor salt water intrusions. Lake surface temperatures during the Tiglian (2.2 to 1.7 m.y.B.P.) were temperate (temperatures around 10°C). During the end of the Tiglian the proportion of "stenothermal" cold water species inceased, and during the final stages of the Eburonian the Black Sea was again restricted in volume and changed into a highly eutrophic freshwater lake. Nutrient conditions balanced during the early Waalian with common *Stephanodiscus niagarae*. Eustatic sea level did not exceed that level which would allow marine influx from the Mediterranean Sea. During the early Menapian the Black Sea volume was extremely restricted and caused hypereutrophic conditions which resulted in production of a strongly stressed freshwater (?) assemblage. A similar case in which several species have shown comparable trends in eccentrically and triangulate frustules has not been reported yet in the literature. Similar conditions were postulated by Paluska and Degens (this volume) for the Post Cauda (cf. Table 9). During termination of the Menapian, ecological conditions unstressed.

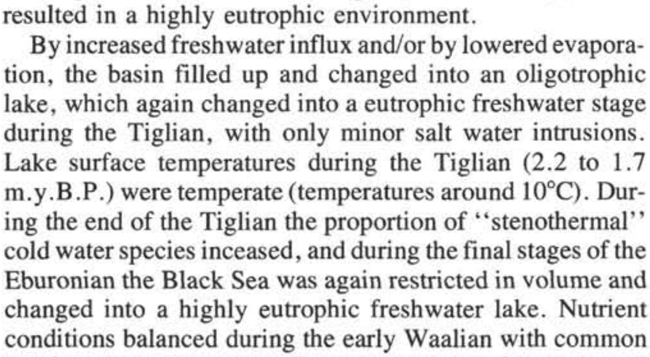


Figure 37. *Schematic reconstruction of the Paratethys in the Pliocene. Black solid lines today's situation, stippled areas expansion of the Paratethys, and stippled-oblique-striped land (redrawn from Cicha et al., 1975, Strat. Correl. Tethys - Paratethys, Project 25). Arrows (left upper part and left lower part) point to probable marine resources.*

The Cromenian, with its frequently oscillating climatic changes (Figure 34) and resulting lake-level change, built up the thickest sedimentary sequence. Sediment accumulation rates changed from 1.2 cm/1000 years during the Pliocene to 5 to 16 cm/1000 years during the Praetiglian-Menapian to 77 cm/1000 years during the Cromenian.

Formation and instability of Seekreide are discussed in Stoffers et al. (this volume), and no more interpretation is presented here, since except for a few samples in Core 380A-17 the total interval is barren of diatoms. The diatom flora of Core 17 indicates eutrophic warm water lake conditions.

No marine influx occurred until the termination of the Cromenian. Only about 300,000 years ago a connection between the Black Sea and the Mediterranean Sea was established again and produced a mesohaline flora.

During the initiation of the Elsterian cold glacial period, sea level dropped slightly and interrupted the Mediterranean-Black Sea connection. This Elsterian freshwater lake changed to a saline environment about 280,000 years ago, during the Holsteinian. The influx of saline, denser water may have been responsible for the strong erosion of the upper section at Site 381, which lies closer to the influx area and about 900 meters higher than Site 380. Sea level was even higher than today, and caused formation of a more polyhalobous flora than the one of today.

This Holsteinian marine phase changed by sea-level lowering into a mesotrophic lake phase, with only slightly lowered lake level and with one short marine phase during the Saalian glacial period (180,000 to 120,000 years B.P.).

During the following Eemian, mesohaline conditions prevailed. Considering worldwide eustatic sea-level changes (Figure 38), after Matthews (1973) and Shackleton and Opdyke (1973), the highest sea-level stands over the last 200,000 years are defined to have occurred around 120,000 to 130,000 years ago (about 30 m above today's NN). Around 110,000 years ago, sea level dropped about 10 meters. This lowering still would have allowed marine influx, assuming unique topographic situations compared with today's.

A lowering of sea level to about 30 to 80 meters below today's NN occurred around 80,000 years ago, and this may have been responsible for establishment of a meso- to eutrophic freshwater lake with considerably reduced volume during the Weichselian
which corresponds to the Euxin-Series (compare Table 9).

On a worldwide basis, several other sea-level fluctuations occurred, one around 75,000 years ago and another around 20,000 years ago. Similar lake-or sea-level changes were not evident in the Black Sea sediments, owing to lack of a continuous sedimentary record. About 8000 years ago lake level rose and again marine Mediterranean Sea water could enter the Black Sea.

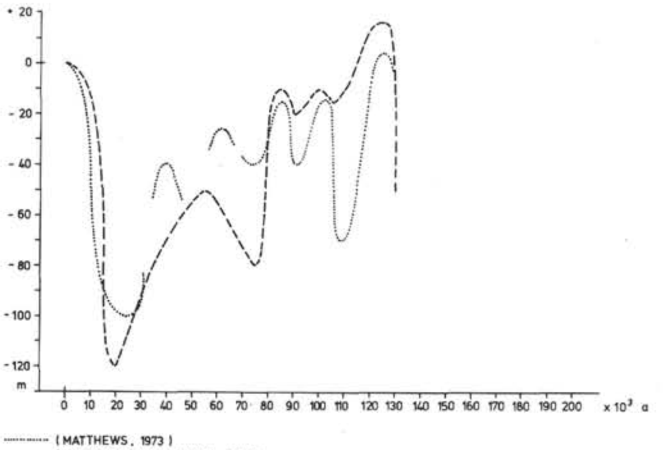


Figure 38. *Past sea-level estimates from Barbados (Matthews, 1973), and glacio-eustatic sea-level curve for the past 130,000 years, derived from oxygen isotopic measurements (Shackleton and Opdyke, 1973) (redrawn with minor changes).*

Figure 39 depicts the changes in lake and sea level, discussed above, over the past 4 million years. Tectonic movements and the relative position of the sea floor compared with NN are not taken into consideration in this figure. Water surface stands near or slightly or considerably below NN are interpreted as oligo-, meso- to eutrophic freshwater lake conditions; surface stands near and above NN are considered as marine phases. The strong fluctuations during late Pleistocene are only briefly documented and are due for a revision after an examination of sediments sampled at intervals.

The discrepancy in correlation of drill holes (compare Stoffers et al., this volume, fig. 2), specifically over the interval documented by correlation lines (Figure 11) 12 and 10 at Site 381, where Stoffers et al. postulate an unconformity, and in correlation of the opal-free interval at Hole 379A (below diatom horizon 8) with the interval between 200 and 300 meters sub-bottom at Hole 380, cannot be resolved. I am of the opinion that no unconformity is present, that Site 380 documents a continuous sedimentary record, and that the opal-free interval of Hole 379A correlates with the opal-free interval of Hole 380A, Cores 4 through 32 and Hole 381, Cores 4 through 19. The difference in sediment structure may be explained by differences in water depth and changes in water levels.

Deuser et al. (this volume) interpret the interval at Site 379A below 450 meters sub-bottom by the $\delta^{18}O$ technique to represent a saline phase, which was also located by Benson (this volume) by ostracode faunal assemblages. This saline phase cannot be interpreted by opal floral analysis, but may be responsible for the increased pore-water salinities (cf. Figure 31).

The interval around 650 meters and higher in Hole 380A is compared by Deuser et al. (this volume) with the sedimentation in the Lake Bonneville Stage, which is a continental-saline facies, and which can change into a classical Scandinavian varve facies. This sedimentation interval cannot be traced by opal floral analysis. The sporadic occurrence of freshwater diatom floral elements in Hole 380A, Core 17 and in Hole 381, Cores 15 and 19, which are interpreted as

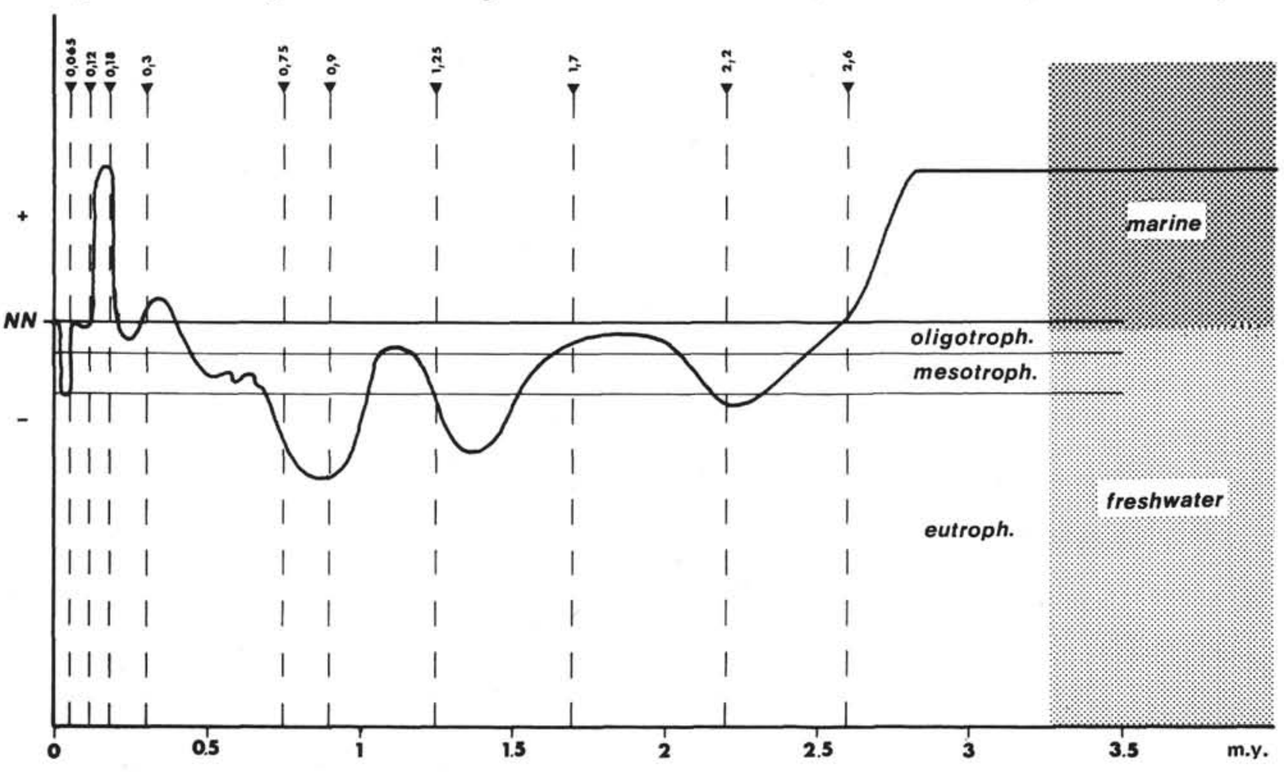


Figure 39. *Past sea- and lake-level changes in the Black Sea for the last 4 million years, as deduced from diatom floral composition. NN = today's situation, drop of ± 10 meters would still give a situation similar to today's. Vertical scale qualitative.*

autochthonous, does *not* indicate a saline phase over the interval 470 meters of Hole 380A and over the interval around 130 to 170 meters of Hole 381.

TAXONOMIC PART AND FLORAL REFERENCES

References are given for all counted and mentioned taxonomic entries from DSDP Leg 42B, Sites 379 through 381. Genera and species within the genera are listed alphabetically. Many taxa are treated here under species indeterminandum and/or treated with an open numerical system, others are only illustrated (e.g., *Thalassiosira* and *Stephanodiscus*), and references to their occurrence in DSDP Leg 42B material can be obtained from the explanations to the plates. I attempted to illustrate as many species as possible in the short time available, so that future investigators can choose the sections which demonstrate the greatest variety within a species. The species concept used here is rather broad since most freshwater planktonic species are described from Recent phytoplankton collections and do not include heavily silicified, larger, and coarser structured individuals which represent the fossil residues in the sediments in the morphological descriptions. Because of this, almost no new species were described within the genera *Melosira* and *Stephanodiscus*.

The main goal of this paper is not to discuss taxonomy, but to determine ecological variations through time. Also, minor morphological variations provide insufficient evidence for interpreting ecological variations, since there is no method for obtaining information about the autecology of that specific fossil species. Taxonomically oriented research will lead to a better understanding of freshwater species of the genera *Stephanodiscus* and *Melosira* (see paper by Jousé and Mukhina, this volume). Ecology of the species is mentioned where possible.

Achnanthes brevipes Agardh
(Plate 15, Figure 9)

Description: Pankow (1976), p. 154, fig. 316.
Ecology: Benthic, mesohalobous (Pankow, 1976).

Achnanthes spp.
(Plate 14, Figure 12)

Several fragments and isolated epi- and hypovalves were found which limited the exact taxonomic classification. Among others, the following species are tentatively identified: *Achnanthes hauckiana, A. septata, A. longipes*.

Actinocyclus ehrenbergii Ralfs
(Plate 2, Figures 9, 14; Plate 4, Figures 1-5; Plate 5, Figure 6; Plate 7, Figure 5)

Description: Hustedt (1930), p. 525-533, figs. 298-302.
Ecology: Planktonic (?), common in all European marine environments, polyhalobous (meso- to meioeuryhaline, Pankow, 1976).

Actinocyclus normannii (Gregory) Hustedt
(Plate 13, Figure 3)

Description: Hustedt (1957), p. 218, fig. 5-6.
Ecology: Planktonic, β-mesohalobous, pH neutral with minor fluctuations around pH 7, meso-oxybiont.

Actinoptychus annulatus (Wallich) Grunow
(Text Figure 40)

Description: Van Heurck (1883), pl. 124, fig. 14; Van Heurck (1896), p. 496, fig. 236.
Remarks: This species occurs very rarely in Black Sea Sample 381-34-6, 50 cm. It has been described from a marine(?)-brackish environment from Java and the China Sea.

Actinoptychus undulatus (Baily) Ralfs

Description: Hustedt (1930), p. 475, fig. 264.
Ecology: Polyhalobous (meioeuryhaline Pankow, 1976), cosmopolitan in all marine coastal areas.

Amphiprora aff. palludosa W. Smith

Description: Hustedt (1930) Pascher, p. 339, fig. 624. The specimen observed at Hole 380A was fragmented, so it was not possible to identify the species precisely.

Figure 40. Actinoptychus annulatus *from Sample 381-34-6, 50 cm, bar equals 20 µm.*

Ecology: Benthic, mesohalobous euryhaline (Pankow, 1976, for *Amphiprora palludosa*), *p*H neutral, oligosaprobic (Hustedt, 1957, for *A. palludosa*).

Amphora proteus Gregory

Description: Hendey (1964), p. 262; Schmidt, Atlas (1886), pl. 27, fig. 3.
Ecology: Benthic, polyhalobous, pleioeuryhaline (Pankow, 1976, for *A. proteus* var. *proteus*).

Biddulphia pulchella Gray

Description: Hustedt (1930), p. 832-834, fig. 490.
Ecology: Benthic, polyhalobous oligo-meioeuryhaline (Pankow, 1976), cosmopolitan.

Biddulphia tuomeyi (Baily) Roper

Description: Hustedt (1930), p. 834-836, fig. 491.
Ecology: Benthic, polyhaline.

Caloneis bacillum (Grunow) Mereschak
(Plate 15, Figure 5)

Description: Pankow (1976), p. 203, fig. 427.
Ecology: Oligohalobous (indifferent) mesoeuryhaline (Pankow, 1976).

Campylodiscus spp.

Several fragments of *Campylodiscus* were observed; they are tentatively classified as *Campylodiscus clypeus, C. echeneis*, and *C. eximius* (fide Peragallo, 1897-1908) and *C. daemilianus*.

Ecology: All above-mentioned species are marine-benthic: *C. clypeus*-β mesohalobous, *C. echeneis*-α mesohalobous (Pankow, 1976).

Ceratoneis arcus (Ehrenberg) Kützing

Description: Hustedt (1959), p. 179-180, fig. 684.
Ecology: Oligohalobous, alkaliphilous (Hustedt, 1957).

Chaetoceros spp. (bristles)

Chaetoceros setae are common in well-preserved diatom assemblages. Mostly the setae are broken into pieces by either zooplanktonic feeding and/or bioturbation. Since a correct taxonomic treatment of *Chaetoceros* by setae fragments only is almost impossible, no further treatment was made.

Chaetoceros spp. (spores)
(Plate 18, Figures 1-15, 18)

The presence of a variety of different spores is indicative of saline water conditions. The taxonomy of *Chaetoceros* spores is not complete. Among others the following species were found: *Chaetoceros simplex, C. socialis*(?), *C. similis, C. paulsenii, C. holsaticus, C. seiracanthus, C. compressus, C. lauderi*. All identifications are based on illustrations in Hustedt (1930) and Proschkina-Lavrenko (1955).

Chrysophyta cysts

(no diatoms)

(Plate 18, Figures 19-22, 25-28)

Remarks: Chrysophyceae cysts occur in almost all diatomaceous samples and are sometimes very abundant. They are tentatively classified in this report into group A, with a smooth exterior, and group B with a rough exterior or with scattered spines. There seems to be a tendency that group A dominates in freshwater assemblages and group B in brackish to marine assemblages, as deduced by the diatom composition. These cysts are more resistant to dissolution than most diatom frustules. This, in addition to occasional blooms, explains the abundance of these cysts. Hajos (1968) stated that these cysts (assigned to the order Archaeomonadaceae Deflandre) are found in Cretaceous to Recent marine sediments only. This is not correct, since they are common today in sediments derived from fresh, brackish, and marine waters (for biological discussion see Fritsch, 1971).

Cocconeis spp.

Within the lower section at Hole 380A, a variety of *Cocconeis* epi- and hypovalves were observed . An exact classification of either raphe-bearing or non-raphe bearing valves is rather complicated so no further detailed taxonomic study was made.

Cocconeis disculoides Hustedt

(Plate 13, Figure 10[?])

Description: Hustedt (1955), p. 17, pl. 5, fig. 8-11; pl. 7, fig. 8.
Ecology: Benthic(?), polyhalobous.

Cocconeis distans Gregory

Description: Hustedt (1959), p. 343-344, fig. 797.

Ecology: Benthic, common along European coastlines, polyhalobous meioeuryhaline (Pankow, 1976).

Cocconeis pediculus Ehrenberg

Description: Hustedt (1959), p. 350-351, fig. 804.

Ecology: Benthic, common in slightly brackish waters, oligohalobous mesoeuryhaline (Pankow, 1976).

Cocconeis placentula Ehrenberg

(Plate 15, Figure 3)

Description: Pankow (1976), p. 151-152, fig. 313.
Ecology: Oligohalobous holo-pleioeuryhaline (Pankow, 1976).

Cocconeis quarnerensis Grunow

Description: Hustedt (1959), p. 360-361, fig. 814.
Ecology: Benthic, polyhalobous meioeuryhaline (Pankow, 1976).

Cocconeis scutellum Ehrenberg

Description: Hustedt (1959), p. 337-339, fig. 790.

Ecology: Benthic, polyhalobous meio-meso-euryhaline (Pankow, 1976).

Coscinodiscus divisus Grunow

(Plate 6, Figure 1)

Description: Hustedt (1930), p. 410-411, fig. 218.
Ecology: Planktonic, polyhalobous.

Coscinodiscus obscurus A. Schmidt

(Plate 6, Figure 2)

Description: Hustedt (1930), p. 418-420, fig. 224.
Ecology: Planktonic, polyhalobous.

Coscinodiscus stokesianus (Greville) Grunow(?)

(Plate 5, Figures 5, 11; Plate 10, Figure 1)

Description: Rehakova (1965), p. 30, pl. 9, fig. 3-7.

Ecology: One of the most common species in brackish water fossil diatom assemblages from south Bohemia.

Remarks: Since the exact taxonomic position of *C. stokesianus* and *C. stokesianus* varieties is not known and the present specimens did clearly possess a pseudonodulus (Text-Figure 41), it will be necessary to examine Pantocsek's type material, which is not available now. The present individuals were classified as *C. stokesianus* using Pantocsek's (1886) and Rehakova's (1965) illustrations and descriptions.

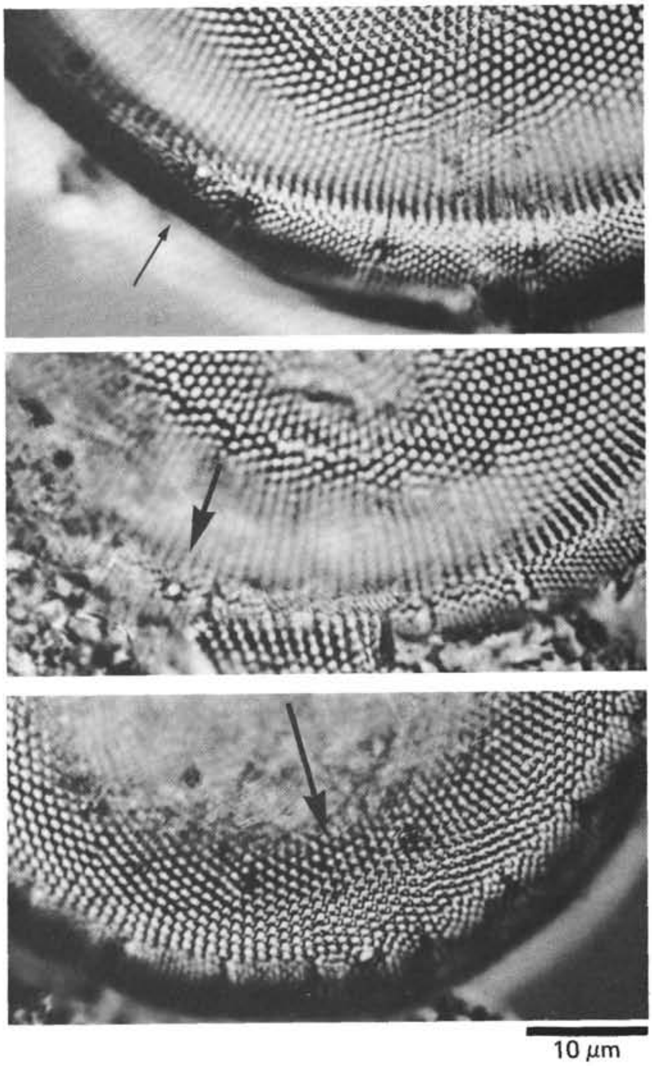


Figure 41. Coscinodiscus *(?)* stokesianus. *Arrows point to pseudonodulus. Differential interference phase contrast. Sample 380A-51-6, 68-70 cm.*

Coscinodiscus sp. 1

Remarks: At distinct horizons a great variety of broken and fragmented *Coscinodiscus* species was observed. Despite intensive search no complete frustules were found. Tentatively it may be said that a few of these fragments are closely related to *C. radiatus, C. granii, C. jonesianus*, and *C. perforatus*. All these species are polyhalobous.

Cyclotella caspia Grunow

(Plate 4, Figures 20, 21; Plate 5, Figures 8, 9;
Plate 12, Figures 2, 3, 6)

Description: Hustedt (1930), p. 347, fig. 177.
Ecology: Planktonic, brackish waters.

Cyclotella comta (Ehrenberg) Kützing

(Plate 4, Figure 10; Plate 14, Figure 5)

Description: Hustedt (1930), p. 354-356, fig. 183.

Ecology: Planktonic, common in European lakes and rivers, oligohalobous meioeuryhaline (Pankow, 1976), common in oligotrophic to mesotrophic lakes (Stoermer and Yang, 1970).

Cyclotella kützingiana Twaites
(Plate 12, Figures 1, 4, 5, 7-11)

Description: Hustedt (1930), p. 338, fig. 171.
Ecology: Planktonic(?), oligohalobous meioeuryhaline (Pankow, 1976), cosmopolitan.

Cyclotella meneghiniana var. pluripunctata Ehrlich
(Plate 11, Figure 8)

Description: Ehrlich (1966), p. 316, pl. 5, fig. 9, 10.

Cyclotella ocellata Pantocsek
(Plate 14, Figure 7)

Description: Hustedt (1930), p. 340-341, fig. 173.
Ecology: Freshwater benthic and planktonic, oligo- to mesotrophic (in the Great Lakes it appears to occupy the extreme oligotrophic end of the spectrum, Stoermer and Yang, 1970).

Cyclotella operculata (Agardh) Kützing
(Plate 5, Figures 3, 4, 10)

Description: Hustedt (1930), p. 351-353, fig. 181.
Ecology: Freshwater, littoral in ponds, sometimes pelagic in greater lakes, abundant in large oligotrophic inland lakes in northern Michigan (Stoermer and Yang, 1970).

Cyclotella pygmaea Pantocsek
(Plate 6, Figures 3, 7; Plate 14, Figure 6)

Description: Pantocsek (1892), p. 37-38, pl. 2, fig. 22; pl. 4, fig. 59; Schmidt, Atlas (1900), pl. 224, fig. 49-56.
Ecology: Found only in fossil-freshwater material from Bodos, Köpecz, and Bibarezfalva.

Cyclotella striata (Kützing) Grunow

Description: Hustedt (1930), p. 344-347, fig. 176.
Ecology: Benthic(?), inhabits brackish waters, β-mesohalobous, *p*H indifferent, mesooxybiontic (Hustedt, 1957).

Cymatopleura elliptica (Brebisson) W. Smith

Description: Hustedt (1930, Pascher), p. 426-428, fig. 825.
Ecology: Benthic(?), oligohalobous, alkaliphilous, oligosaprobic to saproxen (Hustedt, 1957).

Cymatopleura solea (Brebisson) W. Smith
(Plate 13, Figure 14; Plate 14, Figures 2, 3)

Description: Hustedt (1930, Pascher), p. 425-426, fig. 823.
Ecology: Benthic(?), oligohalobous, alkaliphilous, oligosaprobic (Hustedt, 1957).

Diatoma elongatum (Lyngb.) Agardh
(Plate 11, Figure 30)

Description: Hustedt (1959), p. 99-102, fig. 629.
Ecology: Common, sometimes mass occurrence, planktonic, freshwater, maximum reproduction in brackish waters.

Dictyocha crux Ehrenberg
(Silicoflagellatae)

Description: Loeblich and Tappan (1968), p. 85, fig. 29-32.
Ecology: Planktonic, polyhaline.

Dictyocha fibula Ehrenberg
(Silicoflagellatae)
(Plate 18, Figure 29)

Description: Loeblich and Tappan (1968), p. 90, various figures.
Ecology: Planktonic, polyhalobous mesoeuryhaline (Pankow, 1976).

Diploneis budayana (Pantocsek) Hustedt
(Plate 14, Figure 15)

Description: Hustedt (1959), p. 699, fig. 1081.
Ecology: Benthic, polyhalobous(?).

Diploneis ovalis var. oblongella (Naeg.) Cleve
(Plate 14, Figure 15)

Description: Hustedt (1959), p. 672, fig. 1065.
Ecology: Oligohalobous, mesoeuryhaline (Pankow, 1976).

Diploneis smithii (Brebisson) Cleve
(Plate 15, Figure 2)

Description: Pankow (1976), p. 192; Hustedt (1959), fig. 1051.
Ecology: Benthic, polyhalobous pleioeuryhaline (Pankow, 1976).

Diploneis subovalis Cleve
(Plate 13, Figure 12; Plate 14, Figure 8)

Description: Hustedt (1959), p. 667-668, fig. 1063.
Ecology: Common in tropical freshwaters, benthic, oligohaline.

Distephanus speculum (Ehrenberg) Haeckel
(Silicoflagellatae)

Description: Loeblich and Tappan (1968), p. 122.
Ecology: Planktonic, polyhalobous mesoeuryhaline (Pankow, 1976).

Epithemia turgida (Ehrenberg) Kützing
(Plate 15, Figure 18)

Description: Hustedt (1930, Pascher), p. 387, fig. 733.
Ecology: Common, benthic in both freshwater and brackish environment, oligohalobous indifferent pleioeuryhaline (Pankow, 1976), alkalibiontic, saproxen (Hustedt, 1957).

Epithemia zebra (Ehrenberg) Kützing
(Plate 14, Figures 13, 14)

Description: Hustedt (1930, Pascher), p. 384-385, fig. 729.
Ecology: Benthic, oligohalobous (indifferent) mesoeuryhaline (Pankow, 1976), alkalibiontic, saproxen (Hustedt, 1957).

Grammatophora arcuata Ehrenberg

Description: Hustedt (1959), p. 42, fig. 567.
Ecology: Benthic, polyhalobous meioeuryhaline (Pankow, 1976).

Grammatophora oceanica (Ehrenberg) Grunow
(Plate 14, Figure 9)

Description: Hustedt (1959), p. 45-48, fig. 573.
Ecology: Benthic, polyhalobous mesoeuryhaline (Pankow, 1976).

Grammatophora oceanica var. macilenta (W. Smith) Grunow
(Plate 15, Figure 10)

Description: Hustedt (1959), p. 47, fig. 574.
Ecology: Benthic, polyhalobous mesoeuryhaline (Pankow, 1976).

Gyrosigma acuminatum (Kützing) Rabenh.

Description: Hustedt (1930 Pascher); p. 222-224, fig. 329.
Ecology: Benthic(?), oligohalobous (indifferent) mesoeuryhaline (Pankow, 1976), alkalibiont, oligosaprob (indifferent) (Hustedt, 1957).

Gyrosigma kützingii (Grunow) Cleve
(Plate 13, Figure 13; Plate 15, Figure 6[?]; Plate 16, Figures 8, 9)

Description: Hustedt (1930, Pascher), p. 224, fig. 333.
Ecology: Planktonic(?), occasionally in freshwater, oligohalobous.

Gyrosigma sp. 1
(Plate 14, Figure 1)

Discussion: This species differs from all published *Gyrosigma* species by the strongly constricted central parts, and will be taxonomically defined at a later date.

Hermesinum adriaticum Zacharias
(Plate 18, Figures 30-33)

Description: Loeblich and Tappan (1968), p. 168-170, fig. 20.
Ecology: Planktonic, polyhalob—commonly found in plankton samples from the Adriatic Sea.

Mastogloia braunii Grunow

Description: Hustedt (1959), p. 551-552, fig. 982.
Ecology: Benthic(?), common in brackish waters, β-mesohalobous, cosmopolitan (Pankow, 1976).

Mastogloia elliptica (Agardh) Cleve
(Plate 15, Figure 14)

Description: Pankow (1976), p. 173, fig. 363.
Ecology: Benthic, α-mesohalobous (Pankow, 1976).

Melosira ambigua (Grunow) Müller
(Plate 3, Figure 10[?]; Plate 9, Figures 9, 10, 29-32)

Description: Hustedt (1930), p. 256-257, fig. 108.
Ecology: Planktonic, common in eutrophic lakes and rivers throughout Europe, alkaliphilous, oligosaprobic (mesooxybiont) (Hustedt, 1957), oligohalobous meioeuryhaline (Pankow, 1976).

Melosira arenaria Moore
(Plate 7, Figure 1)

Description: Hustedt (1930), p. 269-270, fig. 114.
Ecology: Benthic, common in littoral freshwater lake environment, extreme saproxen, alkaliphilous, oligohalobous, common at O_2-rich biotopes (Hustedt, 1957).

Melosira distans (Ehrenberg) Kützing
(Plate 4, Figure 8; Plate 9, Figures 3, 4; Plate 10, Figure 4; Plate 11, Figures 21, 22, 26, 28, 29)

Description: Hustedt (1930), p. 262-266, fig. 110-111.
Ecology: Benthic, common in ditches and ponds in Northern Europe, stenotherm cold water species (Hustedt, 1926, 1957).
Remarks: For taxonomic discussion see Hustedt (1926).

Melosira granulata (Ehrenberg) Ralfs
(Plate 2, Figure 8)

Description: Hustedt (1930), p. 248-252, fig. 104.
Ecology: Planktonic, common in freshwater lakes and streams, oligohalobous meioeuryhaline, cosmopolitan (Pankow, 1976), dominant in eutrophic, alkaline lakes in northern Europe and north America (Stoermer and Yang, 1970; Hustedt, 1957).

Melosira granulata var. angustissima f. curvata Grunow
(Plate 3, Figures 8, 9)

Description: Hustedt (1930), p. 250, figure in Van Heurck (1880-1885), pl. 87, fig. 18.
Ecology: Planktonic, same ecology as species.

Melosira islandica O. Müller
(Plate 4, Figures 17, 18; Plate 9, Figures 17, 24; Plate 10, Figures 2, 3, 9, 11-18; Plate 11, Figures 23-25, 27; Plate 18, Figures 23, 24)

Description: Hustedt (1930), p. 252-256, figs. 106-107.
Ecology: Planktonic, common in freshwater lakes throughout Europe. *M. granulata* flourishes in stronger eutrophic waters with higher temperatures, whereas *M. islandica* flourishes also in less eutrophic lakes and at lower temperatures. This species is often dominant in large temperate lakes, although it is apparently not tolerant of high degrees of eutrophication. It reaches its maximum abundance at water temperatures of less than 12°C (Stoermer et al., 1974).
Remarks: For taxonomic discussion compare Hustedt (1926) and Miller (1964).

Melosira islandica subspecies helvetica O. Müller

Description: Hustedt (1930), p. 254, fig. 107.
Remarks: This subspecies was observed in small percentages at Hole 381 and at Hole 380A in samples where *M. islandica* dominated and are not separately listed on the tables.

Melosira roeseana Rabenhorst
(Plate 12, Figure 13)

Description: Hustedt (1930), p. 266-268, fig. 112.
Ecology: Benthic, common throughout Europe, oligohalobous, alkaliphilous, saproxen (Hustedt, 1957).

Melosira sulcata (Ehrenberg) Kützing

Description: Hustedt (1930), p. 276-278, figs. 118-119.
Ecology: Benthic, sometimes planktonic, common in marine coastal areas, cosmopolitan, polyhalobous mesoeuryhaline (Pankow, 1976).

Melosira undulata (Ehrenberg) Kützing

Description: Huber-Pestalozzi (1942), p. 378-379, fig. 449.
Ecology: Living in freshwater lakes, common in northern Europe (?) (Hustedt, 1926), Cleve-Euler (1951 ff) noted its occurrence: "oligo-bis dystrophe Seen". This species is reported by Hustedt in Huber-Pestalozzi (1942) and occurs at present only in the tropics; fossil occurrences are common in freshwater Tertiary sediments throughout Europe.

Meridion circulare (Greville) Agardh

Description: Hustedt (1959), p. 93-94, fig. 627.
Ecology: Planktonic, common in freshwater environment, oligohalobous, saproxen, alkaliphilous, rheophilous (Hustedt, 1957).

Navicula hasta Pantocsek
(Plate 15, Figure 17)

Description: Hustedt (1930 Pascher), p. 306, fig. 541.
Ecology: Oligohalobous, benthic.

Navicula lyra Ehrenberg

Description: Hustedt (1964), p. 500-514, fig. 1548.
Ecology: Benthic, polyhaline.

Navicula palpebralis Brebisson
(Plate 15, Figure 4)

Description: Pankow (1976), p. 223-224, fig. 466.
Ecology: Polyhalobous meioeuryhaline (Pankow, 1976).

Navicula scutelloides W. Smith
(Plate 13, Figure 9)

Description: Hustedt (1930 Pascher), p. 311, fig. 557.
Ecology: Oligohalobous (indifferent), alkalibiontic, saproxen (Hustedt, 1957).

Navicula species indet.
(Plate 13, Figure 7)

Nitzschia punctata (W. Smith) Grunow

Description: Hustedt (1930 Pascher), p. 401, fig. 762.
Ecology: Benthic, polyhalobous, mesoeuryhaline (Pankow, 1976).

Pleurosigma angulatum (Queckett) W. Smith

Description: Hendey (1964), p. 245-246, pl. 35, fig. 1-3; pl. 41, fig. 6.
Ecology: A brackish water form, often found on muddy foreshores, polyhalobous mesoeuryhaline (Pankow, 1976).

Opephora martyi Heribaud
(Plate 14, Figures 10, 11)

Description: Hustedt (1959), p. 135, fig. 654.
Ecology: Planktonic(?), oligohalobous pleioeuryhaline (Pankow, 1976), alkaliphilous, saproxen (Hustedt, 1957).

Rhabdonema adriaticum Kützing
(Plate 15, Figure 1)

Description: Hustedt (1959), p. 23-25, fig. 552.
Ecology: Benthic, polyhalobous, meioeuryhaline, epiphytic (Pankow, 1976).

Rhizosolenia alata Brightwell

Description: Hustedt (1930), p. 600-604, fig. 344.
Ecology: Planktonic, polyhalobous meio-mesoeuryhaline (Pankow, 1976).

Rhizosolenia bergonii H. Peragallo

Description: Hustedt (1930), p. 575-577.
Ecology: Planktonic, polyhaline.

Rhizosolenia calcar avis M. Schultze

(Plate 18, Figure 16)

Description: Hustedt (1930), p. 592-594.
Ecology: Planktonic, polyhaline.

Rhizosolenia styliformis Brightwell

Description: Hustedt (1930), p. 584-588, fig. 333.
Ecology: Planktonic, polyhalobous meioeuryhaline (Pankow, 1976).

Rhoicosphenia curvata (Kützing) Grunow

(Plate 15, Figures 12, 13)

Description: Hustedt (1959), p. 430-432, fig. 879.
Ecology: Benthic, oligohalobous holo-pleioeuryhaline (Pankow, 1976), alkaliphilous, oligosaprobic, rheophilous (Hustedt, 1957).

Rhopalodia gibberula (Ehrenberg) O. Müller

(Plate 15, Figure 11)

Description: Hustedt (1930, Pascher), p. 391, fig. 742.
Ecology: Benthic, oligohalobous (indifferent) pleioeuryhaline (Pankow, 1976), *p*H indifferent polyoxybiontic (Hustedt, 1957).

Skeletonema costatum (Greville) Cleve

(Plate 18, Figure 17)

Description: Hustedt (1930), p. 311-313, fig. 149.
Ecology: Planktonic, polyhalobous, pleioeuryhaline, cosmopolitan (Pankow, 1976).

Stephanodiscus astraea (Ehrenberg) Grunow

(Plate 2, Figures 7, 11; Plate 3, Figures 11, 12; Plate 4, Figures 15, 22, 23; Plate 8, Figure 13; Plate 12, Figure 15; Plate 13, Figures 2, 8; Plate 16, Figures 5-6)

Description: Hustedt (1930), p. 368-370, fig. 193.
Ecology: Planktonic, common in eutrophic waters (lakes), mass occurrence in north German lakes during winter and spring season. Hustedt points out that it cannot be grouped as a stenothermic species. Oligohalobous meioeuryhaline (Pankow, 1976), alkalibiontic (Hustedt, 1957).

Stephanodiscus astraea var. intermedia Fricke

(Plate 8, Figure 12)

Description: Hustedt (1930), p. 370, figure in Fricke, A. Schmidt Atlas, pl. 225, fig. 37-39.
Ecology: Planktonic, same ecology as species.

Stephanodiscus astraea var. minutula (Kützing) Grunow

(Plate 2, Figures 1-3, 5; Plate 3, Figures 6, 7; Plate 7, Figure 3; Plate 9, Figure 16)

Description: Hustedt (1930), p. 369-370, fig. 193d, e.
Ecology: Planktonic, same ecology as species.

Stephanodiscus binderianus (Kützing) Krieger

(Plate 4, Figures 16, 19; Plate 5, Figures 12, 13[c]; Plate 9, Figures 25, 26; Plate 11, Figures 1-7, 10, 11, 13[?]; Plate 12, Figures 19-22.)

Description: Hustedt (1930) as *Melosira binderiana* Kützing, p. 246-248, fig. 103, Round (1972).
Ecology: Planktonic, common in eutrophic freshwater lakes and streams, sometimes frequent in stagnant brackish waters. The presence of significant quantities of this species is considered to be indicative of poor water quality. Its optimum temperature for growth is around 9°C, and most world distribution records indicate that it occurs in maximum abundance in the spring and fall (Stoermer et al., 1974).
Remarks: In the present material several different types of *binderianus* were distinguished: (a) types with hyaline costae on the valve mantle; (b) types without hyaline costae but small cells; (c) types without hyaline costae but larger cells, more silicified

Stephanodiscus carconensis Grunow

(Plate 4, Figure 24[a]; Plate 6, Figures 4[?], 8-10; Plate 7, Figures 6, 9[?]; Plate 9, Figures 5, 8, 11-15, 18-23, 27; Plate 10, Figures 5-8, 10; Plate 11, Figures 9, 14, 15, 20; Plate 12, Figure 14; Plate 16, Figure 4)

Description: Van Landingham (1967), p. 17-18, pl. 21, fig. 18; Gasse (1975), p. 20 (v. II), pl. 29, fig. 1-6.
Ecology: Planktonic, *p*H neutral, freshwater, oligotrophic, moderate temperatures (Gasse, 1975).
Remarks: In the present materials several different types were distinguished: (a) normal centrical valves; (b) normal centrical valves, but larger in diameter and more heavily silicified; (c) abnormal triangulate valves.

Stephanodiscus-Cyclotella

(Plate 1, Figure 1; Plate 9, Figures 1, 2, 33 [triangulate]; Plate 16, Figures 2, 3)

Remarks: No similar species was found in the literature. Valves 40-100 μm in diameter, with a flat marginal area and a slightly convex middle area. Areolae in radial rows, sometimes in fascicles, decreasing in size gradually towards the margin. Marginal area has great *Cyclotella*-like chambers, almost totally opened towards the inside and occluded toward the outside with a clear pore membrane. At the central side, between chambers, are hyline costae with spines (like *Stephanodiscus*).

Stephanodiscus dubius (Fricke) Hustedt

(Plate 1, Figures 8, 9; Plate 2, Figure 18; Plate 3, Figure 2; Plate 3, Figure 4[?]; Plate 4, Figure 11; Plate 12, Figures 16, 23; Plate 14, Figure 4)

Description: Hustedt (1930), p. 367-368, fig. 192.
Ecology: Planktonic, common in flowing and stagnant waters, probably halophile, oligohalobous meio-mesoeuryhaline (Pankow, 1976), oligosaprobic, alkalibiontic (Hustedt, 1957).

Stephanodiscus hantzschii Grunow

(Plate 2, Figure 6; Plate 4, Figure 9)

Description: Hustedt (1930), p. 370-372, fig. 294; Round (1971).
Ecology: Planktonic, common in fresh and slightly brackish waters, mass abundance in strongly eutrophic waters (Lange-Bertalot, 1974). Spring and early summer dwelling in northern Germany (Hustedt, 1959b), cosmopolitan (Hustedt, 1942); oligohalobous meioeuryhaline (Pankow, 1976).
Remarks: At specific horizons a more robust form was observed which is tentatively included in this species (compare Plate 4, Figure 9) and its relative abundance is marked on the Tables under *hantzschii* **(B)**.

Stephanodiscus niagarae Ehrenberg

(Plate 5, Figure 1; Plate 6, Figure 5; Plate 7, Figure 10; Plate 8, Figure 1; Plate 16, Figure 1; Plate 17, Figures 1, 2)

Description: Gasse (1975), p. 20-21 (vol. II), pl. 30, figs. 4-5.
Ecology: Planktonic, neutral *p*H, freshwater, oligotrophic, moderate temperatures.

Stephanodiscus omarensis Kuptzova

(Plate 3, Figure 3; Plate 12, Figure 12)

Description: Kuptzova (1962), p. 37-39, fig. 1-11.
Ecology: Found only in fossil freshwater sediments.

Stephanodiscus pantocseki Fricke

(Plate 4, Figure 12)

Illustration: Fricke (1902) in A.Schmidt, Atlas, pl. 229, fig. 12-14.
Ecology: No recent report found in the literature. Individuals are reported from Siebenbürgen (freshwater fossil).

Stephanodiscus robustus Proschkina-Lavrenko

(Plate 2, Figure 15 [?]; Plate 3, Figure 1; Plate 6, Figure 4; Plate 13, Figures 1, 4)

Description: Proschkina-Lavrenko (1962), p. 19-21, figs. 1-9.
Ecology: This species is found in Quaternary Black Sea sediments, and since it is associated at all timeswith *Stephanodiscus astraea*, it may have a similar ecological habitat.

Stephanodiscus transylvanicus (Pantocsek) Serv.-Vild.

(Plate 1, Figure 7; Plate 2, Figure 4; Plate 5, Figures 2, 7; Plate 6, Figure 6; Plate 7, Figure 8; Plate 8, Figures 2,5-7; Plate 16, Figure 7; Plate 17, Figures 3,4)

Synonym: *Stephanodiscus astraea* var. *transylvanica* Pantocsek.
Description: Gasse (1975), p. 20 (vol. II), pl. 29, figs. 1-6.
Ecology: Planktonic, freshwater.

Stephanodiscus sp. indet c

(Plate 1, Figures 2-4, 6; Plate 7, Figure 7; Plate 6, Figure 11)

Remarks: No similar species was observed in the literature. Cells semispherical, one valve with an almost flat valve surface, the other one convex. A typical *Stephanodiscus* structure is the flat valve with spines at the end of the hyaline rays separating the fascicles. Areolation radial to irregularly oriented, areolae decreasing in size from the center to the margin. The convex valve (Plate 1, Figures 2-4, 6) has a radial areolation, areolae decreasing in size toward the margin. Parallel to the margin there is one ring of loosely scattered spines. Additionally, one ring of strutted tubuli were observed, similar to those found in *Stephanodiscus binderianus* (Round, 1972). Since these individuals occur only associated with mass occurrences of *S. binderianus* (a), both may belong to one species and the present one may be resting spores of *S. binderianus*.

Stephanodiscus species indet.

(Plate 2, Figure 12; Plate 3, Figure 5; Plate 4, Figure 13; Plate 8, Figure 4; Plate 8, Figure 11; Plate 9, Figure 7; Plate 9, Figure 28[?]; Plate 12, Figure 17)

Several abnormal and/or badly preserved individuals were found and are illustrated. No taxonomic treatment was attempted in this paper.

Surirella turgida W. Smith

(Plate 13, Figure 6)

Description: Hustedt (1930,Pascher), p. 433, fig. 836.

Synedra indica Taylor

(Plate 15, Figures 7, 8; Text-Figure 32)

Description: Taylor (1966),p. 440, pl. 3, fig. 22-24; Simonsen (1974), p. 36, pl. 23, fig. 9-18.

Ecology: Planktonic, polyhalobous (Indian Ocean).

Remarks: The observed individuals at Holes 380A and 381 had 15 to 16 striae in 10 μm, parallel, which consisted of 3 to 5 (max.) pores oriented in longitudinal lines. Apical fields heteropolar, one with a continuation of the striae, in radiate orientation and the other field being hyaline. Comparison with Recent individuals from the Indian Ocean (courtesy of Dr. R. Simonsen, Bremerhaven) revealed the almost identical morphological features. The great variety in valve shape was also observed in both the Recent and fossil material.

Rhaponeis maeotica (Milov.) Sheshukova and Gleser in Proschkina-Lavrenko et al. (1974) seems to be almost identical with *S. indica,* especially those individuals illustrated in pl. XLIV, fig. 3a, b but definitely not those individuals illustrated on pl. XL, fig. 14 and pl. XLVI, fig. 7.

Synedra undulata Bail.

(Plate 15, Figure 16)

Description: Pankow (1976), p. 134, fig. 256, 257.

Ecology: Benthic, polyhalobous meioeuryhaline (Pankow, 1976).

Thalassionema nitzschioides Grunow

Description: Hustedt (1959), p. 244-246, fig. 725.

Ecology: Planktonic, polyhalobous, meio-mesohaline (Pankow, 1976).

Thalassiothrix frauenfeldii Grunow

Description: Hustedt (1959), p. 247-248, fig. 727.

Ecology: Planktonic, common in temperate oceans.

Thalassiosira antiqua var. septata Proschkina-Lavrenko

(Plate 2, Figure 10)

Description: Prosckina-Lavrenko (1955), p. 67, fig. 14.

Ecology: Planktonic, polyhalobous.

Thal$ssiosira eccentrica (Ehrenberg) Cleve

Description: Hustedt (1930) as *Coscinodiscus eccentricus*, p. 388-391, fig. 201.

Ecology: Planktonic, polyhalobous meio-mesoeuryhaline, cosmopolitic (Pankow, 1976).

Thalassiosira aff. lineata Jousé

(Plate 7, Figure 2; Text-Figure 34)

Description: *T. lineata* Jousé (1968), p. 18, pl. 1, fig. 1-2; Simonsen (1974), p. 9, 10, pl. 1, fig. 4-7.

Discussion: The observed individuals have the scattered strutted tubuli in common with *T. lineata*. The structure is composed of concave tangential areolation with 15-16 areolae in 10 μm, whereas the areolation in *T. lineata* is composed of straight tangential rows approximately 10-11 in 10 μm. Similar specimens were observed in diatomaceous samples from the Capo Rossello type Zanklian section in Sicily. Complete taxonomy for this species will be presented in a future publication.

Thalassiosira oestrupii (Ost.) Proschkina-Lavrenko

(Plate 2, Figure 13; Plate 8, Figure 3)

Description: Hustedt (1930) as *Coscinosira oestrupii*, p. 318, fig. 155.

Ecology: Planktonic, common in marine environment.

Thalassiosira subsalina Proschkina-Lavrenko

(Plate 1, Figure 5; Plate 8, Figures 9, 10)

Description: Proschkina-Lavrenko (1955), p. 64, fig. 2, 3.

Ecology: Planktonic, polyhalobous.

Thalassiosira sp. indet. b

(Plate 11, Figures 12, 16-19)

Remarks: No similar individuals were described in the literature. Individuals found are 15 to 18 μm in diameter and slightly convex. Areolation is radially oriented; pores decrease in size from the center to the margin. A few scattered larger pores (strutted tubuli?) are present in the center. Along the margin one row of spines (strutted tubuli?) are present and one larger one is interpreted as a labiate process. They are common at Hole 380A, Core 47, and represent freshwater conditions.

Thalassiosira sp. indet.

(Plate 2, Figure 16; Plate 2, Figure 17; Plate 4, Figure 14; Plate 8, Figure 8; Plate 12, Figure 18;, Plate 13, Figure 5; Plate 13, Figure 11)

All above listed *Thalassiosira* species occurred in trace abundance and are illustrated mainly for purposes of documentation.

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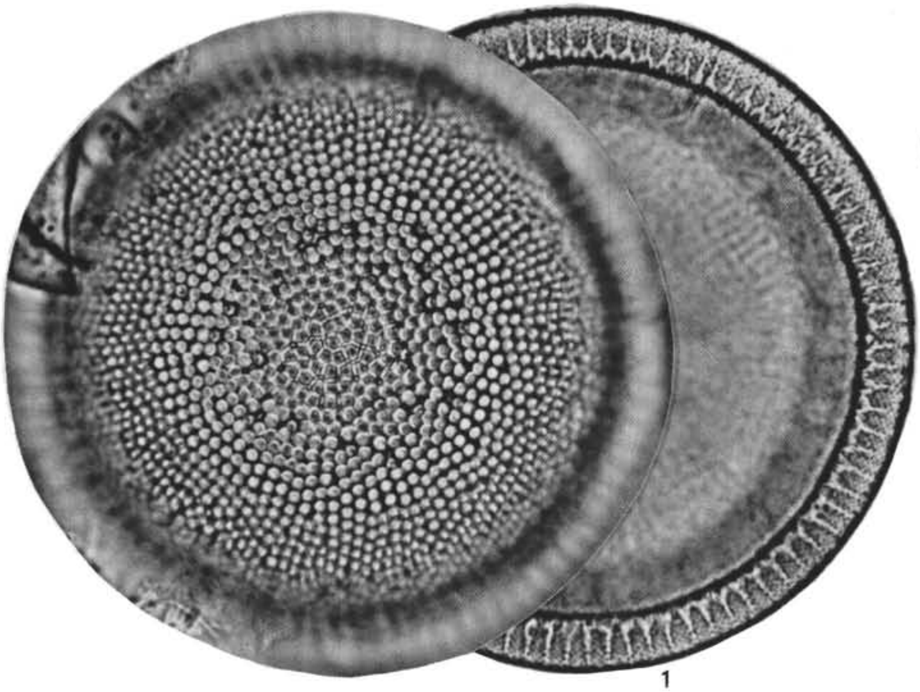
PLATE 1

Figure 1	*Stephanodiscus-Cyclotella* sp. indet. Sample 381-22-3, 74 cm.
Figures 2-4	*Stephanodiscus* spores. Sample 381-31-2, 86-88 cm.
Figure 5	*Thalassiosira subsalina* Prosk.-Lavr. Sample 379A-9-4, 60 cm.
Figure 6	*Stephanodiscus* spore. Sample 381-31-2, 86-88 cm.
Figure 7	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 381-23-3, 74 cm.
Figures 8, 9	*Stephanodiscus dubius* (Fricke) Hustedt. 8. Sample 381-26-3, 104 cm. 9. Sample 381-23-3, 74 cm.

PLATE 1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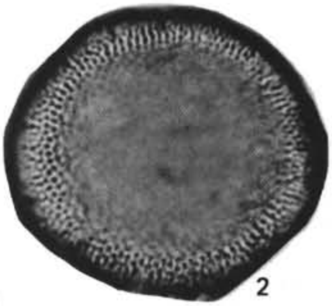
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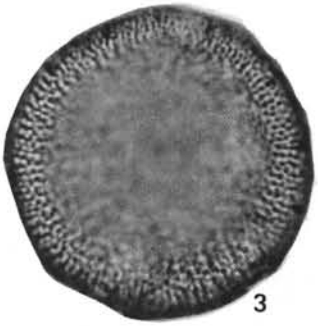
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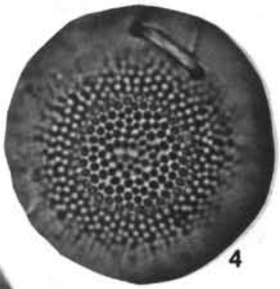
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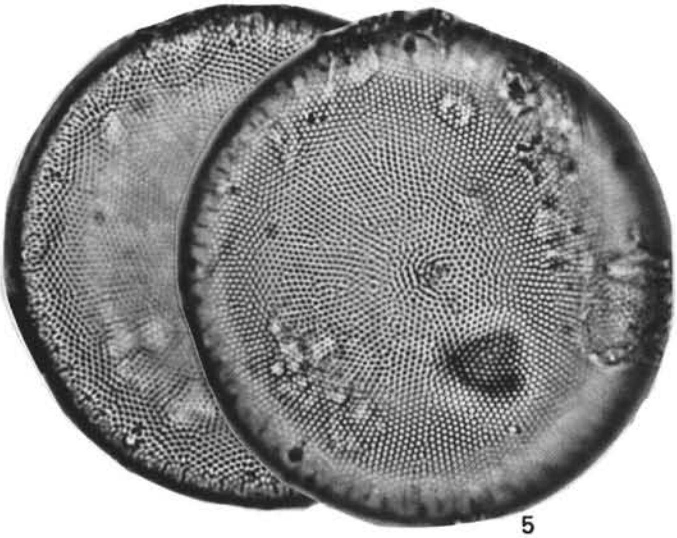
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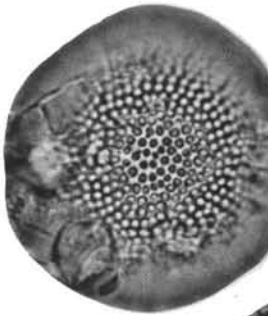
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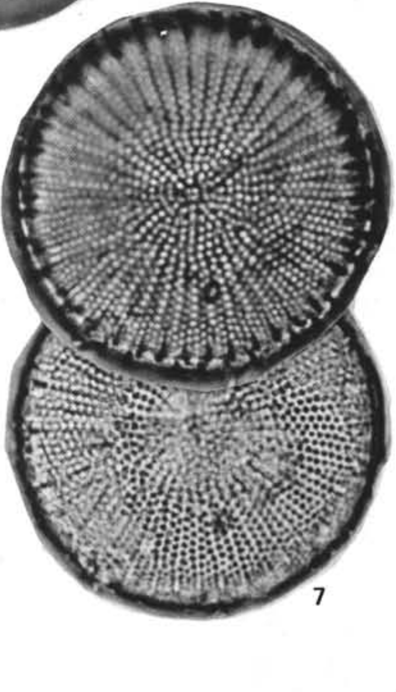
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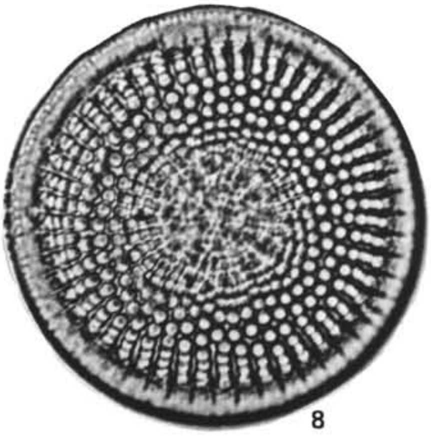
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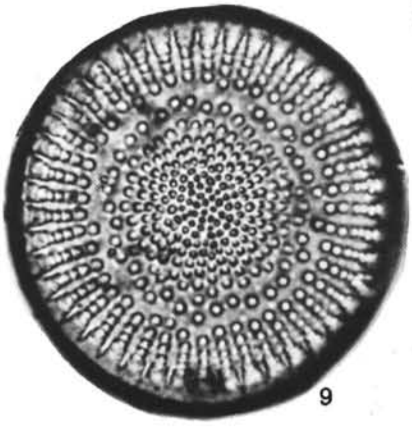
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PLATE 2

Figures 1-3	*Stephanodiscus astraea* var. *minutula* (Kütz.) Grunow. 1. Sample 379A-9-4, 60 cm. 2, 3. Sample 379A-24-6, 36 cm.
Figure 4	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 381-22-3, 74 cm.
Figure 5	*Stephanodiscus astraea* var. *minutula* (Kütz.) Grunow. Sample 379A-24-6, 36 cm.
Figure 6	*Stephanodiscus hantzschii* Grunow. Sample 379A-8-1, 100 cm.
Figure 7	*Stephanodiscus astraea* (Ehr.) Grunow. Sample 379A-8-1, 100 cm.
Figure 8	*Melosira granulata* (Ehr.) Ralfs. Sample 379A-8-1, 100 cm.
Figure 9	*Actinocyclus ehrenbergii* Ralfs. (aberrant individual). Sample 379A-24-6, 36 cm.
Figure 10	*Thalassiosira antiqua* var. *septata* Prosk.-Lavr. Sample 379A-8-1, 100 cm.
Figure 11	*Stephanodiscus astraea* (Ehr.) Grunow. Sample 379A-18-2, 137 cm.
Figure 12	*Stephanodiscus* species indet. Sample 381-26-3, 104 cm.
Figure 13	*Thalassiosira oestruppi* (Ost.) Prosk.-Lavr. Sample 379A-9-4, 60 cm.
Figure 14	*Actinocyclus ehrenbergii* Ralfs. (aberrant individual). Sample 379A-24-6, 36 cm.
Figure 15	*Stephanodiscus* aff. *robustus* Prosk.-Lavr. Sample 379A-8-1, 100 cm.
Figure 16	*Thalassiosira* sp. indet. Sample 381-35-5, 61 cm.
Figure 17	*Thalassiosira* sp. indet. Sample 381-35-5, 61 cm.
Figure 18	*Stephanodiscus dubius* (Fricke) Hustedt.

PLATE 2

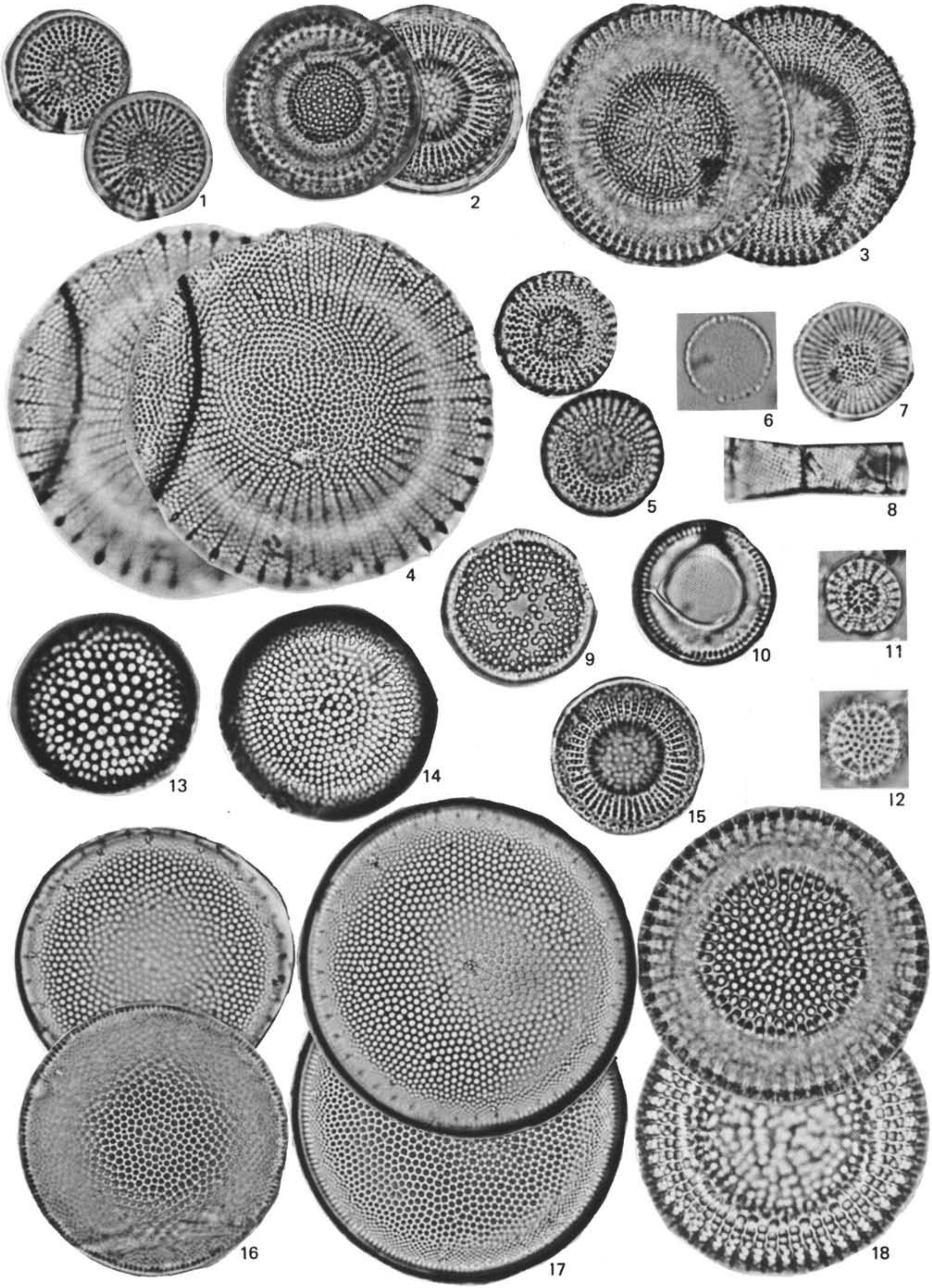
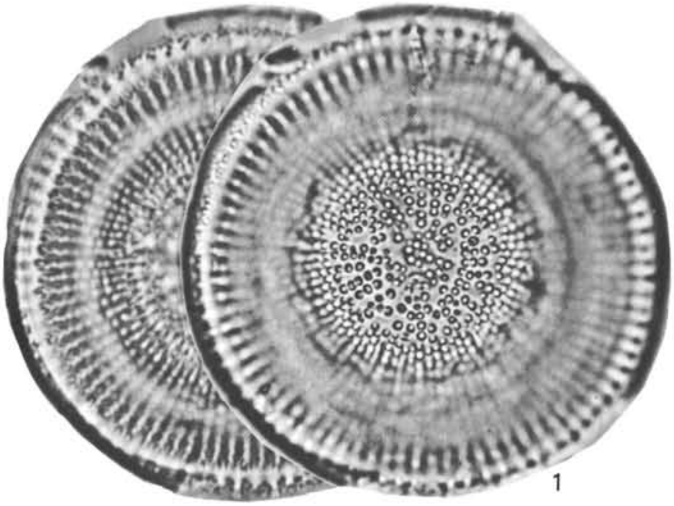


PLATE 3

Figure 1	*Stephanodiscus robustus* Prosk.-Lavr. Sample 380A-3-4, 67 cm.
Figure 2	*Stephanodiscus dubius* (Fricke) Hustedt. Sample 380A-38-6, 15-17 cm.
Figure 3	*Stephanodiscus omarensis* Kuptz. Sample 380A-38-6, 15-17 cm.
Figure 4	*Stephanodiscus* aff. *dubius* (Fricke) Hustedt. Sample 380A-38-6, 15-17 cm.
Figure 5	*Stephanodiscus* sp. indet. Sample 380A-45-3, 123 cm.
Figures 6,7	*Stephanodiscus astraea* var. *minutula* (Kütz.) Grunow. 6. Sample 379A-9-4, 60 cm. 7. Sample 379A-8-1, 100 cm.
Figures 8,9	*Melosira granulata* var. *angustissima* f. *curvata* Grunow. Sample 380A-35-3, 90-92 cm.
Figure 10	*Melosira* aff. *ambigua* (Grun.) Müller Sample 380A-38-6, 15-17 cm.
Figures 11,12	*Stephanodiscus astraea* (Ehr.) Grunow. 11. Sample 380A-3-4, 67 cm. 12. Sample 381-26-3, 104 cm.

PLATE 3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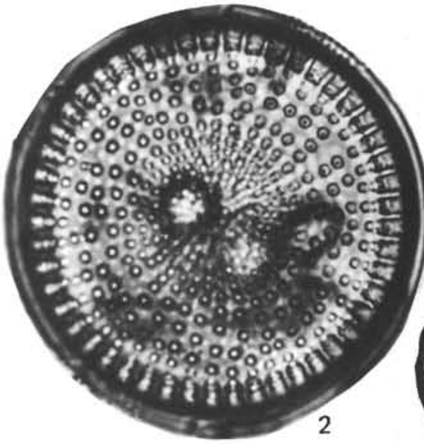
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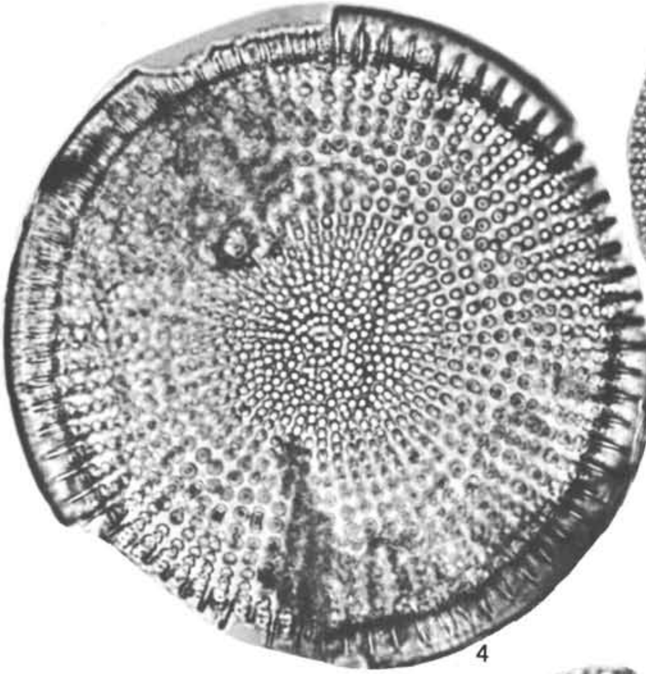
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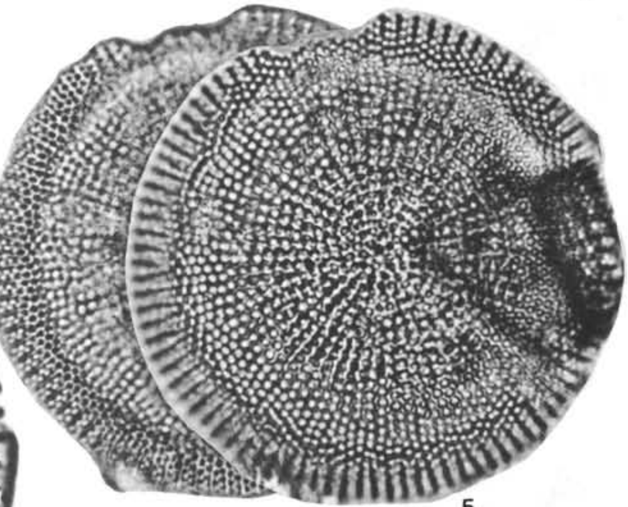
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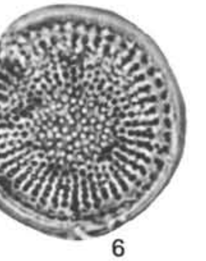
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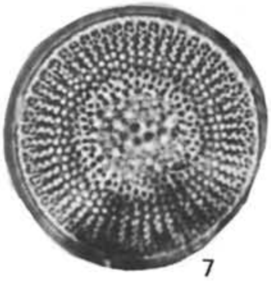
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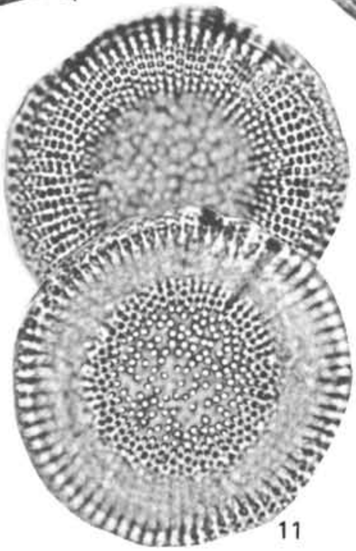
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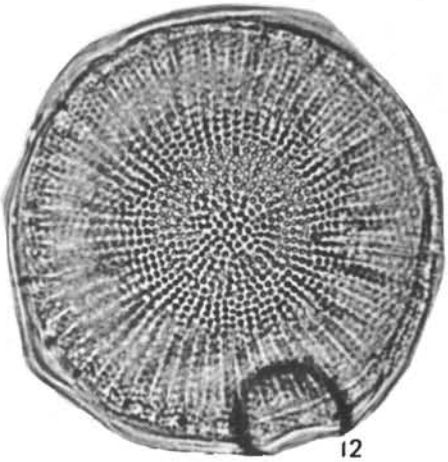
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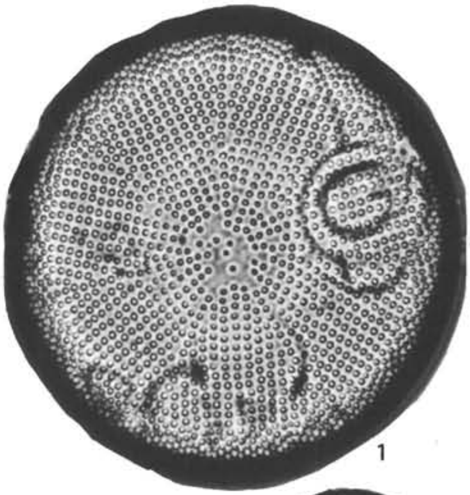
PLATE 4

Figures 1-5	*Actinocyclus ehrenbergii* Ralfs. Sample 380A-51-3, 66 cm.
Figure 6	*Melosira distans* (Ehr.) Kütz. Sample 380A-47-3, 75 cm.
Figure 7	*Stephanodiscus omarensis* Kuptz. Sample 380A-38-6, 15-17 cm.
Figure 8	*Melosira distans* (Ehr.) Kütz. Sample 380A-47-2, 75 cm.
Figure 9	*Stephanodiscus hantzschii* Grunow. Sample 380A-3-4, 67 cm.
Figure 10	*Cyclotella* aff. *comta* (Ehr.) Kützing Sample 380A-35-3, 90-92 cm.
Figure 11	*Stephanodiscus dubius* (Fricke) Hustedt. Sample 380A-38-6, 15-17 cm.
Figure 12	*Stephanodiscus pantocsekii* Fricke. Sample 380A-38-6, 15-17 cm.
Figure 13	*Stephanodiscus* species indet. Sample 380A-51-3, 66 cm.
Figure 14	*Thalassiosira* species indet. Sample 380A-47-1, 75-76 cm.
Figure 15	*Stephanodiscus astraea* (Ehr.) Grunow. Sample 380A-51-3, 66 cm.
Figure 16	*Stephanodiscus binderianus* (Kütz.) Krieger. Sample 380A-51-3, 66 cm.
Figures 17,18	*Melosira islandica* O. Müller. 17. Sample 380A-47-3, 75 cm. 18. Sample 380A-47-2, 75 cm.
Figure 19	*Stephanodiscus binderianus* (Kütz.) Krieger. Sample 380A-51-3, 66 cm.
Figures 20,21	*Cyclotella caspia* Grunow. Sample 380A-51-3, 66 cm.
Figures 22,23	*Stephanodiscus astraea* (Ehr.) Grunow 22. Sample 380A-3-4, 67 cm. 23. Sample 380A-51-3, 66 cm.
Figure 24	*Stephanodiscus* aff. *carconensis* var. *pusilla* Grunow. Sample 380A-46-2, 75 cm.

PLATE 4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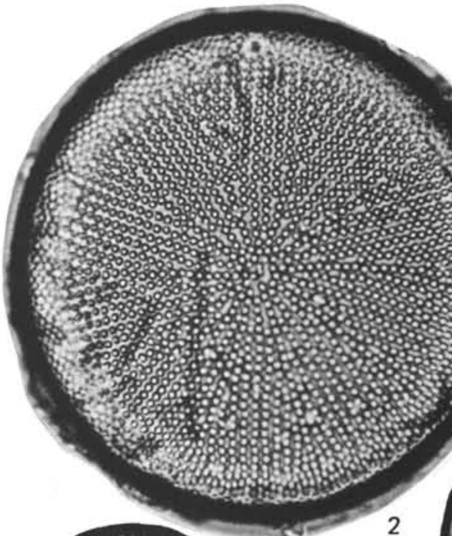
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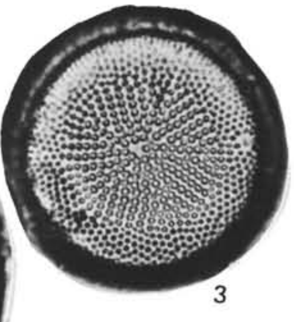
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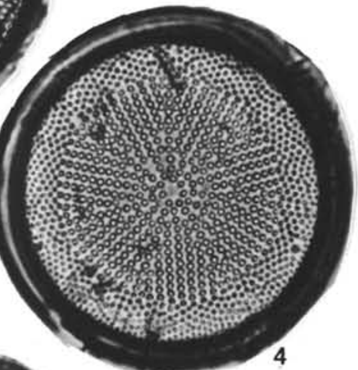
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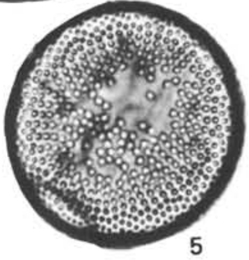
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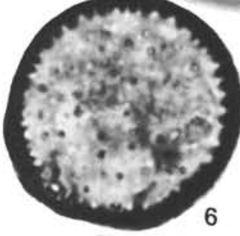
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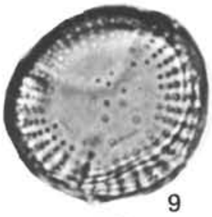
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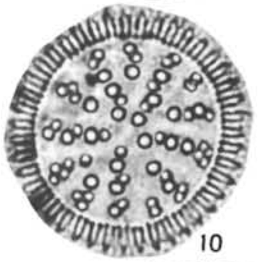
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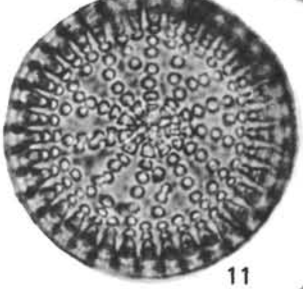
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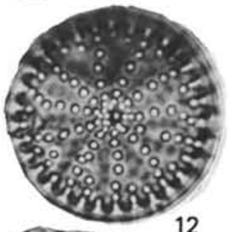
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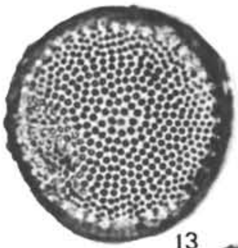
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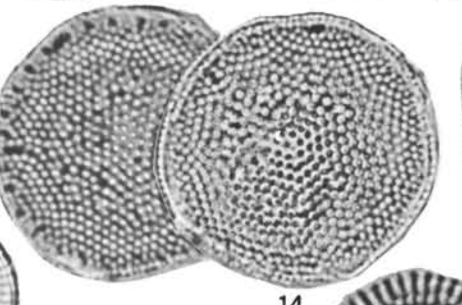
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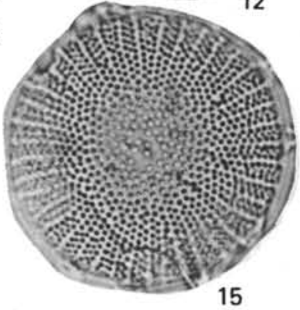
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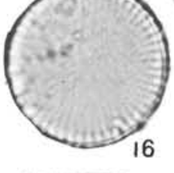
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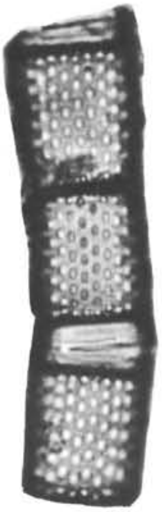
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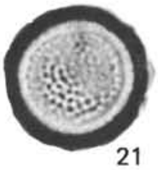
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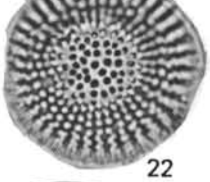
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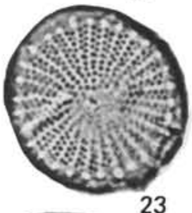
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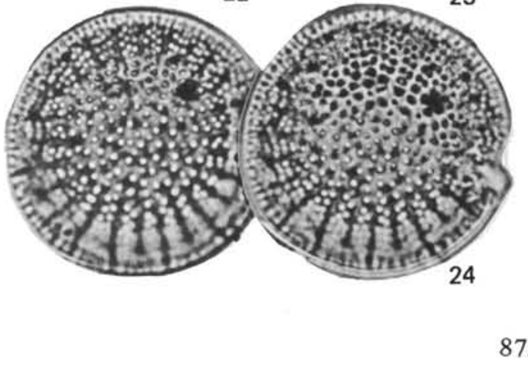
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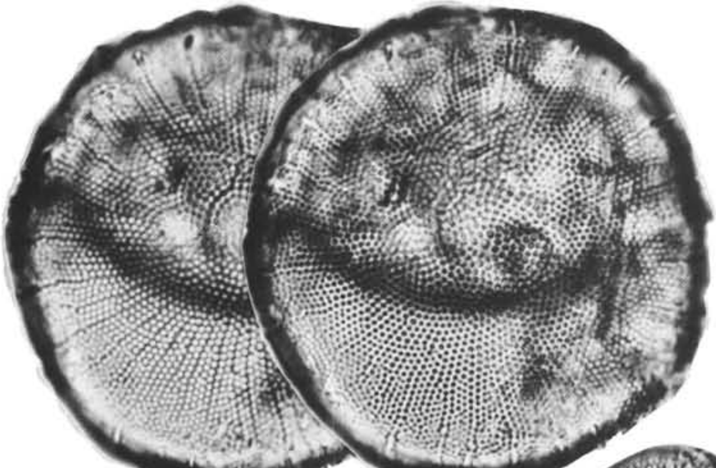
PLATE 5

Figure 1	*Stephanodiscus niagarae* Ehr. Sample 380A-51-6, 68-70 cm.
Figure 2	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 380A-51-6, 68-70 cm.
Figures 3,4	*Cyclotella operculata* (AG.) Kützing. 3. Sample 380A-51-6, 68-70 cm. 4. Sample 380A-51-6, 68-70 cm.
Figure 5	*Actinocyclus* species (aff. *Coscinodiscus stokesianus* f. *minor* Grun.) Sample 380A-51-6, 68-70 cm.
Figure 6	*Actinocyclus ehrenbergii* Ralfs (girdle view) Sample 380A-56-1, 76-78 cm.
Figure 7	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 380A-51-6, 68-70 cm.
Figures 8,9	*Cyclotella caspia* Grunow. Sample 380A-56-1, 76-78 cm.
Figure 10	*Cyclotella operculata* (Ag.) Kützing. Sample 380A-53-2, 84-86 cm.
Figure 11	*Actinocyclus* species (aff. *Coscinodiscus stokesianus* f. *minor* Grun.) Sample 380A-51-6, 68-70 cm.
Figures 12,13	*Stephanodiscus binderianus* (Kütz.) Krieger. Sample 380A-51-6, 68-70 cm.

PLATE 5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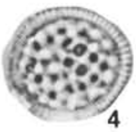
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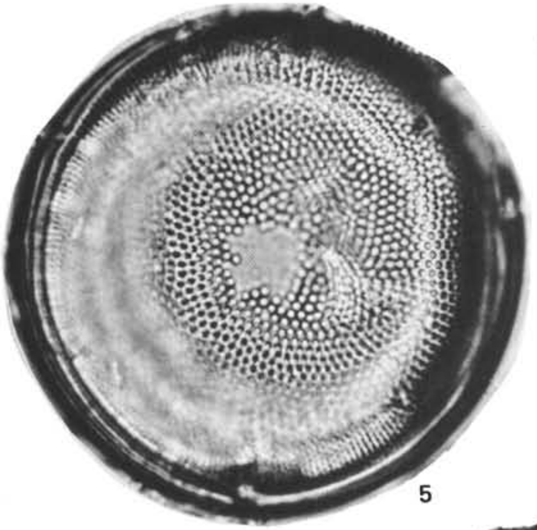
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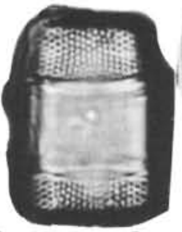
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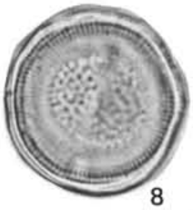
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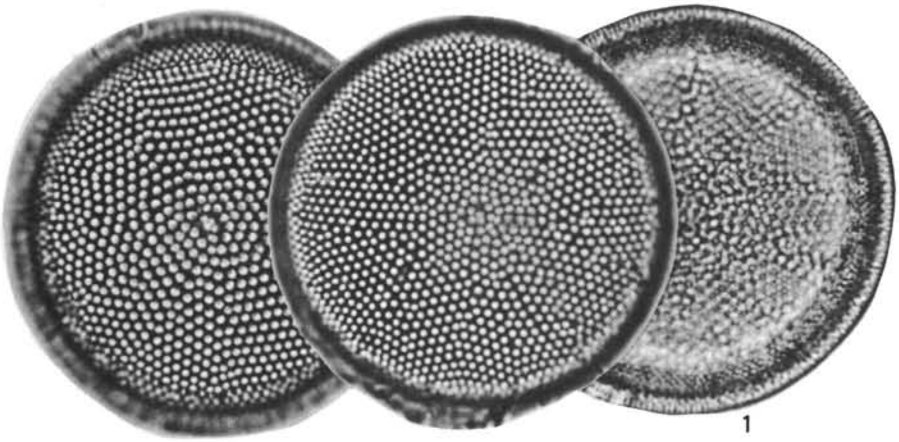
PLATE 6

Figure 1	*Coscinodiscus divisus* Grunow. Sample 381-1-3, 74 cm.
Figure 2	*Coscinodiscus obscurus* A. Schmidt (700 x). Sample 381-1-3, 74 cm.
Figure 3	*Cyclotella pygmaea* Pantocsek. Sample 380A-38-6, 15-18 cm.
Figure 4	*Stephanodiscus* aff. *carconensis* Grunow. Sample 381-26-3, 104 cm.
Figure 5	*Stephanodiscus niagarae* Ehr. Sample 380A-42-4, 114 cm.
Figure 6	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 380A-42-4, 114 cm.
Figure 7	*Cyclotella pygmaea* Pantocsek. Sample 380A-38-6, 15-18 cm.
Figures 8-10	*Stephanodiscus carconensis* Grunow. 8. Sample 380A-43-3, 145 cm. 9. Sample 380A-42-5, 61-63 cm. 10. Sample 380A-42-4, 114 cm.
Figure 11	*Stephanodiscus* sp. indet. Sample 380A-42-4, 114 cm.

PLATE 6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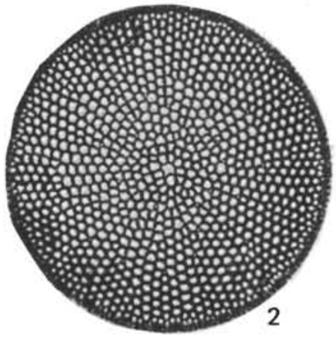
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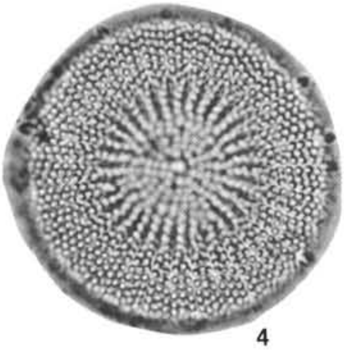
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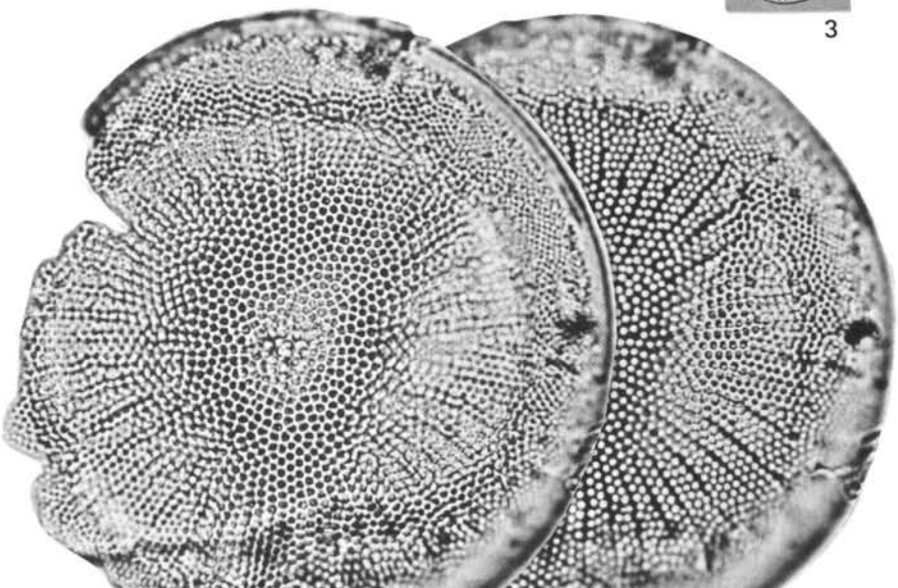
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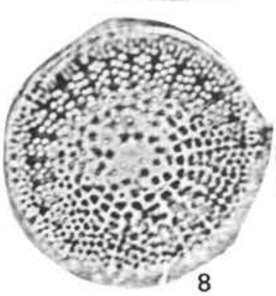
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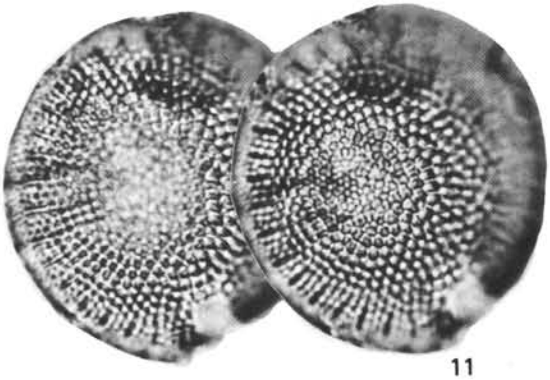
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PLATE 7

Figure 1	*Melosira arenaria* Moore (700 x). Sample 381-2-1, 74 cm.
Figure 2	*Thalassiosira* aff. *lineata* Jousé. Sample 380A-46-2, 75 cm.
Figure 3	*Stephanodiscus astraea* var. *minutula* (Kütz.) Grunow. Sample 381-31-2, 86-88 cm.
Figure 4	*Stephanodiscus robustus* Prosk.-Lavr. Sample 381-31-2, 86-88 cm.
Figure 5	*Actinocyclus ehrenbergii* Ralfs. Sample 379A-31-1, 98 cm.
Figure 6	*Stephanodiscus carconensis* Grunow. Sample 381-28-5, 56 cm.
Figure 7	*Stephanodiscus* sp. indet. C. Sample 381-31-2, 86-88 cm.
Figure 8	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 381-23-3, 74 cm.
Figure 9	*Stephanodiscus* aff. *carconensis* Grunow. Sample 381-29-2, 30 cm.
Figure 10	*Stephanodiscus niagarae* Ehr. Sample 381-22-3, 74 cm.

PLATE 7


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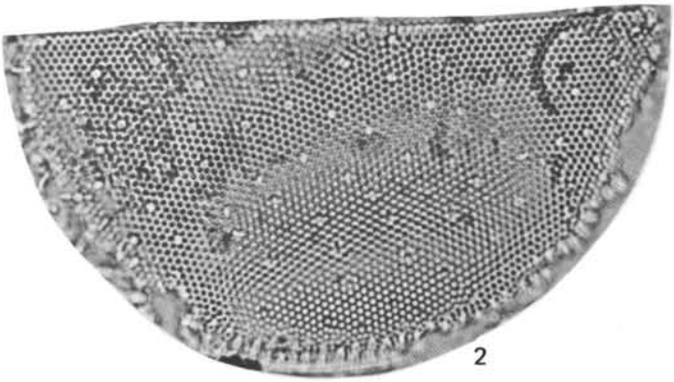
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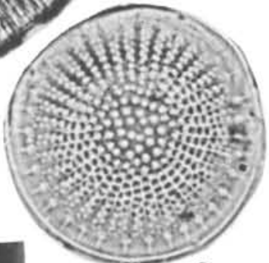
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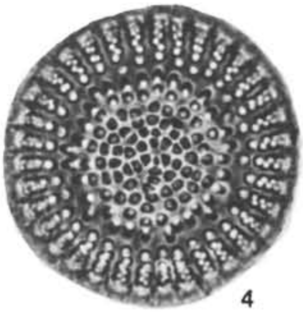
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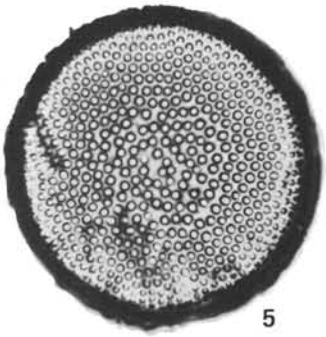
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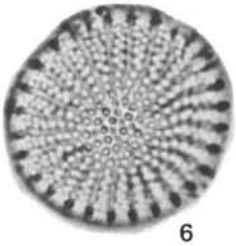
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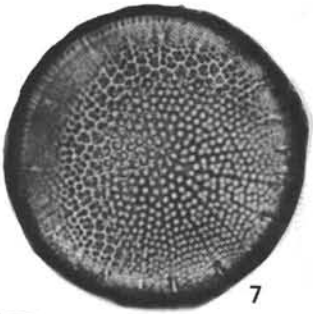
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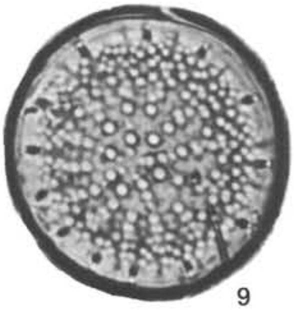
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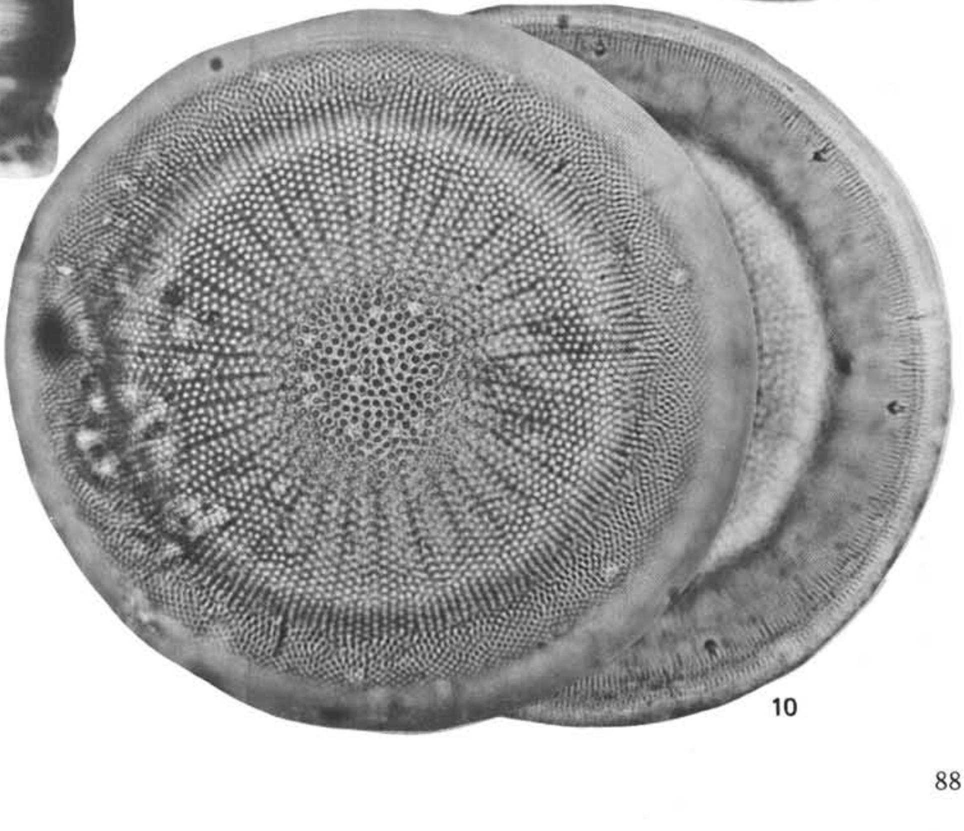
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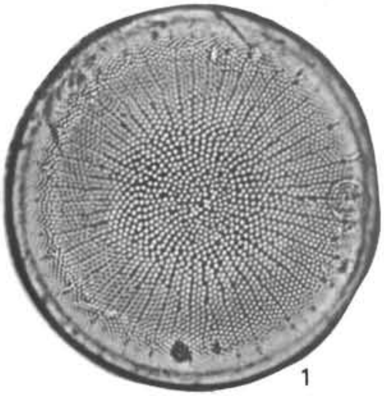
PLATE 8

Figure 1	*Stephanodiscus niagarae* Ehr. (700 x). Sample 381-28-5, 56 cm.
Figure 2	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 380A-51-6, 68-70 cm.
Figure 3	*Thalassiosira oestrupii* (Ost.) Prosk-Lavr. Sample 379A-18-2, 137 cm.
Figure 4	*Stephanodiscus* sp. indet. Sample 380A-51-6, 68-70 cm.
Figures 5-7	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 380A-51-6, 68-70 cm.
Figure 8	*Thalassiosira* sp. indet. Sample 379A-18-2, 137 cm.
Figures 9, 10	*Thalassiosira subsalina* Prosk.-Lavr. Sample 379A-9-4, 60 cm.
Figure 11	*Stephanodiscus* sp. indet. Sample 380A-42-4, 114 cm.
Figure 12	*Stephanodiscus astraea* var. *intermedia* Fricke. Sample 381-26-3, 104 cm.
Figure 13	*Stephanodiscus astraea* (Ehr.) Grunow. Sample 381-26-3, 104 cm.

PLATE 8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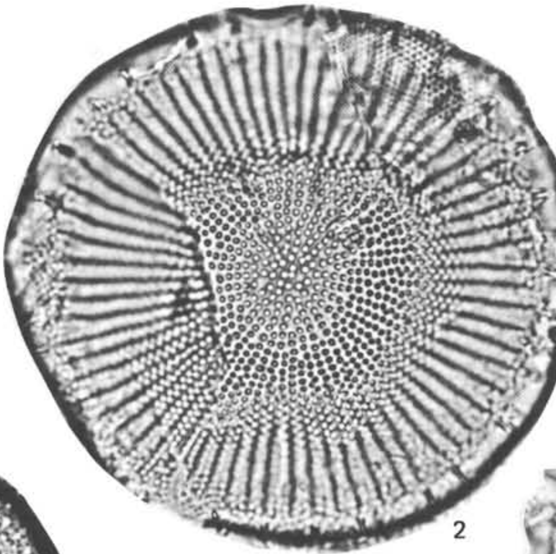
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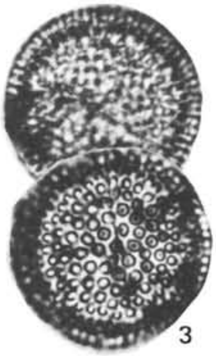
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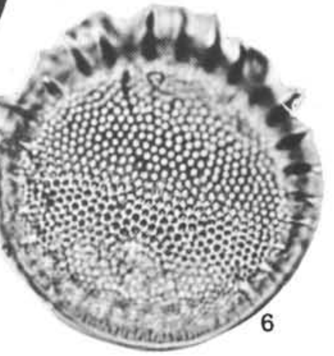
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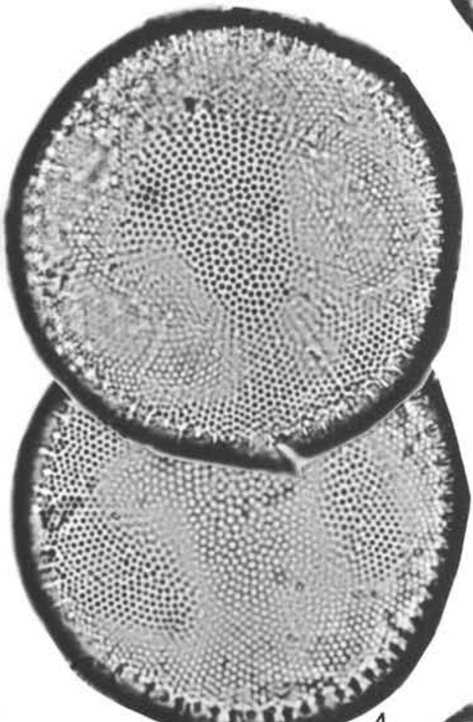
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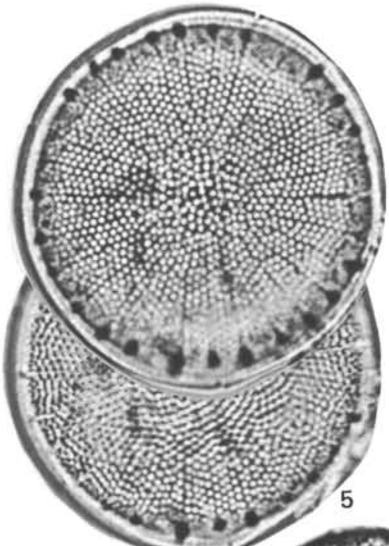
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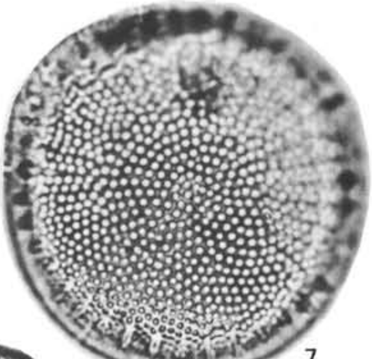
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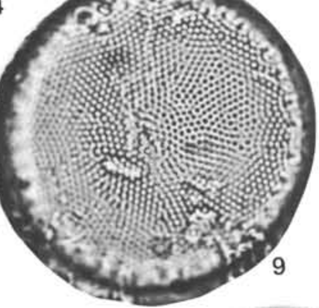
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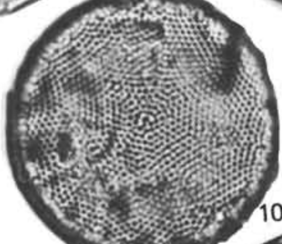
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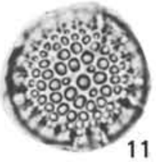
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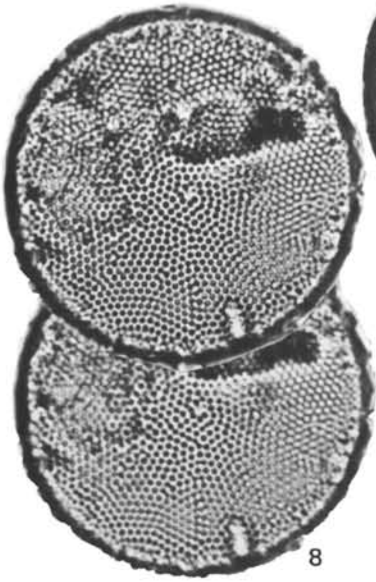
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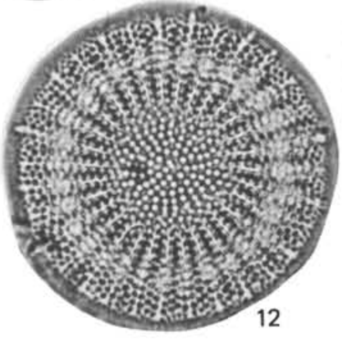
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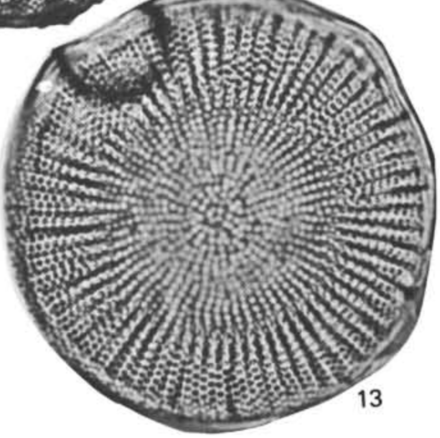
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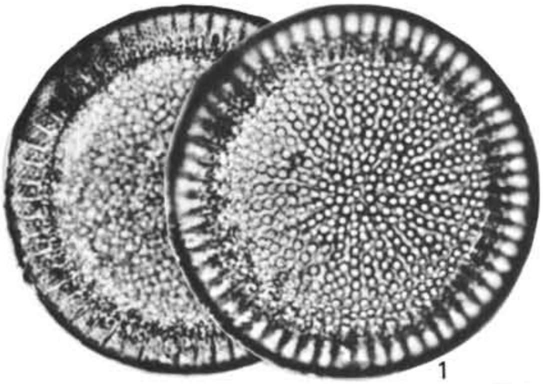
PLATE 9

Figures 1, 2	*Stephanodiscus-Cyclotella* sp. indet. 1. Sample 380A-42-5, 6-8 cm. 2. Sample 380A-45-3, 45-47 cm.
Figures 3, 4	*Melosira distans* (Ehr.) Kütz. Sample 380A-42-4, 114 cm.
Figure 5	*Stephanodiscus carconensis* Grunow (asymmetrical). Sample 380A-42-4, 114 cm.
Figure 6	*Stephanodiscus dubius* Fricke. Sample 380A-38-6, 15-17 cm.
Figure 7	*Stephanodiscus* sp. indet. Sample 380A-45-3, 45-47 cm.
Figure 8	*Stephanodiscus carconensis* Grunow (triangulate). Sample 380A-41-1, 110 cm.
Figures 9, 10	*Melosira ambigua* (Grun.) Müller. 9. Sample 380A-42-4, 114 cm. 10. Sample 380A-41-6, 146 cm.
Figures 11-13	*Stephanodiscus carconensis* Grunow. 11. Sample 380A-42-4, 67 cm. 12. Sample 380A-43-3, 145 cm. 13. Sample 380A-42-4, 67 cm.
Figures 14, 15	*Stephanodiscus carconensis* Grunow (triangulate). 14. Sample 380A-41-6, 122-124 cm. 15. Sample 380A-41-1, 110-112 cm.
Figure 16	*Stephanodiscus astraea* var. *minutula* (Kütz.) Grunow. Sample 380A-3-4, 67 cm.
Figure 17	*Melosira islandica* O. Müller (valve view). Sample 380A-45-3, 45-47 cm.
Figures 18-23	*Stephanodiscus carconensis* Grunow. 18. Sample 380A-42-4, 114-116 cm (asymmetrical). 19, 20. Sample 380A-41-4, 109 cm (triangulate). 21. Sample 380A-41-1, 110-112 cm (triangulate). 22. Sample 380A-41-1, 110-112 cm. 23. Sample 380A-41-4, 109-111 cm.
Figure 24	*Melosira islandica* O. Müller. Sample 380A-42-4, 67 cm.
Figures 25, 26	*Stephanodiscus binderianus* (Kütz.) Krieger. Sample 380A-41-1, 110-112 cm.
Figure 27	*Stephanodiscus carconensis* Grunow. Sample 380A-41-6, 146 cm.
Figure 28	*Stephanodiscus* sp. indet. Sample 380A-41-1, 110-112 cm.
Figures 29-32	*Melosira ambigua* (Grun.) Müller. 29. Sample 380A-42-4, 67 cm. 30. Sample 380A-41-6, 144-146 cm. 31. Sample 380A-42-4, 67 cm. 32. Sample 380A-41-6, 146 cm.
Figure 33	*Stephanodiscus-Cyclotella* sp. indet. (triangulate). Sample 380A-41-4, 109-111 cm.

PLATE 9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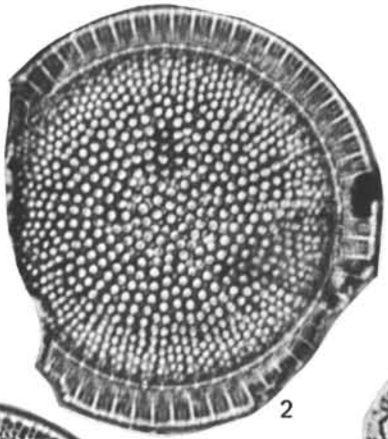
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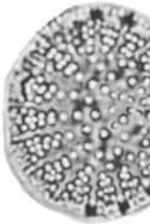
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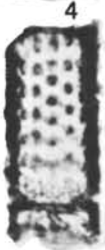
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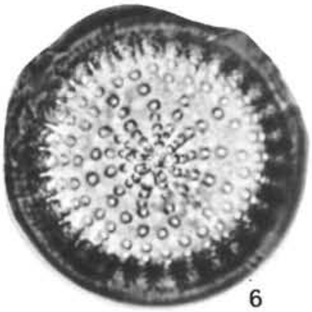
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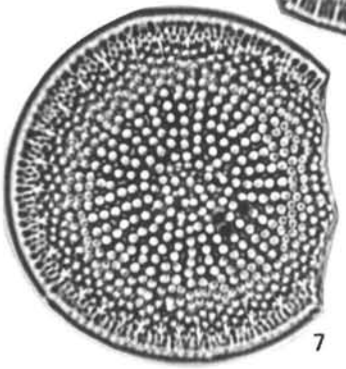
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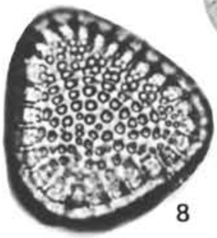
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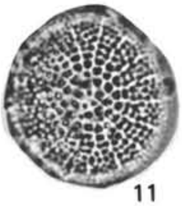
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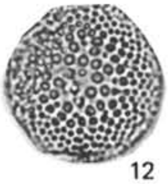
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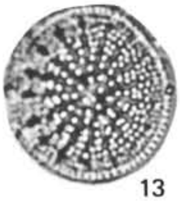
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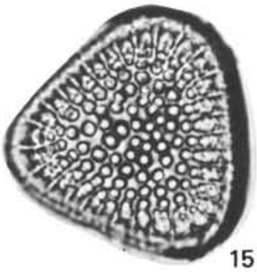
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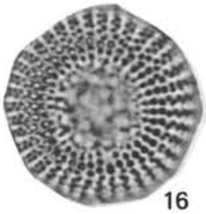
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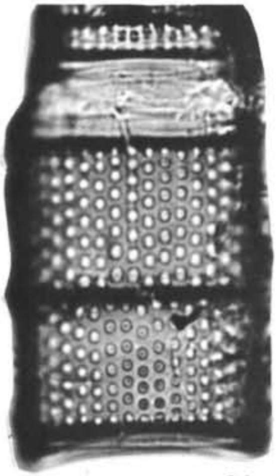
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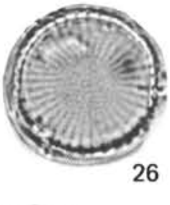
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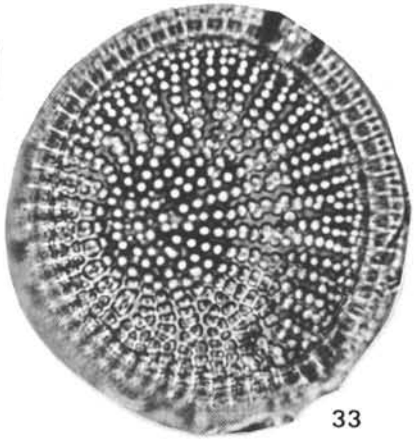
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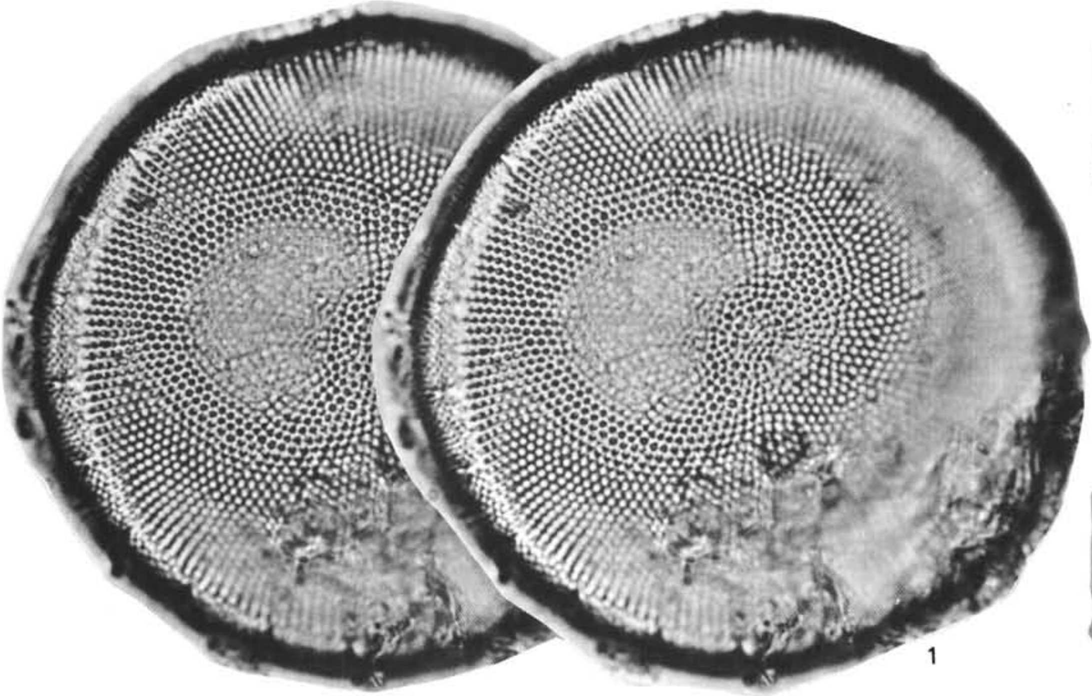
PLATE 10

Figure 1	*Actinocyclus* species (*Coscinodiscus stokesianus* [Grev.] Grunow). Sample 380A-51-6, 68-70 cm.
Figures 2, 3	*Melosira islandica* O. Müller 2. Sample 380A-41-4, 86-88 cm (1200 ×). 3. 380A-41-4, 86-88 cm.
Figure 4	*Melosira distans* (Ehr.) Kützing (valve view). Sample 380A-41-4, 86-88 cm.
Figures 5-8	*Stephanodiscus carconensis* Grunow (triangulate). Sample 380A-41-4, 86-88 cm.
Figure 9	*Melosira islandica* (O. Müller) Sample 380A-41-4, 86-88 cm.
Figure 10	*Stephanodiscus carconensis* Grunow (triangulate). Sample 380A-41-4, 86-88 cm.
Figures 11-18	*Melosira islandica* O. Müller. 11, 12. Sample 380A-41-4, 86-88 cm. 13. Sample 380A-41-4, 86-88 cm (1200 ×). 14. Sample 380A-51-6, 68-70 cm. 15. Sample 380A-41-4, 86-88 cm. 16, 17. Sample 380A-41-4, 86-88 cm. 18. Sample 380A-41-4, 86-88 cm (auxospore).

PLATE 10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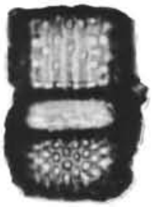
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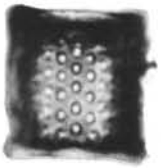
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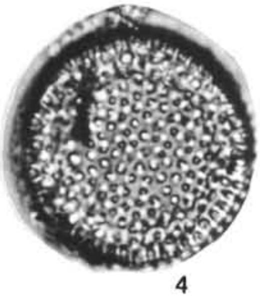
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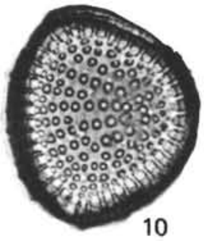
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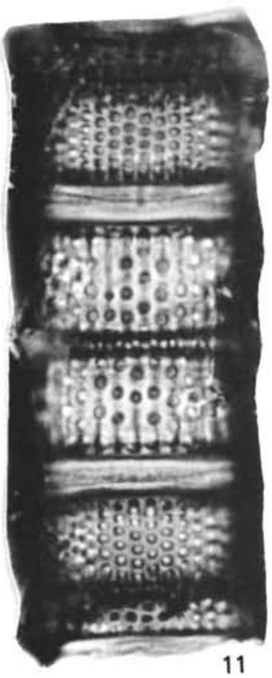
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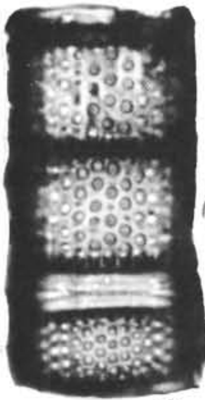
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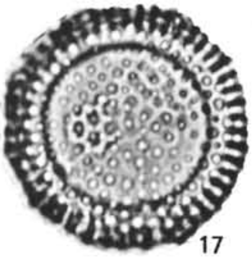
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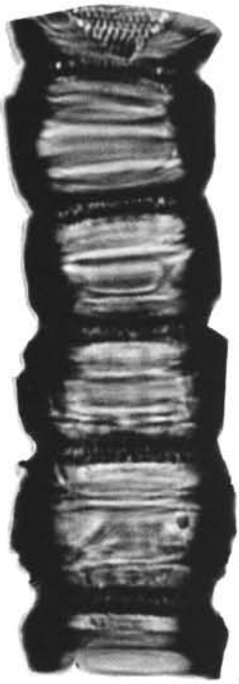
PLATE 11

Figures 1-7	*Stephanodiscus binderianus* (Kütz.) Krieger. 1. Sample 380A-52-2, 82-84 cm. 2. Sample 380A-54-4, 74-76 cm. 3. Sample 380A-47-3, 75-77 cm. 4. Sample 380A-46-2, 75 cm. 5. Sample 380A-47-1, 75-76 cm. 6. Sample 380A-46-2, 75 cm. 7. Sample 380A-47-1, 75-76 cm.
Figure 8	*Cyclotella meneghiniana* var. *pluripunctata* Ehrlich. Sample 380A-63-3, 46-48 cm.
Figure 9	*Stephanodiscus carconensis* Grunow. Sample 380A-45-3, 123 cm.
Figures 10, 11	*Stephanodiscus binderianus* (Kütz.) Krieger (strongly silicified). 10. Sample 380A-46-2, 75 cm. 11. 380A-51-6, 68-70 cm.
Figure 12	*Thalassiosira* sp. indet. b. Sample 380A-47-1, 75-76 cm.
Figure 13	*Stephanodiscus* aff. *binderianus* (Kütz) Krieger. Sample 380A-47-2, 75 cm.
Figures 14, 15	*Stephanodiscus carconensis* Grunow. Sample 380A-45-3, 123 cm.
Figures 16-19	*Thalassiosira* sp. indet. b. 16, 17. Sample 380A-47-1, 75-76 cm. 18. Sample 380A-47-2, 75 cm. 19. Sample 380A-47-1, 75-76 cm.
Figure 20	*Stephanodiscus carconensis* Grunow. Sample 380A-46-2, 75 cm.
Figures 21, 22	*Melosira distans* (Ehr.) Kützing. Sample 380A-45-3, 123 cm. 21. Valve view. 22. Valve view of auxospore
Figures 23-25	*Melosira islandica* O. Müller. 23. Sample 380A-47-2, 75 cm. 24. Sample 380A-47-1, 75-76 cm. 25. Sample 380A-45-3, 123 cm.
Figure 26	*Melosira distans* (Ehr.) Kützing. Sample 380A-46-2, 75-76 cm.
Figure 27	*Melosira islandica* O. Müller. Sample 380A-46-2, 75 cm.
Figures 28, 29	*Melosira distans* (Ehr.) Kützing. Sample 380A-45-3, 123 cm.
Figure 30	*Diatoma elongatum* (Lyngb.) AG. (1200 ×). Sample 380A-52-2, 82-84 cm.

PLATE 11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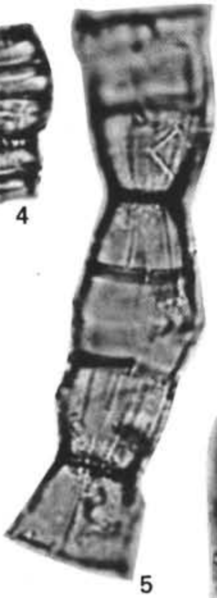
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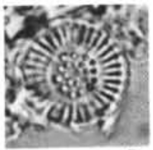
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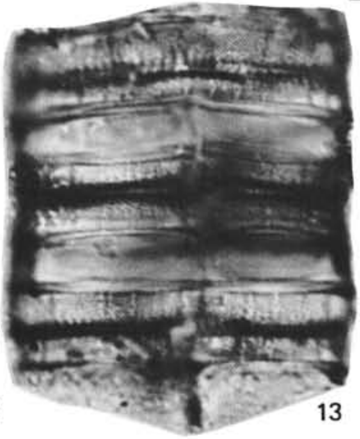
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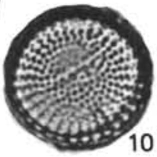
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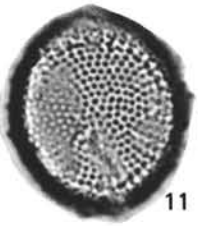
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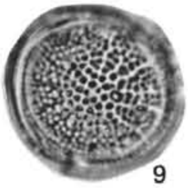
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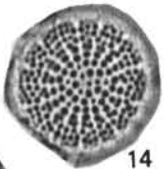
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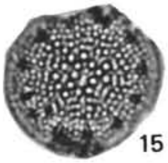
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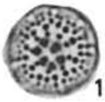
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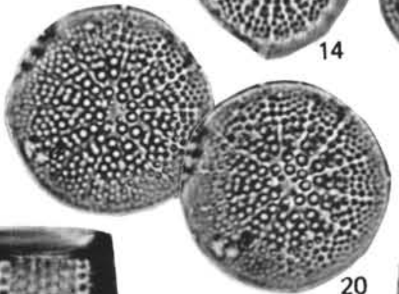
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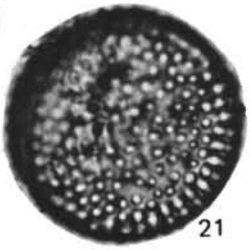
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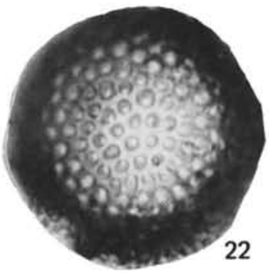
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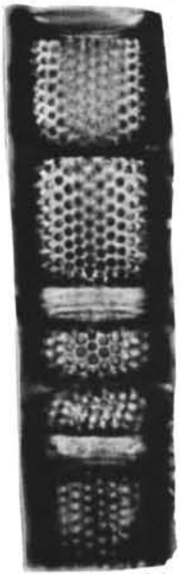
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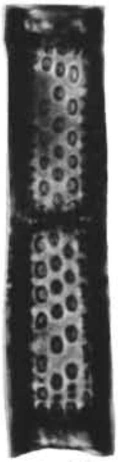
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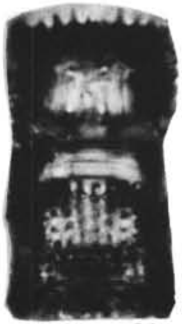
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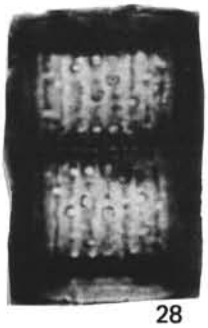
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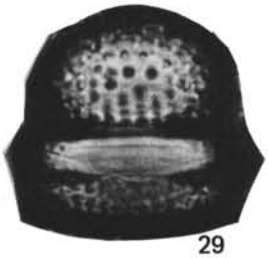
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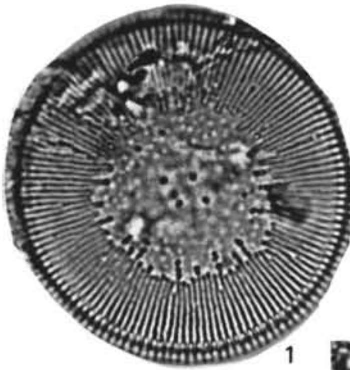
PLATE 12

Figure 1	*Cyclotella kützingiana* Twait. Sample 379A-8-1, 100 cm.
Figures 2, 3	*Cyclotella caspia* Grunow. Sample 379A-18-2, 137 cm.
Figures 4, 5	*Cyclotella kützingiana* Twait. Sample 379A-8-1, 100 cm.
Figure 6	*Cyclotella caspia* Grunow (girdle view). Sample 379A-18-2, 137 cm.
Figures 7-11	*Cyclotella kützingiana* Twait. Sample 379A-8-1, 100 cm.
Figure 12	*Stephanodiscus omarensis* Kuptz. Sample 381-26-3, 104 cm.
Figure 13	*Melosira roeseana* Rabenhorst. Sample 381-35-5, 61 cm.
Figure 14	*Stephanodiscus carconensis* Grunow (asymmetrical). Sample 381-29-2, 30 cm.
Figure 15	*Stephanodiscus astraea* (Ehr.) Grunow (asymmetrical). Sample 381-28-5, 56 cm.
Figure 16	*Stephanodiscus dubius* (Fricke) Hustedt (600 ×). Sample 381-26-3, 104 cm.
Figure 17	*Stephanodiscus* sp. indet. Sample 381-28-5, 56 cm.
Figure 18	*Thalassiosira* sp. indet. Sample 381-35-5, 61 cm.
Figures 19-22	*Stephanodiscus binderianus* (Kütz.) Krieger. 19. Sample 381-26-3, 104 cm. 20. Sample 381-29-2, 30 cm (700 ×). 21. Sample 381-31-2, 86-88 cm. 22. Sample 381-26-3, 104 cm.
Figure 23	*Stephanodiscus dubius* (Fricke) Hustedt. Sample 381-22-3, 74 cm.

PLATE 12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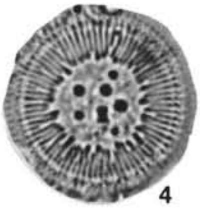
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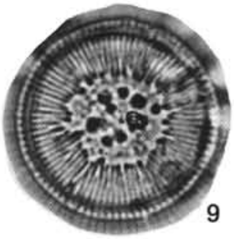
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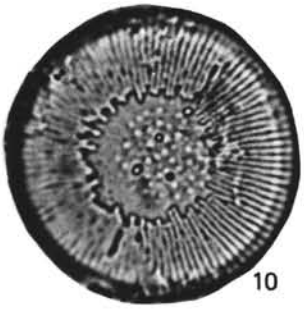
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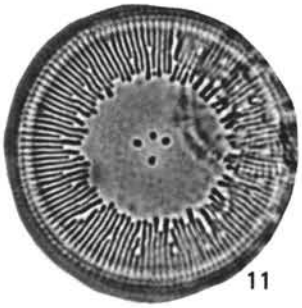
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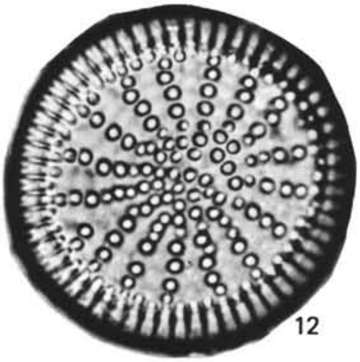
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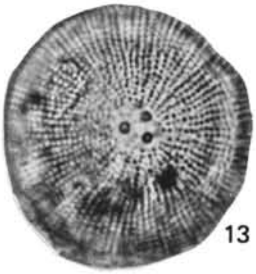
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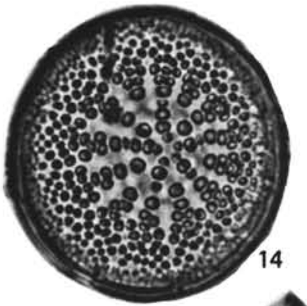
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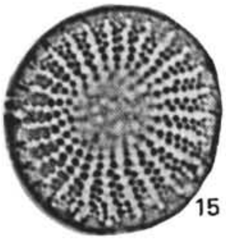
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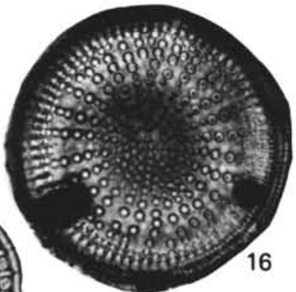
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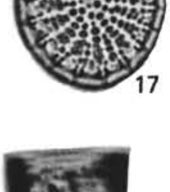
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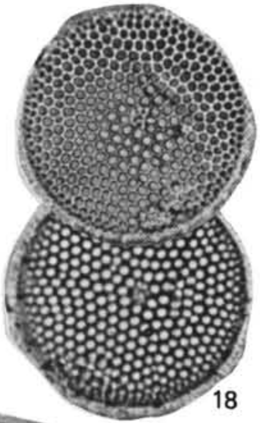
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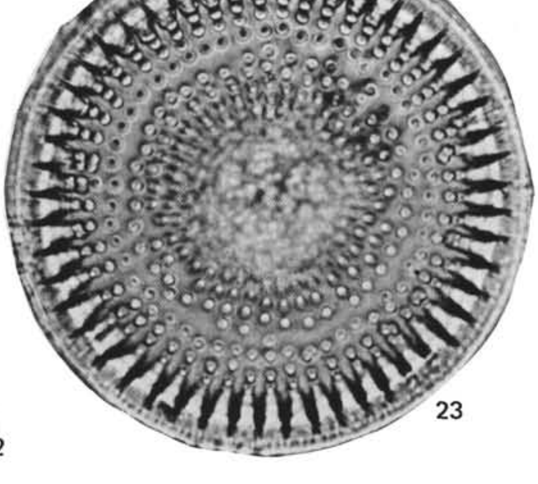
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PLATE 13

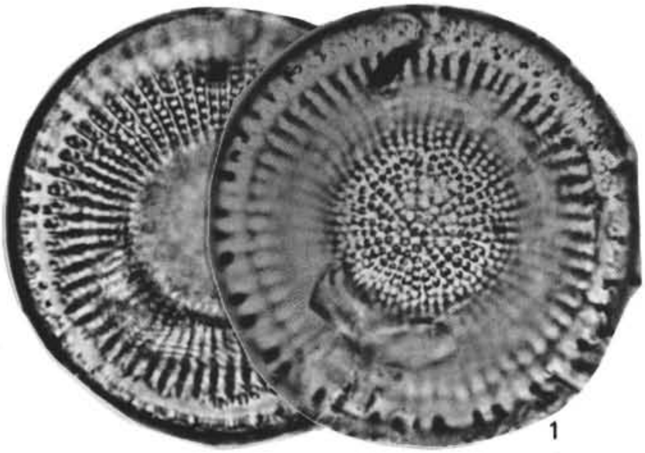
Figure 1	*Stephanodiscus robustus* Prosk.-Lavr. Sample 381-2-1, 74 cm.
Figure 2	*Stephanodiscus astraea* (Ehr.) Grunow Sample 381-2-1, 74 cm.
Figure 3	*Actinocyclus normannii* (Gregory) Hustedt. Sample 381-1-3, 74 cm.
Figure 4	*Stephanodiscus robustus* Prosk.-Lavr. Sample 381-2-1, 74 cm.
Figure 5	*Thalassiosira* sp. indet. Sample 381-1-3, 74 cm.
Figure 6	*Surirella turgida* W. Smith. Sample 381-2-1, 74 cm.
Figure 7	*Navicula* sp. indet. Sample 380A-51-3, 66 cm.
Figure 8	*Stephanodiscus astraea* (Ehr.) Grunow. Sample 381-2-1, 74 cm.
Figure 9	*Navicula scutelloides* W. Smith. Sample 381-2-1, 74 cm.
Figure 10	aff. *Cocconeis disculoides* Hustedt. Sample 381-2-1, 74 cm.
Figure 11	*Thalassiosira* species indet. Sample 381-1-3, 74 cm.
Figure 12	*Diploneis subovalis* Cleve. Sample 380A-51-3, 66 cm.
Figure 13	*Gyrosigma kützingii* (Grun.) Cleve. Sample 380A-47-1, 75-76 cm (600 ×).
Figure 14	*Cymatopleura solea* (Breb.) W. Smith. Sample 381-2-1, 74 cm (700 ×).

PLATE 14

Figure 1	*Gyrosigma* species indet. (1) Sample 381-22-3, 74 cm (600 ×).
Figures 2, 3	*Cymatopleura solea* (Breb.) W. Smith. Sample 381-2-1, 74 cm.
Figure 4	*Stephanodiscus dubius* (Fricke) Hustedt. Sample 381-22-3, 74 cm (875 ×).
Figure 5	*Cyclotella comta* (Ehr.) Kützing. Sample 381-2-1, 74 cm.
Figure 6	*Cyclotella pygmaea* Pantocsek. Sample 381-22-3, 74 cm.
Figure 7	*Cyclotella ocellata* Pantocsek. Sample 381-2-1, 74 cm.
Figure 8	*Diploneis subovalis* Cleve. Sample 380A-51-3, 66 cm.
Figure 9	*Grammatophora oceanica* (Ehr.) Grunow. Sample 380A-54-4, 74-76 cm.
Figures 10, 11	*Opephora martyi* Herib. 10. Sample 380A-51-6, 68-70 cm. 11. Sample 381-2-1, 74 cm.
Figure 12	? *Achnanthes* sp. indet. Sample 381-2-1, 74 cm.
Figures 13, 14	*Epithemia zebra* (Ehr.) Kützing Sample 381-2-1, 74 cm.
Figure 15	*Diploneis budayana* (Pant.) Hustedt. Sample 381-2-1, 74 cm.

(see p. 894)

PLATE 13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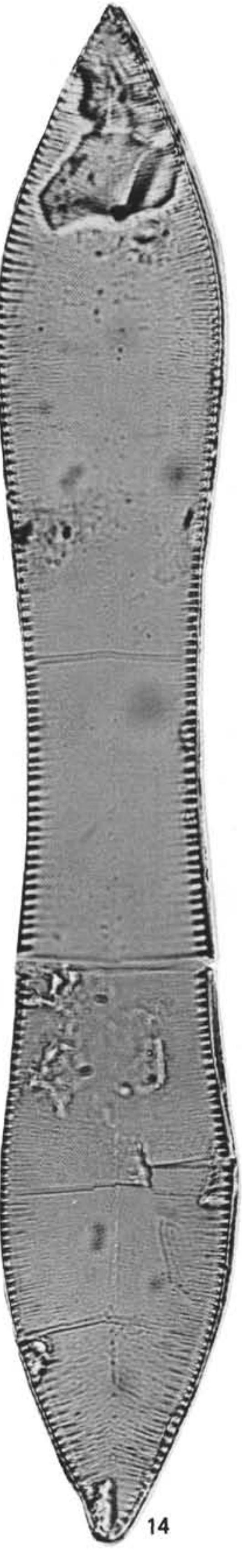
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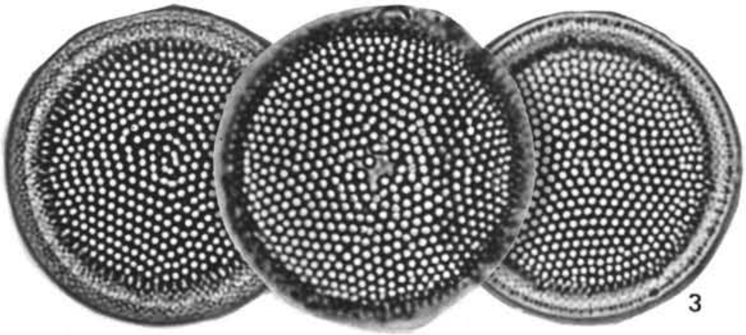
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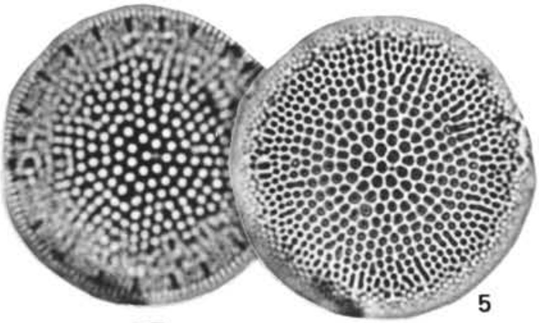
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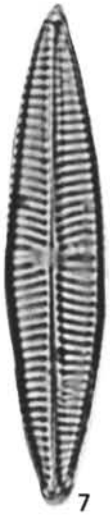
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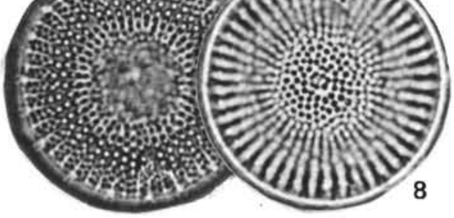
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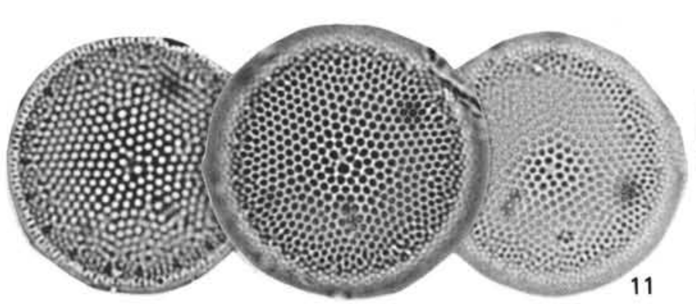
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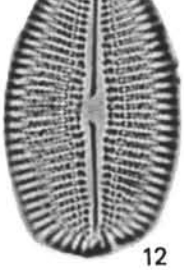
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PLATE 14


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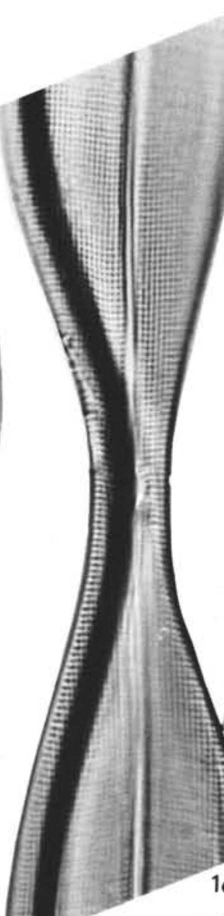
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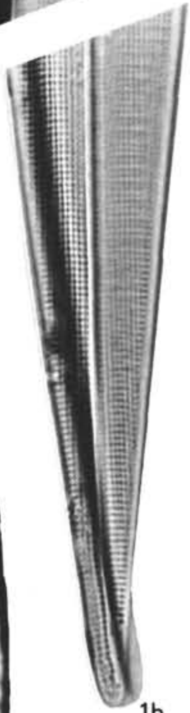
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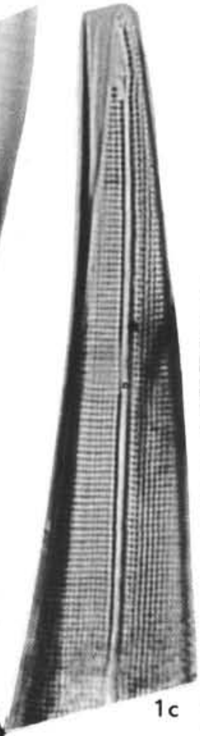
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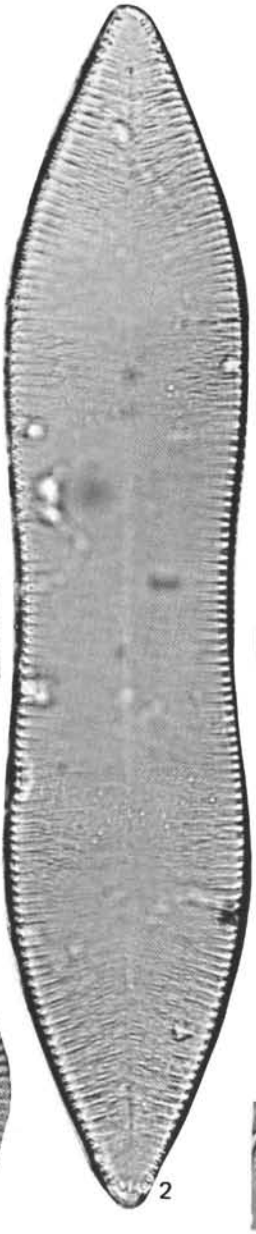
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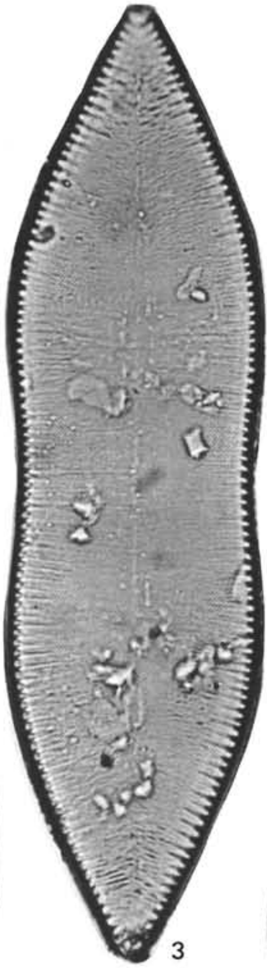
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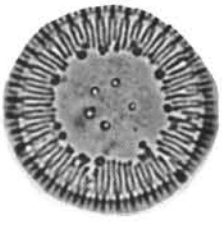


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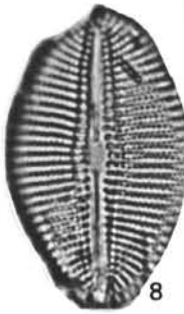
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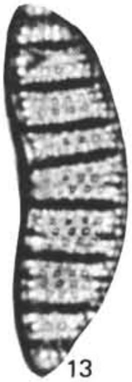
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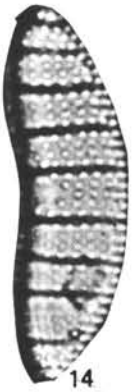
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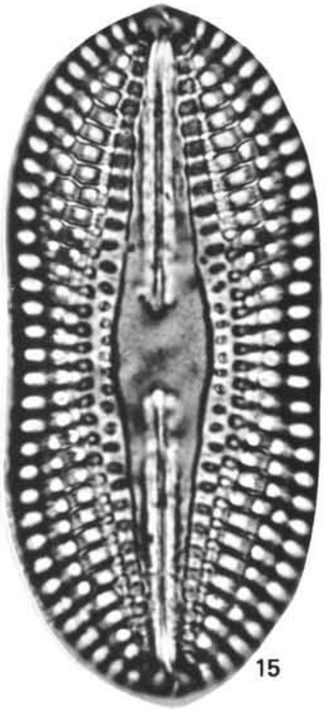
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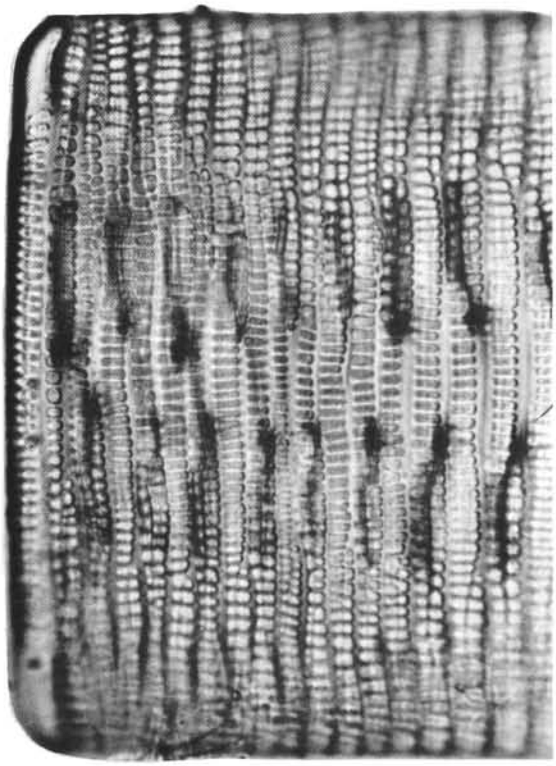
PLATE 15

Figure 1	*Rhabdonema adriaticum* Kützing. Sample 381-35-5, 61 cm.
Figure 2	*Diploneis smithii* (Breb.) Cleve. Sample 381-35-5, 61 cm.
Figure 3	*Cocconeis placentula* Ehr. Sample 381-37-2, 114 cm.
Figure 4	*Navicula palpebralis* Breb. Sample 381-35-5, 61 cm.
Figure 5	*Caloneis bacillum* (Grun.) Mereschk. Sample 381-35-5, 61 cm.
Figure 6	*Gyrosigma kützingii* (Grun.) Cleve. Sample 381-26-3, 104 cm (700 ×)
Figures 7,8	*Synedra indica* Taylor. Sample 381-35-5, 61 cm.
Figure 9	*Achnanthes brevipes* Ag. Sample 381-37-2, 114 cm.
Figure 10	*Grammatophora oceanica* var. *macilenta* (W. Sm.) Grunow. Sample 381-37-2, 114 cm.
Figure 11	*Rhopalodia gibberula* (Ehr.) O. Müller. Sample 380A-63-3, 46-48 cm.
Figures 12,13	*Rhoicosphenia curvata* (Kütz.) Grunow Sample 379A-18-2, 137 cm.
Figure 14	*Mastogloia elliptica* (Ag.) Cleve. Sample 381-35-5, 61 cm.
Figure 15	*Diploneis ovalis* var. *oblongella* (Naegeli) Cleve. Sample 379A-8-1, 100 cm.
Figure 16	*Synedra undulata* Bail. Sample 379A-9-4, 60 cm.
Figure 17	*Navicula hasta* Pantocsek. Sample 381-28-5, 56 cm.
Figure 18	*Epithemia turgida* (Ehr.) Kützing. Sample 379A-8-1, 100 cm.

(see p. 896)

PLATE 15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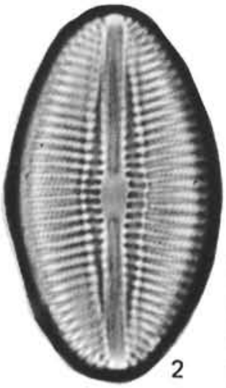
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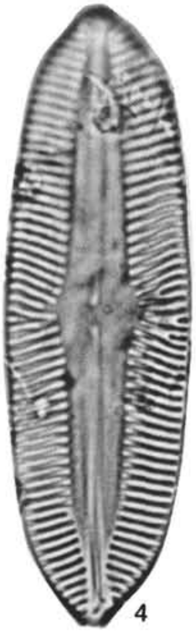
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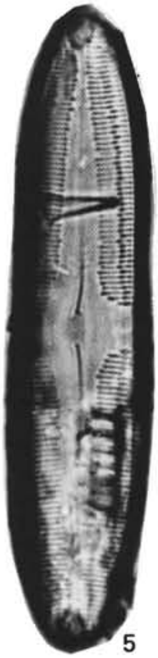
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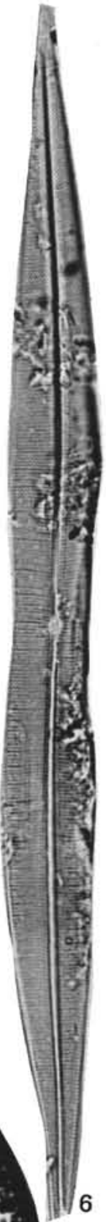
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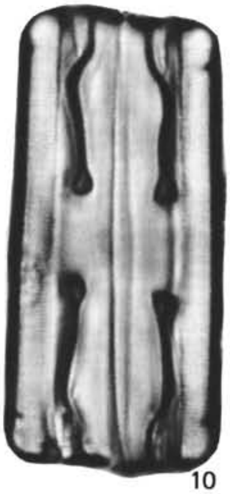
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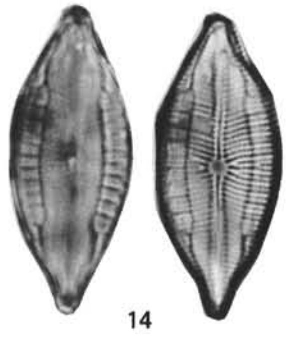
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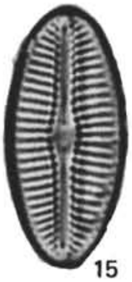
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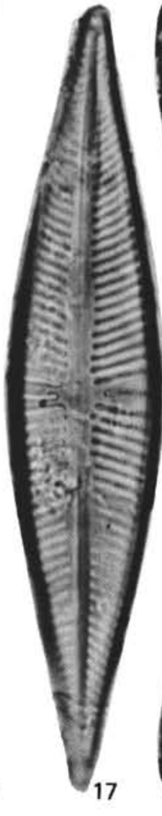
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PLATE 16

Figure 1	*Stephanodiscus niagarae* Ehr. Sample 381-29-5, 32 cm.
Figures 2,3	*Stephanodiscus-Cyclotella* sp. indet. 2. Sample 381-29-6, 50 cm. 3. Sample 381-29-5, 32 cm.
Figure 4	*Stephanodiscus carconensis* Grunow (asymmetric). Sample 381-29-4, 69 cm.
Figures 5,6	*Stephanodiscus astraea* (Ehr.) Grunow (triangulate). Sample 381-29-5, 32 cm.
Figure 7	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 381-29-6, 50 cm.
Figures 8,9	*Gyrosigma kützingii* (Grun.) Cleve. 8. Sample 381-31-2, 86 cm (1140 ×). 9. Sample 381-31-3, 42 cm (1200×).

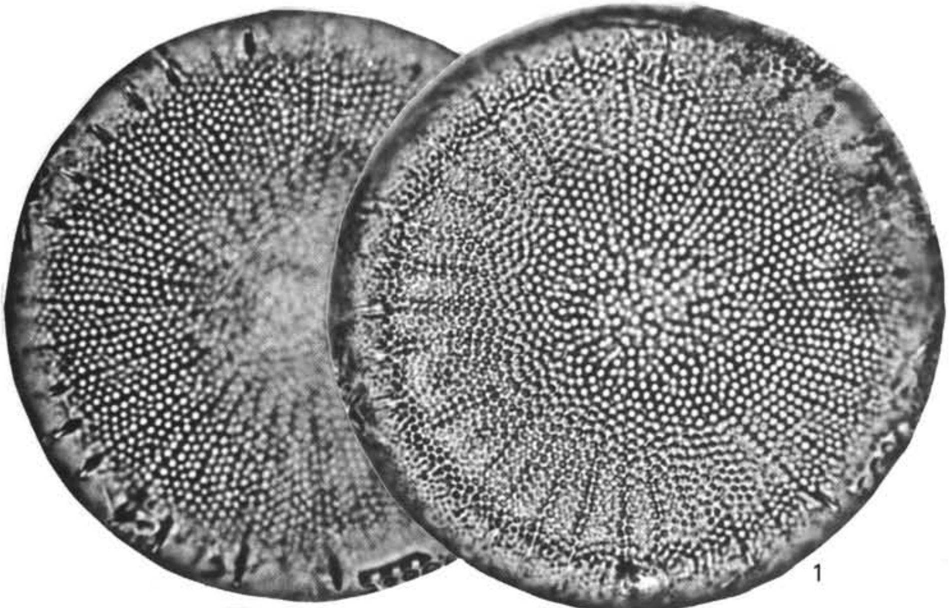
(see p. 898)

PLATE 17

Figures 1,2	*Stephanodiscus niagarae* Ehr. 1. Sample 381-29-6, 50 cm. 2. Sample 381-29-5, 32 cm.
Figures 3,4	*Stephanodiscus transylvanicus* (Pant.) Serv.-Vild. Sample 381-29-6, 50 cm.

(see p. 899)

PLATE 16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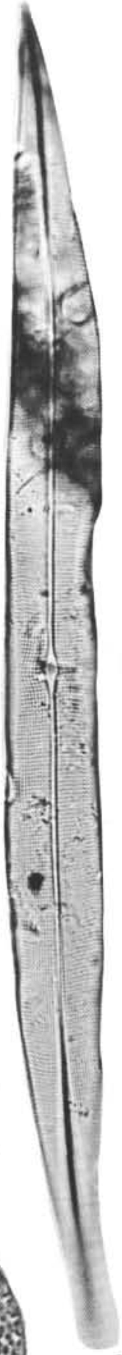
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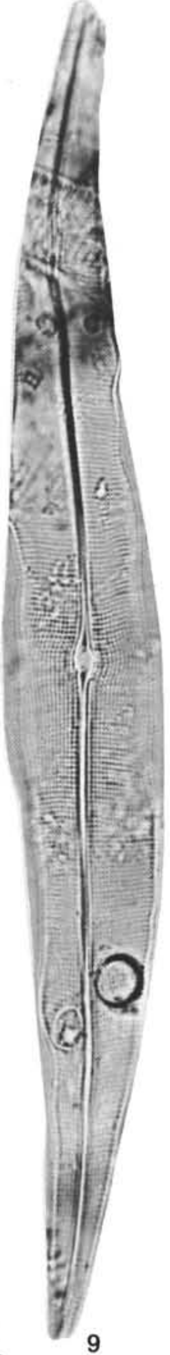
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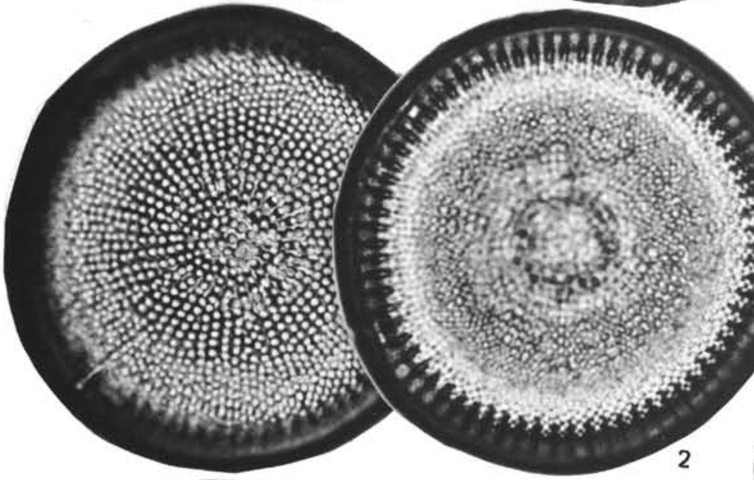
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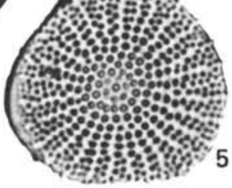
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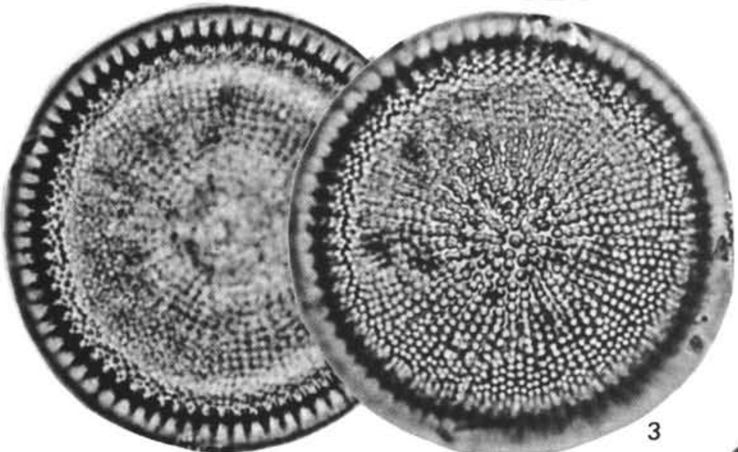
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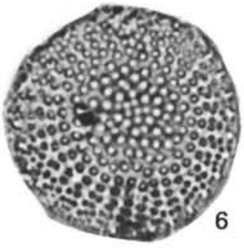
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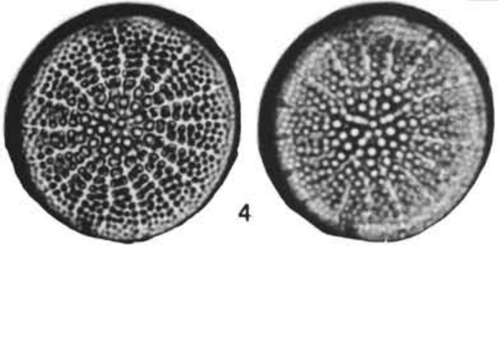
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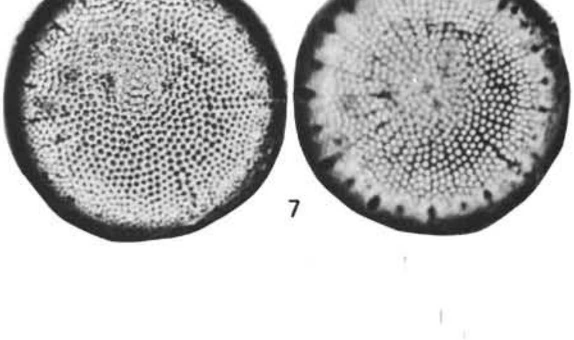
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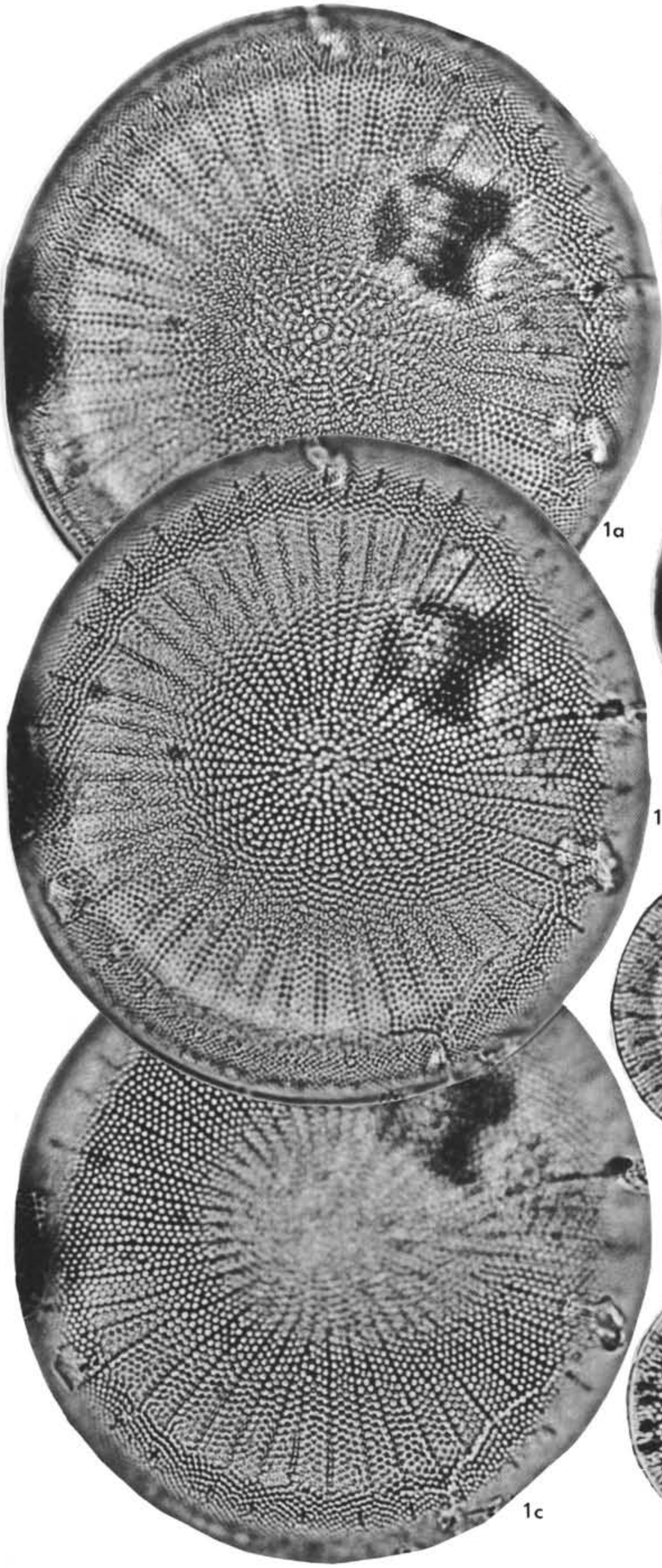
PLATE 17



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1c

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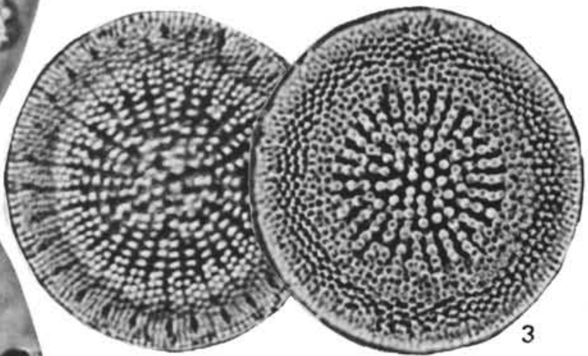

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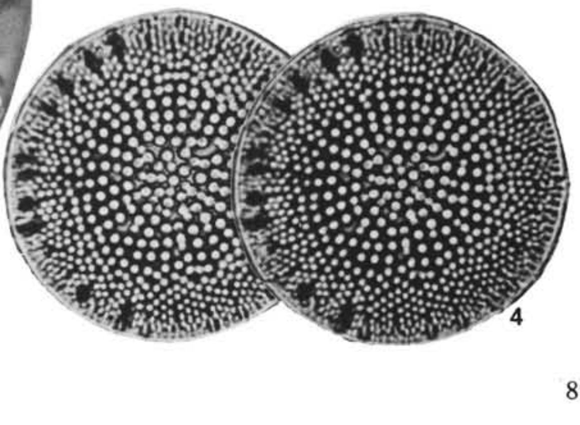

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PLATE 18

Figures 1-15	*Chaetoceros* spores — different species. 1. Sample 381-37-2, 114 cm. 2. Sample 379A-8-1, 100 cm. 3,4. Sample 381-37-2, 114 cm. 5,6. Sample 379A-18-2, 137 cm. 7-9. Sample 381-37-2, 114 cm. 10. Sample 380A-51-6, 68-70 cm. 11. Sample 381-37-2, 114 cm. 12. Sample 380A-51-6, 68-70 cm. 13. Sample 380A-3-4, 67 cm. 14, 15. Sample 381-37-2, 114 cm.
Figure 16	*Rhizosolenia calcaravis* M. Schulz. Sample 381-1-3, 74 cm (1140 ×).
Figure 17	*Skeletonema costatum* (Grev.) Cleve Sample 379A-18-2, 137 cm.
Figure 18	*Chaetoceros* spore. Sample 379A-18-2, 137 cm.
Figures 19-22	*Chrysophyceae*-cysts. 19, 20. Sample 380A-54-4, 74-76 cm. 21, 22. Sample 380A-51-6, 68-70 cm.
Figures 23,24	*Melosira islandica* O. Müller (valve view). Sample 380A-53-2, 84-86 cm.
Figures 25-28	*Chrysophyceae*-cysts. 25. Sample 379A-18-2, 137 cm. 26. Sample 380A-41-1, 110-112 cm. 27. Sample 380A-52-6, 94-96 cm. 28. Sample 381-37-2, 114 cm.
Figure 29	*Dictyocha fibula* Ehr. Sample 379A-9-4, 60 cm.
Figures 30-33	*Hermesinum adriaticum* Zachar. 30. Sample 381-35-5, 61 cm. 31. Sample 381-1-3, 74 cm. 32, 33. Sample 380A-56-1, 76-78 cm.

PLATE 18


1


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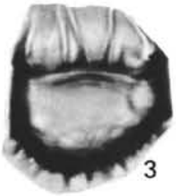
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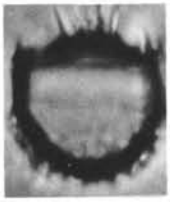
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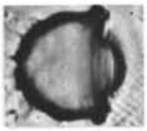
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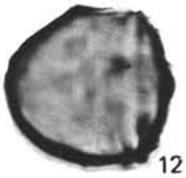
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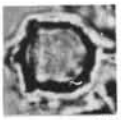
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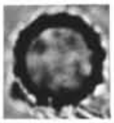
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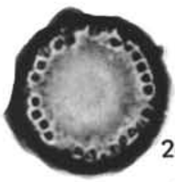
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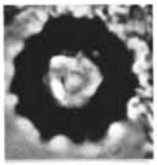
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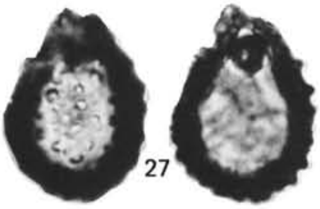
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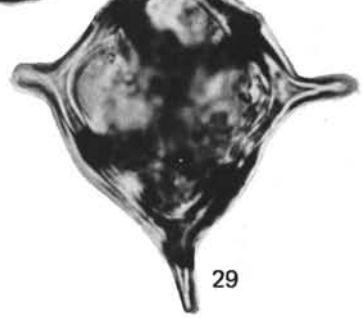
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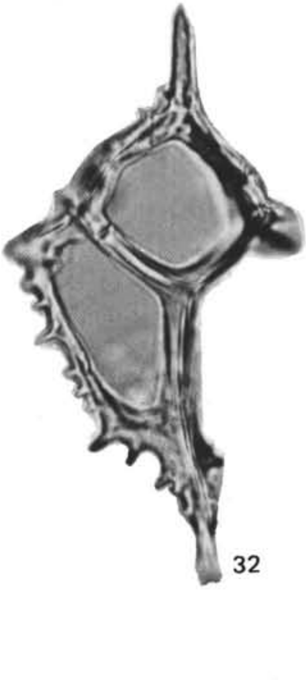
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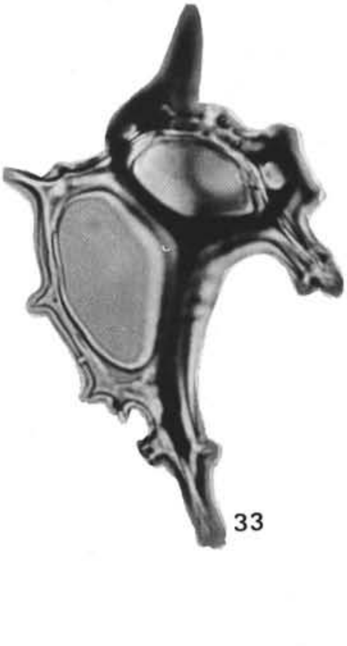
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