34. THE LATE MESSINIAN MEDITERRANEAN BRACKISH TO FRESHWATER ENVIRONMENT, DIATOM FLORAL EVIDENCE

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ABSTRACT

Uppermost Messinian dolomitic mudstone with intercalated biogenic siliceous ooze in both Sites 124 (today at a water depth of 2726 m) and Site 374 (today at a water depth of 4090 m) contain a low diversified, autochthonous, almost monospecific, brackish, planktonic diatom assemblage, indicating a salinity range from 0°/₀₀ to 17°/₀₀ and 17°/₀₀ to 40°/₀₀, respectively. These findings indicate a 'lac mer' type of shallow euryhaline, isolated lake environment.

INTRODUCTION

First indications and proof of a brackish to freshwater upper Messinian environments in the Mediterranean area, based on diatoms, was published by Hajos (1973). Schrader (1975) presented evidence for a late Miocene age of the Tripoli at the Capodarso Messinian stratotype section in Sicily, and concluded from directly overlying shallow-water brackish floras within the Pasquasia section that the desiccation of the Mediterranean basin, as postulated on paleontological and sedimentological data (Hsü et al., 1973), occurred within the uppermost part of the Miocene (around 5.5 m.y.B.P.). Since the sample preparation of Hajos (1973) did not follow the standardized procedure of Schrader (1974b) and because, after comparison of her occurrence charts, most of the finer silicified and smaller frustules appeared to have been removed from the samples, the original samples were restudied (from DSDP Leg 13, Site 124) (Figure 1). Moreover, the proposed ecological habitats of Hajos (1973) could only be proven by re-examination of original material and it is our aim to provide detailed information on the total diatom flora and to try to place the assemblages into the halobian system of Simonsen (1962) presented in Figure 2.

METHOD

Samples from DSDP Leg 13 were sampled by the curatorial staff at Lamont-Doherty Geological Observatory on a sample request by Andrew Gombos; samples from DSDP Leg 42A were collected by Carla Müller upon the senior author's authorized request to Ken Hsü; samples from the Pasquasia-Capodarso Section were collected by M. J. Brolsma, Geol. Inst., Utrecht.

All samples were cleaned and microscopic slides were made according to the standardized method of Schrader (1974b). Abundance calls were made using definitions given in Schrader and Fenner (1976).

Microscopic investigations were done on Leitz-Orthoplan-Orthomat automatic photocamera using high power and high resolution apochromatic oil immersion objectives (n.A.1.4). Counts were made, using highest available magnifications on all diatom individuals, along one or two traverses, randomly laid across the slide. Generally more than 500 individuals were counted per sample.

Site 124 (Figures 1, 2, 3 and Table 1)

Site 124 of DSDP Leg 13 is located over the western flank of a buried nonmagnetic basement ridge at the foot of the continental rise southeast of the Balearic Platform, at 38°52,28'N and 04°59,69'E, and was drilled in water depth of 2726 meters into 422.2 meters subbottom (Figure 1). This site has already been studied for its diatomaceous flora by Hajos (1973), who had Samples 124-13-2, 89 cm, and 124-13-2, 127 cm available for her shore-based study. Because these samples were washed (there is no indication if they were sieved) and mounted in Caedax as Hajos (1973) stated, we restudied newly obtained samples. All four samples were selected from Core 13, Section 2 (at 65 cm, at 80 cm, at 95 cm, and at 110 cm) within finely laminated dolomitic marls with dark green to black interbeds. The section was considered by the shipboard paleontologists to be late Miocene in age. A thin interbed of anhydrite separates the dolomitic ooze into an upper and a lower part. An overlying massive anhydrite section with fine "chicken-wire" structure is comparable to modern deposits in coastal sabkha environment of the Trucial Coast in the Persian Gulf (Kinsman, 1966, 1969).

Sixty-three percent of the diatom assemblage of the sample at 65 cm consists of *Synedra indica*, which is a weakly silicified marine planktonic species and is today

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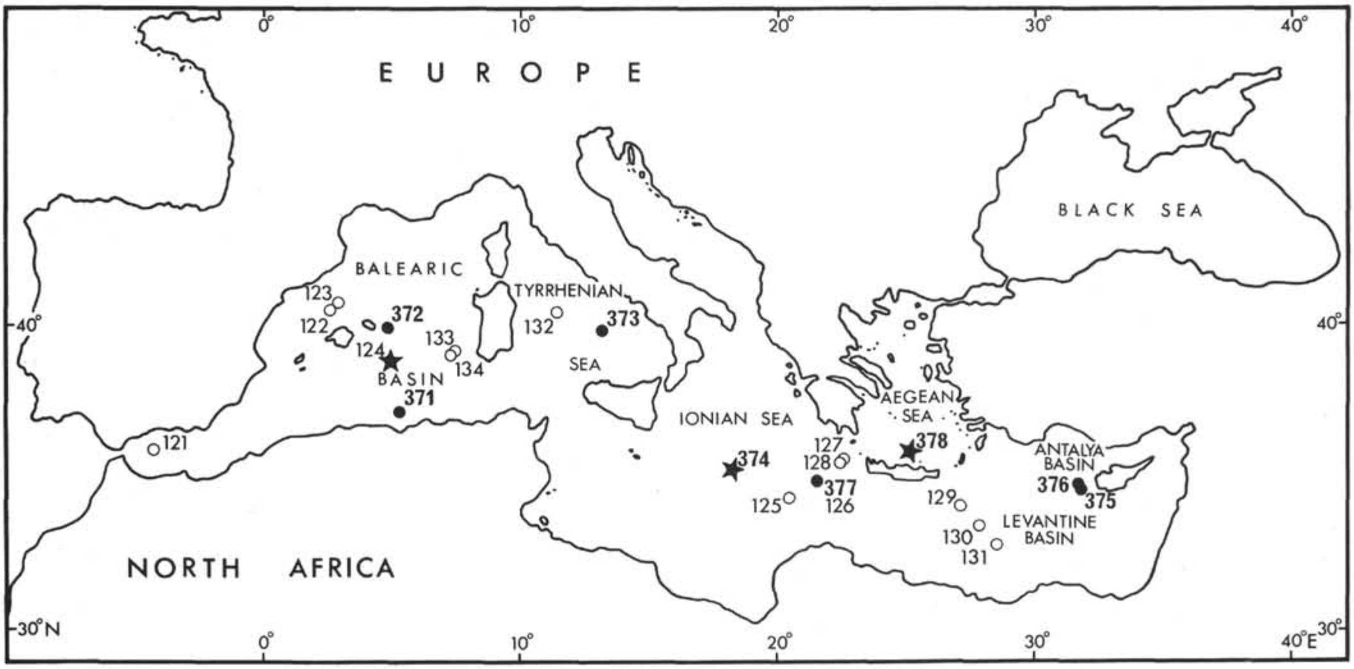

Figure 1. *Drill sites of Leg 42A and Leg 13; starred locations are investigated in this paper.*

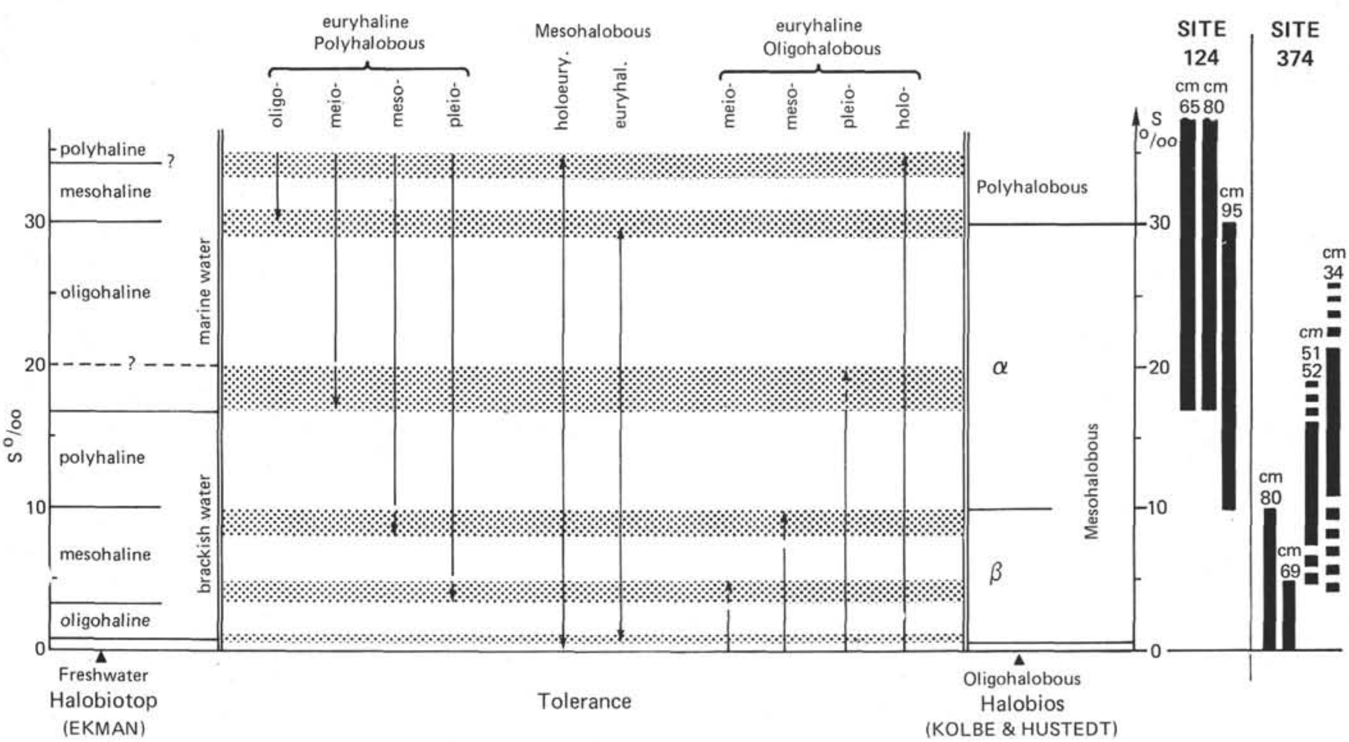

Figure 2. *Classification of halobiotops, of inhabitants of saline environments and salinity tolerance of species (after Simonsen, 1962) and tentative positions of Site 124, Core 13, Section 2 and Site 374, Core 17, Section 1 within the halobian system.*

restricted to the Indian Ocean (salinity 35-36°/₀₀) where it was frequently observed in near-shore stations (Simonsen, 1974). The species has also been found in large quantities in several Pliocene core sections from Leg 42B, Black Sea (Schrader 1976, in press). There it is accompanied by *Actinocyclus ehrenbergii* (polyhalobous, euryhaline, 10-37°/₀₀), *Chaetoceros* spores (polyhalobous, euryhaline), and the ebridiaceae *Hermesinum adriaticum* (polyhalobous). The salinity tolerance of *Synedra indica* is not known; from study of the assemblages from the Black Sea cores it may be euryhaline. Most of the individuals were found packed into fecal pellets.

Chaetoceros spores of the *Chaetoceros holsaticus* type are the next common constituent and make up 29% of the assemblage. Minor constituents are *Asterio-*

nella japonica (2.7%) and *Coscinodiscus kützingii* (1.8%). Approximately 0.01% of the total diatom assemblage is interpreted as being displaced by erosion; they constitute the marine element and include *Coscinodiscus oculus-iridis, Distephanus speculum, Thalassiothrix longissima, Actinoptychus undulatus, Thalassionema nitzschioides*, and *Diploneis smithi*. Radiolarians and sponge spicules are present in trace amounts.

The following species present are used as salinity indicators: *Synedra indica* (polyhalobous), *Chaetoceros spores* (polyhalobous), *Asterionella japonica* (mesohalobous), *Melosira dubia* (mesohalobous, Hustedt, 1930), *Mastogloia braunii* (β-mesohalobous, Simonsen, 1962), *Coscinodiscus kützingii* (polyhalobous) *Thalassiosira visurgis* (oligohalobous), *Melosira westii* (polyhalobous), *Opephora martyi* (oligohalobous, indifferent pleioeuryhaline, Simonsen, 1962), *Thalassiosira baltica* (mesohalobous). A marine water halobiotop (Ekman), or a polyhalobe halobios (Kolbe and Hustedt) with a salinity range of 17-40°/∘∘ can be concluded (Figure 2); 96.5% of the diatom assemblage is planktonic and only 3.5% is benthic. Typical freshwater diatoms are not observed. Floral analysis can be obtained from Figure 3 and Table 1. Because of good preservation of almost all individuals and lack of size sorting, the assemblage is interpreted to be autochthonous.

The sample at 80 cm differs from the above-described sample in having only rare *Chaetoceros* spores, and trace occurrences of displaced marine species such as *Coscinodiscus nodulifer* and *Thalassionema nitzschioides*. The assemblage consists of *Synedra indica* (88%), *Cyclotella striata* (3.3%, β-mesohalob, *p*H indifferent, mesooxybiont, Hustedt, 1957), *Melosira dubia* (1.1%), *Thalassiosira baltica* (1.1%), *Asterionella japonica* (1.8%), *Mastogloia braunii* (0.2%), *Mastogloia elliptica* (0.5%, α-mesohalobous, Simonsen, 1962), *Mastogloia* sp. a (1.4%). These species also represent a marine water halobious environment (17-40%). The majority of the assemblage is autochthonous. The floral content is listed in Table 1 and summarized in Figure 3; 95.6% of the flora is interpreted as planktonic.

The sample at 95 cm contains only trace amounts of displaced polyhaline species such as *Nitzschia granulata, Thalassionema nitzschioides*, and *Diploneis campylodiscus*. Radiolarians and sponge spicules are found sporadically. The assemblage (99.1% planktonic species), consists of 84.3% *Synedra indica, Cyclotella striata* (β-mesohalobous, 0.5-10°/∘∘ S.), *Asterionella japonica* (3.1%), and *Mastogloia* spp. (0.8%) and is thought to indicate a salinity range of 10-30°/∘∘ S, slightly less saline than the sample at 80 cm (Figure 2). The total flora appears to represent an autochthonous assemblage. Results are tabulated in Table 1 and Figure 3.

The sample at 110 cm contains a diatom flora of heavily silicified frustules, all in small quantities and most of them fall into the size fraction of 40 μm. Polyhaline species are *Cocconeis pediculus* (R), *C. quarnerensis* (R), *Nitzschia granulata* (R), *Achnanthes brevipes* (R), *Actinoptychus undulatus* (R), *Thalassiothrix longissima* (R), *Coscinodiscus marginatus* (R); mesohaline species are *Mastogloia* sp., *Campylodiscus clypeus* (R), *Cyclotella striata* (F), *Mastogloia elliptica* (R), *Asterionella japonica* (R), and *Thalassiosira baltica* (R). Scarce occurrences of *Melosira granulata* are noted. The total flora is interpreted to be displaced and mixed. Quartz grain contents up to 40% support this conclusion and therefore no ecological interpretations are made.

Site 374 (Figures 1, 2, 4, and Table 2)

Site 374 of Leg 42A is located in the central part of the Ionian Abyssal Plain at 35°51′N and 18°12′E in a water depth of 4078 meters (Figure 1).

Ten samples (14-1, 140-141 cm; 15-1, 80-82 cm; 15-2, 138-140 cm; 17-1, at 34 cm, at 51 cm, at 52 cm, at 69 cm, at 80 cm; 19-1, 135 cm; 21-1, 126 cm) were made available for diatom studies. Only in the laminated gray to black dolomitic mudstone sediments of Core 17, Section 1, is found an abundant and well-preserved diatom assemblage. The other samples are barren of diatoms (see above). The diatomaceous organic-rich mudstone of Core 17, Section 1, overlies a breccia of mudstone pieces and crenulated gypsum layers, and underlies a thin stromatolithic mudstone and a black coarsely crystalline gypsum layer (Figure 4). The section is considered by the shipboard paleontologists to be late Miocene (Messinian) in age.

The diatom assemblages in all five samples of Core 17, Section 1, are well preserved. They are composed of a limnic to brackish flora. A few marine species with coarse frustule structure (*Actinocyclus ehrenbergii, Actinoptychus undulatus, Cocconeis quarnerensis, Melosira sulcata, Navicula lyra*, and *Thalassiothrix longissima*) were found only in the samples at 51 cm, 52 cm, and at 80 cm. The flora has a very low diversity and consists of only two to six main components making up approximately 95% of the total flora (Figure 4 and Table 2). These most abundant species show a large variability in size and structure (compare *Asterionella japonica*: Plate 2, Figures 3-7, *Thalassiosira* sp. a: Plate 2, Figures 13-18). Two of the principal species, *Cyclotella* aff. *meneghiniana* and *Cyclotella* aff. *kützingiana*, were not accurately identified due to taxonomic uncertainties. Thus, the plankton:benthos ratio in all samples is questionable. If the two species are planktonic, the calculated ratio follows the solid line in Figure 4, but if *Cyclotella* aff. *kützingiana* is a benthic dwelling species, the ratio follows the stippled line. In the latter case the fraction of benthic diatoms in the sample at 34 cm makes up approximately 99% of the flora, because *Mastogloia braunii* is also a benthic species. This result agrees with the sedimentological observation at this level: stromatolithic mudstone, overlain by a gypsiferous interval.

The diatom flora of the sample at 80 cm consists of three main components: *Asterionella japonica* (61.5%), *Stephanodiscus astraea* (19%), and *Cyclotella* aff. *kützingiana* (11.5%). *Asterionella japonica* is mesohalobous and *S. astraea* is oligohalobous, and a typical

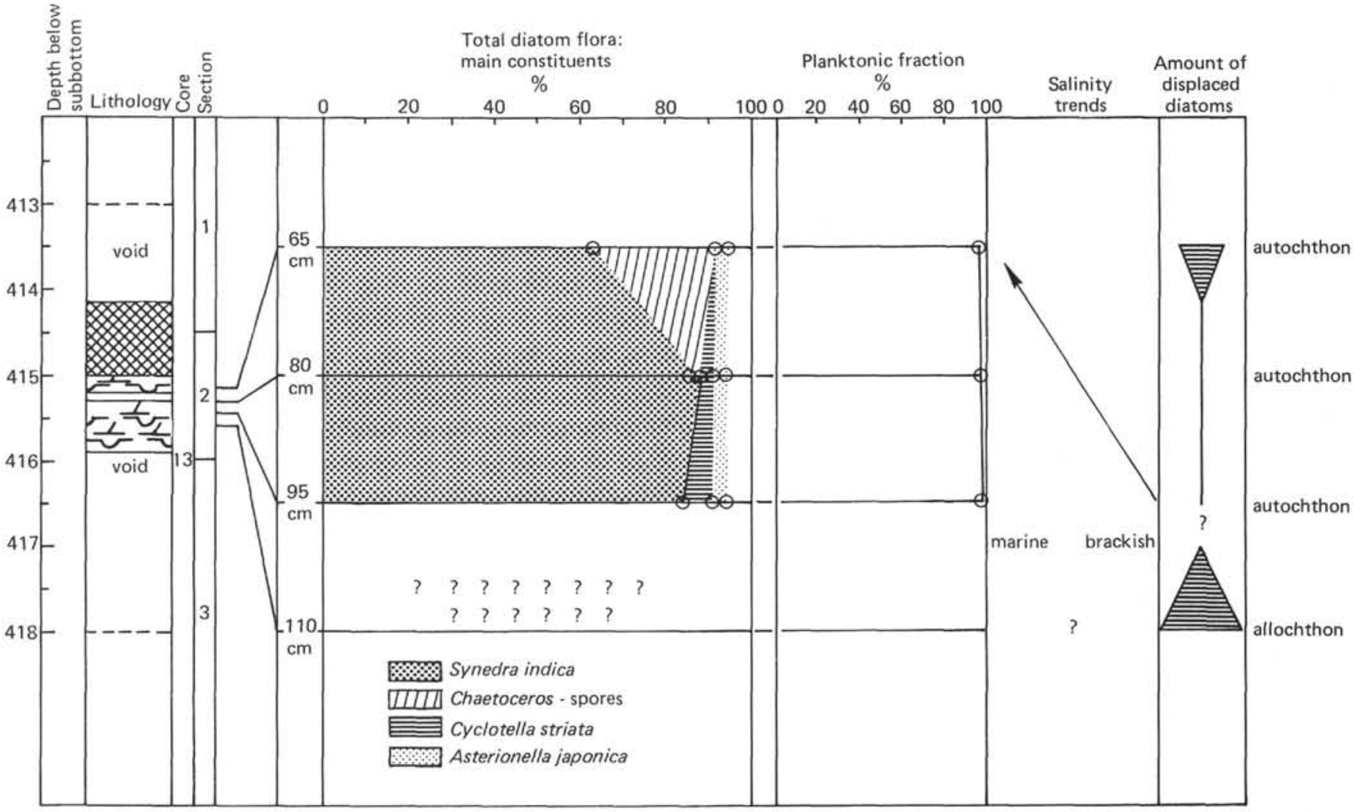

Figure 3. *Summary figure of diatom analysis of Leg 13, Site 124, Core 13, Section 2.*

freshwater dwelling species (Hustedt, 1959; Simonsen, 1962). Because the exact taxonomic position of *C.* aff. *kützingiana*, as well as *C.* aff. *meneghiniana*, could not be determined, the ecological habitat interpretation is rather tentative (see under the sample at 34 cm). Species with mesohalobous habitat form up to 64.7% of the flora (*Mastogloia braunii* 1.7%, *Melosira dubia* 1.5%, and *Asterionella japonica* 61.5%), species with oligohalobous habitat are less common (*Melosira granulata* 1.3% and *Stephanodiscus astraea* 19%). These indicator species point to halobios (Kolbe and Hustedt) with a β-mesohalobous salinity range (0-10‰ S, Figure 2). Over 80% of the flora is planktonic. The preservation of the diatom assemblage is good and supports the assumption that this flora is autochthonous. An almost negligible fraction (<0.01%) of marine species is interpreted as being allochthonous. Results are tabulated on Table 2 and Figure 4.

The diatom assemblage in the sample at 69 cm differs from the former in the abundance of oligohalobous diatom species. The oligohalobous species make up more than 50% of the flora. The high abundance of oligohalobous species point to a halobious environment with salinity less than in the sample at 80 cm (lower β-mesohalobious approximately 0-5°/°° S, Figure 2); 80% of the flora is planktonic and the assemblage is interpreted, by the excellent preservation of tests, to be autochthonous. Fecal pellets packed with *Asterionella japonica* are common. No admixture of displaced marine species was observed. All fecal pellets observed in this study are thought to be produced by zooplankton. Their diameter ranges from 30 to 75 μm.

The sample at 51 cm and 52 cm contain an almost equal diatom assemblage. Oligohalobous species are rare or absent. *Asterionella japonica* (mesohalobous) forms the main constituent of the assemblage. *Cyclotella* aff. *meneghiniana* forms a relatively minor (20%) constituent. An increased salinity is postulated for these two samples relative to the lower two samples because of the absence of oligohalobous indicator species. Over 90% of the assemblage is planktonic. Fecal pellets packed with *Asterionella japonica* are again common. Although weakly silicified species are abundant, the assemblage is well preserved, and therefore the flora is thought to be autochthonous. Only a few (<0.01%) displaced marine species occur.

The sample at 34 cm, taken from a stromatolothic mudstone which almost directly underlies a gypsum bed, differs in the diatom flora from all samples taken below; 94% of the total flora is formed by *Cyclotella* aff. *kützingiana* (79%) and *Mastogloia braunii* (15%), which is a mesohalobous benthic species. Since we were unable to determine the ecological habitat (whether planktonic or benthic) of *C.* aff. *kützingiana,* we have used sedimentary data which indicate a shallow depositional environment (Shipboard Scientific Party). Typical planktonic species such as *Asterionella japonica* are almost absent from this sample; other oligohalobous planktonic species such as *Stephanodiscus astraea* and *Melosira granulata* are rare (<0.1%), *Cyclotella* aff. *meneghiniana* and *Thalassiosira* sp. a are both absent. The monospecific character of the diatom assemblage certainly is indicative of conditions of extreme ecological stress.

TABLE 1
Diatom Floral Analysis, Site 124

DSDP Leg 13, Site 124 Core 13, Section 2	65 cm	80 cm	95 cm	110 cm		
Occurrence of Diatoms	C	A	C	F		
Preservation of Diatoms	G	G	G	M	Salinity range after Simonsen (1962) Hustedt (1959)	p-planktonic species b-benthic species
Counted Diatom Frustules	1376	1099	771			
Fecal Pellets	R	R	C			
Synedra indica	63	88.8	84.3	–	polyhalob	p
Chaetoceros-spores	29	0.1	–	–	polyhalob	p
Asterionella japonica	2.7	1.8	3.1	R	mesohalob	p
Melosira dubia	0.3	1.1	4.0	F	mesohalob	p
Melosira westii	0.3	–	–	–	polyhalob	p
Melosira cf. *dickei*	1.2	1.5	–	R		p
Thalassiosira baltica	R	1.1	–	R	mesohalob	p
Cyclotella striata	0.07	3.3	7.7	F	β mesohalob	p
Coscinodiscus kützingii	1.8	0.4	–	–	polyhalob	p
Mastogloia braunii	0.4	0.2	0.2	–	β mesohalob	b
Mastogloia sp. a	0.5	1.4	0.6	R		b
Mastogloia elliptica	–	0.5	–	R	α mesohalob	b
Thalassiosira visurgis	R	–	–	–	oligohalob	p
Phytoliths	–	–	–	R		
Coscinodiscus marginatus	–	–	–	R	polyhalob	p
Campylodiscus clypeus	–	–	–	R	α mesohalob	b
Achnanthes brevipes	–	–	–	R	mesohalob, euryhalin	
Melosira granulata	–	–	–	R	oligohalob,(?) meioeuryh.	p
Epithemia turgida	–	–	–	R	oligohalob, pleioeuryh.	b
Cocconeis pediculus	–	–	–	R	oligohalob, mesoeuryh.	b
Opephora martyi	R	–	–	–	oligohalob, pleioeuryh.	b
Stephanopyxis turris	T	–	–	–	polyhalob	p
Coscinodiscus oculus-iridis	T	–	–	–	polyhalob	p
Distephanus speculum	T	–	–	–	polyhalob	p
Thalassiothrix longissima	T	–	–	R	polyhalob	p
Actinoptychus undulatus	T	–	–	R	polyhalob	p
Thalassionema nitzschioides	T	T	T	–	polyhalob	p
Diploneis smithii	T	–	–	–	polyhalob, pleioeuryh.	b
Cocconeis quarnerensis	T	–	–	R	polyhalob	b
Nitzschia granulata	–	T	T	–	polyhalob	b
Coscinodiscus nodulifer	T	–	–	–	polyhalob	p
Diploneis campylodiscus	–	–	T	–	polyhalob	b
Sponge spicules	T	–	T	R		
Radiolarians	T	–	T	–		

Note: Numbers are percent of total diatom flora. T = trace, R = rare, C = common, A = abundant.

Site 378 (Figures 1 and 5 and Table 3)

Site 378 is located on the northern flank of a small depression in the North Cretan Basin of the Aegean Sea. Its coordinates are 35°55.67′N and 25°06.97′E with a water level of 1829 meters below sea level (Figure 1). Three samples were made available for shore-based diatom studies. All three samples were taken from sapropelic layers within dominantly nannofossil marls.

Sample 1, 81 cm, contains a low diversified fully marine diatom assemblage with minor admixtures of displaced marine benthic species (10%) and displaced freshwater species (5%). The dominating forms are *Thalassionema nitzschioides, Thalassiosira oestrupii*, and *Thalassiosira oestrupii* var. *parva*. The rather scarce occurrence of *Pseudoeunotia doliolus* places this sample into the Pleistocene and the co-occurrence of *Nitzschia reinholdii* confirms an interval midway of the Brunhes Magnetic Epoch and the Olduvai Event (Schrader and Burckle, 1976).

Sample 8-2, 44 cm, contains a highly diversified full marine planktonic diatom assemblage with abundant and well-preserved tests. Silicoflagellates, sponge spicules, and radiolarians form a minor constituent. Amongst others, *Coscinodiscus nodulifer, Thalassionema nitzschioides, Thalassiothrix longissima*, and *Actinocyclus ehrenbergii* form, together with unidentifiable *Chaetoceros* spores, the main constituents. Occasionally even well-preserved fecal pellets were found fully compacted with *Thalassiosira* sp. Ninety-eight percent of the total diatom flora is marine planktonic and only 2% are regarded as displaced marine benthic species (*Diploneis* spp., *Caloneis* spp.). The occurrence of *Nitzschia fossilis*, the ancestor of *Pseudoeunotia doliolus*, and *Thalassiosira convexa* places this sample in the upper Pliocene (lower part of the Matuyama Reversed Magnetic Epoch). The absence of *Nitzschia jouseae* from the sample confirms this assignment even though the characteristic species of the *Rhizosolenia praebergonii* Partial Range Zone is lacking as well. The present authors as yet have failed to find evidence for

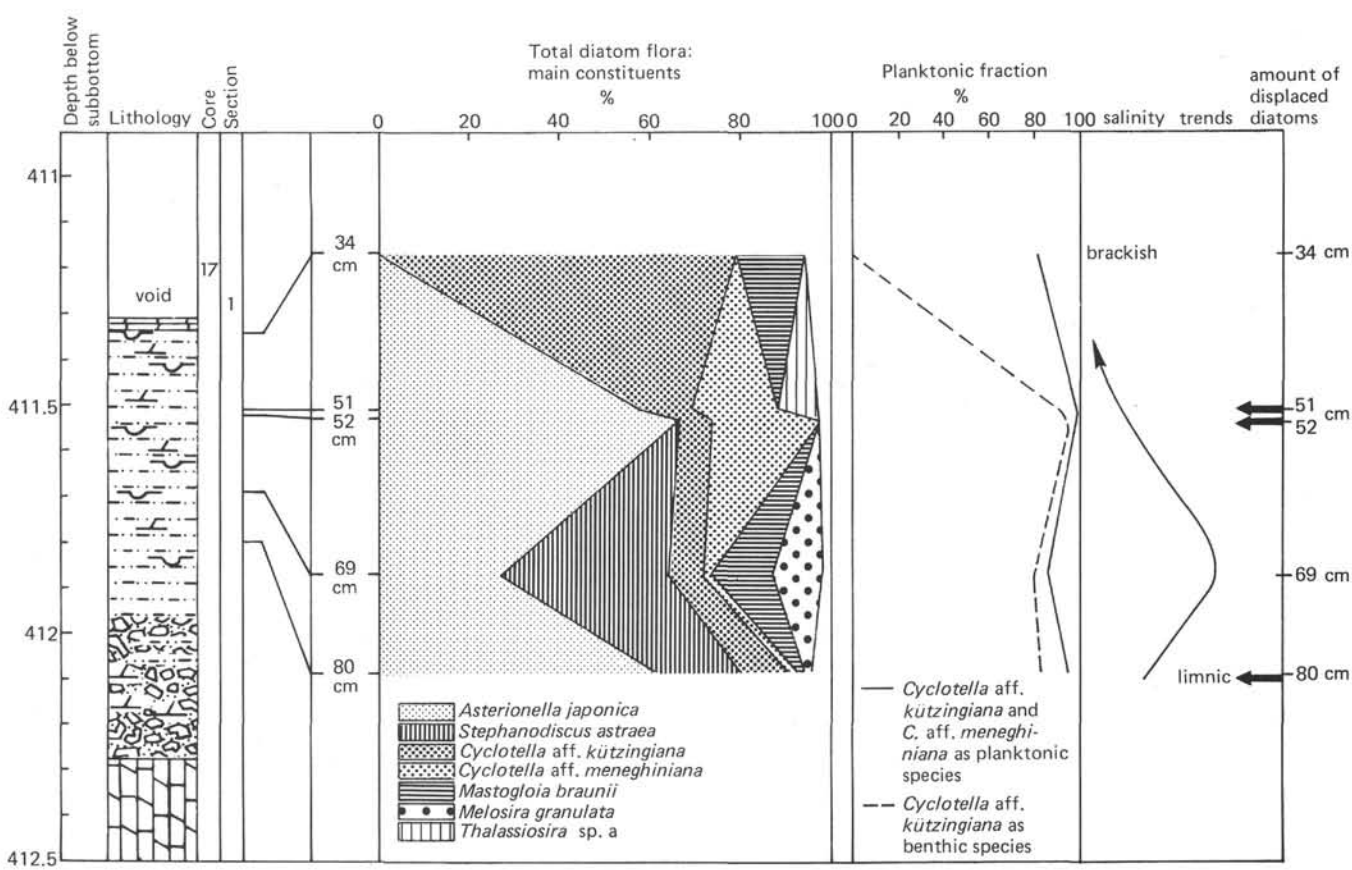

Figure 4. *Summary figure of diatom analysis of Leg 42A, Site 374, Core 17, Section 1.*

TABLE 2
Diatom Floral Analysis, Site 374

DSDP Leg 42A, Site 374 Core 17, Section 1	34 cm	51 cm	52 cm	69 cm	80 cm	Salinity Range after Simonsen (1962) Hustedt (1959)	p-planktonic species b-benthic species
Occurrence of Diatoms	A	A	A	A	C		
Preservation of Diatoms	G	G	G	G	G		
Counted Diatom Frustules	527	442	488	514	515		
Fecal pellets	–	C	C	C	–		
Asterionella japonica	–	58.4	66.6	26.9	61.5	mesohalob	p
Cocconeis pediculus	0.03	–	–	–	–	oligohalob, mesoeuryh.	b
Cyclotella aff. *meneghiniana*	–	19.5	23.6	2.0	1.7		? b
Cyclotella aff. *kützingiana*	79.0	11.3	5.5	8.6	11.5		? p
Epithemia zebra	–	–	–	T	–	oligohalob, mesoeuryh.	b
Mastogloia brauni	15.0	0.4	–	12.5	1.7	β mesohalob	b
Mastogloia aff. *brauni*	R	–	–	–	–		b
Melosira dubia	–	–	0.01	0.7	1.5	mesohalob	p
Melosira granulata	0.01	–	0.02	11.6	1.3	oligohalob,(?) meioeuryh.	p
Stephanodiscus astraea	0.05	–	1.0	37.7	19.0	oligohalob	p
Thalassiosira sp. a	–	10.4	1.6	–	–		p
Species indet.	5.9	–	1.7	–	2.5		
Actinoycylus ehrenbergii	–	T	T	–	–	polyhalob	p
Actinoptychus undulatus	–	–	–	–	T	polyhalob	p
Archaeomonadacea	–	–	–	–	T	polyhalob	p
Cocconeis quarnerensis	–	–	–	–	T	polyhalob	b
Melosira sulcata	–	–	T	–	–	polyhalob	p
Navicula lyra	–	–	T	–	T	polyhalob	b
Thalassiothrix longiss.	–	–	–	–	T	polyhalob	p
Hyalodiscus sp.		T	T			polyhalob	
Mastogloia smithi	R	–	–	–	–		

Note: Numbers are percent of total diatom flora. T = trace, R = rare, C = common, A = abundant.

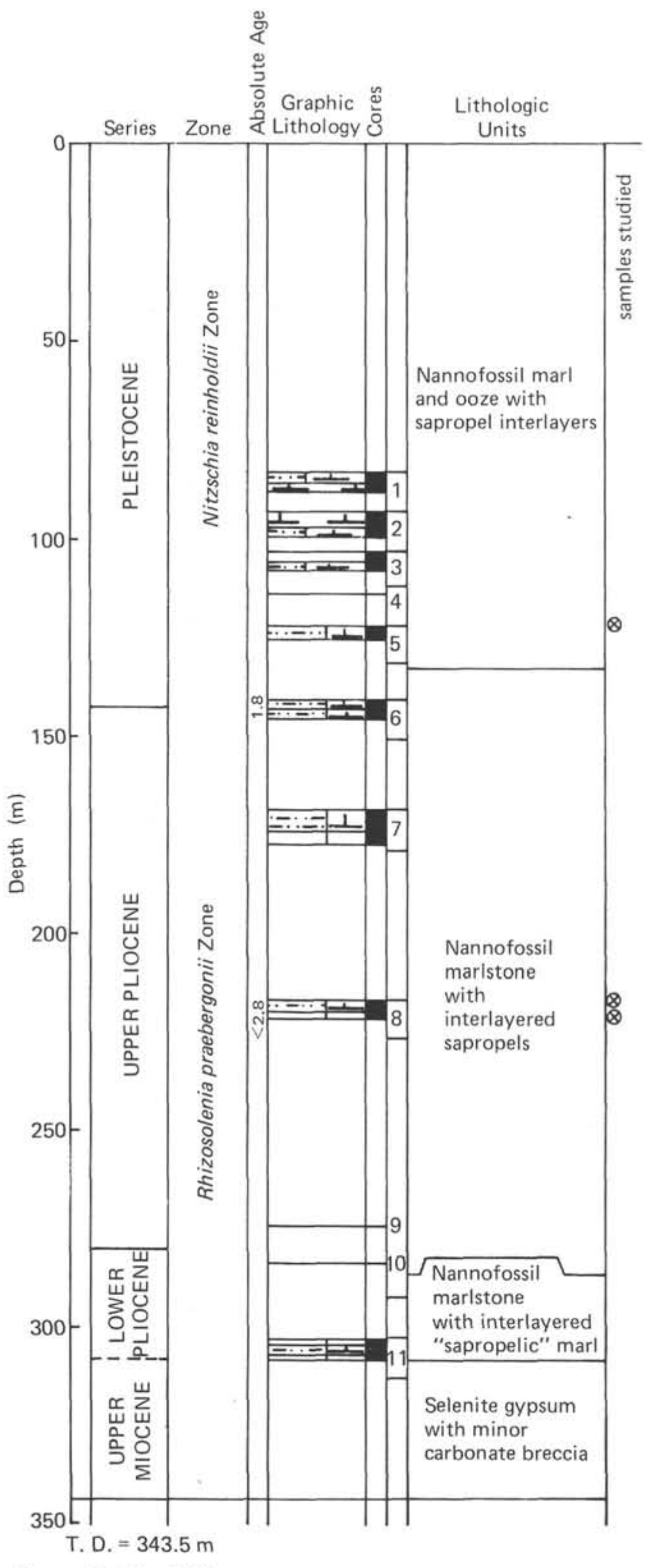

Figure 5. *Site 378 summary.*

the occurrence of *Rhizosolenia praebergonii* in the Mediterranean. The single occurrence reported by Burckle in Sanfilippo et al., 1973, is questioned since we were not able to detect the species in Section 8-2. The diatom flora of the sample indicates high nutrient supply and high primary productivity in the overlying water during part of the late Pliocene.

Sample 378-8, CC contains a highly diversified marine planktonic diatom assemblage but with higher admixtures of displaced marine benthic species (*Navicula lyra, Grammatophora oceanica, Synedra robusta, Melosira westii*) and displaced freshwater species (*Melosira granulata*). The floral content is very similar to the above sample and consists primarily of *Chaetoceros* spores and bristle fragments, *Thalassionema nitzschioides* and *Thalassiothrix longissima. Thalassiosira nativa* occurs together with *Thalassiosira oestrupii* in this sample. The differentiation between these two closely related species is based on the following morphological characteristics: the central process in *T. oestrupii* is slightly excentrically positioned whereas in *T. nativa* it is almost consistently positioned in the center. Girdle bands in *T. oestrupii* are thickened on one side, whereas in *T. nativa* they form almost symmetrical rings. This sample is also placed (floral reference, see Table 3) within the upper Pliocene, in the *Rhizosolenia praebergonii* Partial Range Zone (Burckle, 1972). The assemblage consists of 89% marine planktonic species and 11% displaced marine benthic species. The higher admixture of sponge spicules plus the increased admixture of marine benthic species indicates displacement of shallow-water material (range 0-50 m of water depth). A sedimentation rate of approximately 121 to 80 meters/m.y. can be calculated using the calibration (Schrader, 1974a) of diatom zones to the paleomagnetic stratigraphy and to the absolute time scale.

DISCUSSION

Samples from Site 374, Core 17, Section 1, represent part of the Upper Messinian "cyclic" evaporitic sediment sequences first observed in Leg 42A (see Site Summary chapter, shipboard scientific party). The environment of deposition for part of the finely laminated sapropelitic sequence was not typically marine, but brackish to limnic as deduced from diatom floral evidence. The brackish water environment of samples at 51-52 cm and 80 cm, β-mesohalobous, has changed to a more limnic environment at the level of the sample at 69 cm as a consequence of freshwater influx. Whether these freshwater influxes are cyclic or solitary, could not be tested by means of the available samples. Freshwater influx may have originated either from (1) the Paratethys, which was brackish to limnic in Messinian time, (2) river influx, or (3) heavy rainfalls. The proposed 'lac mer' hypothesis (Hsü et al., this volume) could be confirmed from the few available samples: a brackish-water environment with freshwater input. A true marine influence was not observed at the Ionian site.

Differing from the results of the Ionian Basin are those from the Balearic Rise, Site 124, Core 13, Section 2. The general trend from the bottom towards the top of the investigated section is one of an increase of surface water salinity. In the upper three samples the diatom assemblage is dominated by one polyhalobous species, although a normal marine diatom assemblage was not established. Only in the uppermost sample (65 cm) numerous euryhaline marine *Chaetoceros* spores

TABLE 3
Occurrence of Diatoms at Site 378

Site 378	Abundance marine planktonic diatoms	Preservation of diatoms	Abundance radiolarians	Abundance sponge spicules	Abundance silicoflagellates	*Actinocyclus ehrenbergii*	*Actinocyclus undulatus*	*Bacteriastrum* spp.	*Chaetoceros* spp. bristles	*Chaetoceros* spores	*Caloneis* spp. (benthic)	*Coscinodiscus obscurus*	*Coscinodiscus radiatus*	*Coscinodiscus nodulifer*	*Coscinodiscus lineatus*	*Coscinodiscus stellaris* var. *symbolophora*	*Grammatophora* spp. (benthic)	*Hemidiscus cuneiformis*	*Melosira granulata* (freshwater)
5-1, 81 cm	R	M	R	F	F					C		F					R	R	R
8-2, 44 cm	A	G	R	R	F	F	R		F	C	R	R	R	F					
8, CC	C	G	F	F	F	R	R	R	F	C					R	R	R		

Site 378	*Melosira sulcata*	*Melosira westii*	*Navicula lyra* (benthic)	*Nitzschia reinholdii*	*Nitzschia fossilis*	*Pseudoeunotia doliolus*	*Thalassionema nitzschioides*	*Thalassiothrix longissima*	*Thalassiosira excentrica*	*Thalassiosira oestrupii*	*Thalassiosira nativa*	*Thalassiosira convexa*	*Stephanopyxis turris*	*Thalassiosira oestrupii* var. *parva*	*Rhizosolenia styliformis*	*Rhizosolenia calcar avis*	*Synedra robusta*	*Diploneis* spp. (benthic)
5-1, 81 cm				R		T	C			F				F	R	R		
8-2, 44 cm				R	R		C	C	R	R		R	R		R			R
8, CC	R	R	R	R	R		C	F	R		R	R	R		R	R	R	

were observed. The almost entirely marine diatom assemblage of the sample at 110 cm is interpreted as being totally allochthonous. These most excellently preserved diatom floras, with abundant weakly silicified frustules, and an abundance of fecal pellets, packed with planktonic diatom species (Plate 2, Figure 24), enable us to make the following environmental interpretations:

1) Planktonic diatom productivity was high.

2) Anoxic bottom conditions limited production of benthic species.

3) Water depth: at Site 374, the depth ranges are most probably within 0 to 150 meters; while at Site 124 it was most probably within the range 50 to 1000 meters.

4) Increased intraspecific variability caused by numerous salinity changes.

5) Completely coherent algal rafting in the uppermost water column, as proposed elsewhere in this volume, cannot have occurred at those levels rich in fecal pellets.

The brackish-marine influx at the Balearic Rise site (124) can be interpreted as having resulted from periodic overflow of marine waters through the relatively close nearby Atlantic Ocean: marine waters entering the more remote Ionian Basin were restricted to entrance through the distant Strait of Sicily.

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PLATE 1

(Magnification 1500×)

Figures 1-3	*Cyclotella striata* (Kützing) Grunow. Sample 124-13-2, 65 cm.
Figures 4, 5	*Cyclotella comensis* Grunow. 4. Sample 374-17-1, 52 cm. 5. Sample 374-17-1, 34 cm.
Figures 6-8	*Cyclotella* aff. *meneghiniana* Kützing. 6, 7. Sample 374-17-1, 52 cm. 8. Sample 374-17-1, 34 cm.
Figures 9-16	*Cycylotella* aff. *kuetzingiana* Thwaites. 9-10. Sample 374-17-1, 52 cm. 11-16. Sample 374-17-1, 34 cm.
Figures 17, 18	*Melosira* cf. *dickei* (Thwaites) Kützing. Sample 124-13-2, 65 cm.
Figures 19-22	*Melosira dubia* Kützing. 19. Sample 124-13-2, 65 cm. 20-22. Sample 374-17-1, 34 cm.
Figure 23	*Melosira granulata* (Ehr.) Ralfs. Sample 374-17-1, 80 cm
Figures 24-28	*Thalassiosira* sp. a. Sample 374-17-1, 52 cm.
Figures 29-32	*Stephanodiscus astraea* (Ehr.) Grunow. 29, 30, 32. Sample 374-17-1, 80 cm. 31. Sample 374-17-1, 52 cm.
Figure 33	*Cyclotella* aff. *meneghiniana* Kützing. Sample 374-17-1, 52 cm.

PLATE 1

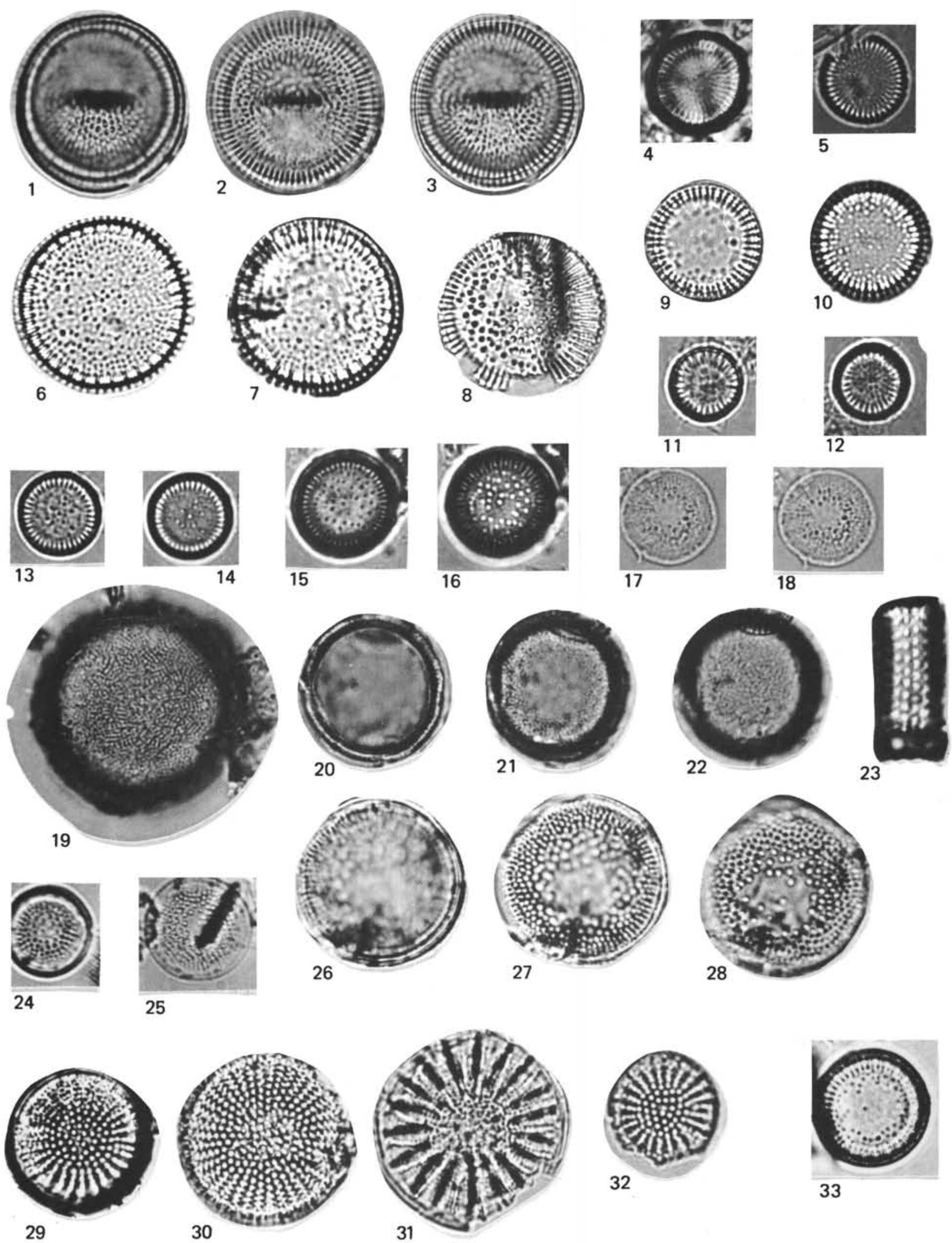
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PLATE 2

(Magnification 1500×)

Figures 1, 2	*Mastogloia* (?) sp. Sample 124-13-2, 65 cm
Figures 3-7	*Asterionella japonica* Cleve 3. Sample 374-17-1, 80 cm. 4. Sample 374-17-1, 34 cm. 5. Sample 374-17-1, 52 cm. 6. Sample 374-17-1, 80 cm. 7. Sample 374-17-1, 52 cm.
Figures 8-12	*Stephanodiscus astraea* (Ehr.) Grunow. Sample 374-17-1, 69 cm.
Figures 13-18	*Thalassiosira* sp. d. Sample 374-17-1, 51 cm.
Figures 19-23	*Synedra indica* Taylor. Sample 124-13-2, 95 cm.
Figure 24	Fecal pellet packed with *Asterionella japonica* Cleve. Sample 374-17-1, 52 cm (700 ×).

PLATE 2

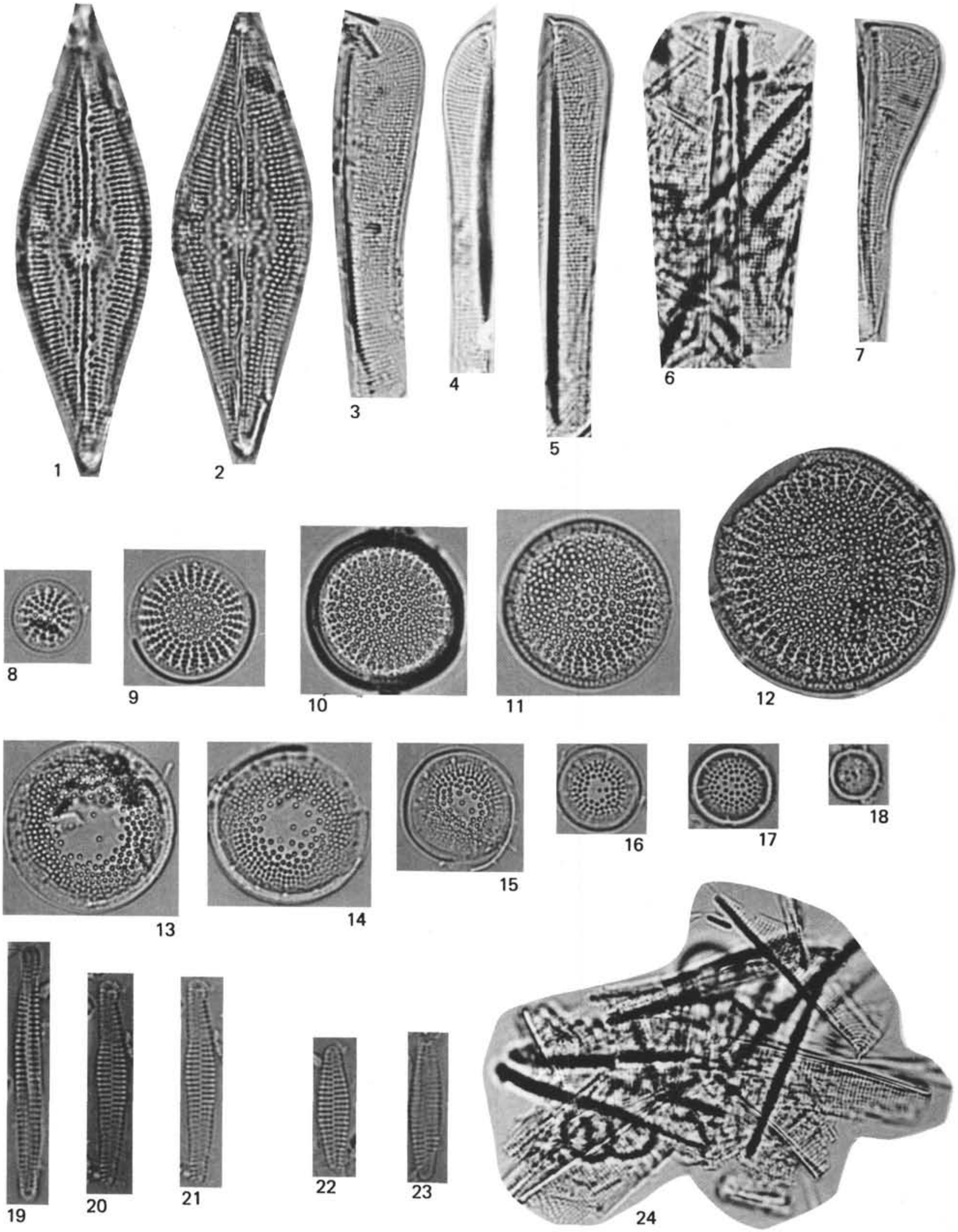

PLATE 3

(Magnification 1500 ×)

Figures 1-4	*Thalassiosira visurgis* Hustedt. Sample 124-13-2, 65 cm.
Figures 5-11	*Mastogloia brauni* Grunow. 5. Sample 124-13-2, 65 cm. 6. Sample 374-17-1, 34 cm. 7, 8. Sample 374-17-1, 34 cm. 9, 10. Sample 124-13-2, 65 cm. 11. Sample 124-13-2, 80 cm.
Figures 12-16	*Mastogloia* sp. a. 12-15. Sample 124-13-2, 65 cm. 16. Sample 124-13-2, 80 cm.
Figures 17, 18	*Mastogloia brauni* Grunow. Sample 374-17-1, 34 cm.
Figures 19, 20	*Mastogloia* aff. *brauni* Grunow. Sample 374-17-1, 34 cm.
Figures 21, 22	*Mastogloia elliptica* (Ag.) Cleve. Sample 124-13-2, 80 cm.
Figures 23, 24	*Mastogloia smithi* Thwaites. Sample 374-17-1, 34 cm.
Figure 25	*Mastogloia* sp. b. Sample 124-13-2, 80 cm.
Figure 26	*Synedra indica* Taylor. Sample 124-13-2, 65 cm.
Figure 27	*Opephora martyi* Heribaud. Sample 124-13-2, 65 cm.

PLATE 3