36. NEOGENE DIATOMS FROM THE NORTHWESTERN PACIFIC OCEAN, DEEP SEA DRILLING PROJECT

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INTRODUCTION

From studies of deep-sea cores made in the last few years (Hays et al., 1969; Donahue, 1970; Kobayashi et al., 1971; Burckle, 1972), the ranges of a number of diatom species in the North Pacific have become known in terms of the paleomagnetic scale. Among them, a biostratigraphic diatom zonation proposed by Burckle (1972) for the east equatorial Pacific is most useful in age assignments for the diatom events (tops and bottoms of ranges of taxa) in stratigraphic order. The comparisons of time ranges of the selected species in the subarctic section taken by DSDP Leg 19 (Koizumi, 1973b) and in the sections from the western margin of the North Pacific taken by DSDP Leg 31 (Koizumi, in press) with those from the east equatorial Pacific have not been well established. The reason for this is because there are only rare occurrences of the more common species of the diatom assemblages shown by Koizumi (1973b, in press) and those by Burckle (1972) in the same samples, due to the difference in geographic provinces of the living diatoms in each assemblage.

The mixing of the Pacific subarctic and Pacific central waters is known to take place in the northwest Pacific where the Oyashio and the Kuroshio currents meet to flow east, more or less along the parallel of 40° N. The study by Kanaya and Koizumi (1966) shows that a mixed diatom assemblage named is found only in the bottom sediments taken in the area within the geographic range of the mixed zone of two upper water masses mentioned. This mixed assemblage, the "Subarctic-Central Mixed Assemblage," in which both group I (formed by subtropical-tropical species) and group II (formed by subarctic species) components are represented.

Several Deep Sea Drilling Project sites in the middle latitudes of the northwestern Pacific allow a comparison within the same strata of zonal boundaries based on the high-latitude and low-latitude diatom assemblages.

The purposes of this report are (1) to present the stratigraphic distribution of diatom species in the northwestern Pacific, and (2) to correlate the Neogene diatom events between the subarctic and northwest Pacific margin sections by Koizumi (1973b, in press) and the east equatorial Pacific section by Burckle (1972). In addition, the paleoclimatic fluctuations, based on the percentages of cold and warm water species in each assemblage, were analyzed for the Pliocene through Pleistocene interval at each site.

Taxonomic references are made for all diatom taxa mentioned in this report. Most of the marine planktonic diatoms are illustrated.

MATERIAL AND METHOD OF STUDY

All of the samples are from DSDP cores, as listed below (Figure 1):

Leg 32, Site 303: 40°48.50′N, 157°27.07′E; water depth 5609 meters

Leg 32, Site 310: 36°52.11′N, 176°54.09′E; water depth 3516 meters

Leg 6, Site 47.2: 32°26.90′N, 157°42.70′E; water depth 2689 meters

Leg 20, Site 194: 33°58.66′N, 146°48.64′E; water depth 5754 meters

All materials have been treated with hydrogen perioxide but not with hydrochloric acid. The slide preparation procedures are those described by Koizumi (1973b, in press). Aroclor was used as a medium for making slides for light microscope observation.

All diatom species were identified and counted until a total of 100 or 200 specimens was found, excluding the genus *Chaetoceras*. The main attention in this study is directed toward the occurrences of the marine planktonic taxa selected by Koizumi (1973b, in press) and Burckle (1972) to be of stratigraphic importance in dealing with the Neogene diatom flora of the North and equatorial Pacific. Therefore, the microscope work was completed by examining the slides and by adding more occurrences of 100 or 200 specimens. Additions to the regular counting are shown by a black circle in the distribution charts.

Samples and slides studied in this report are deposited in the Micropaleontologic Laboratory of the Institute of Geological Sciences, College of General Education at Osaka University, Toyonaka, Osaka, Japan.

OCCURRENCES OF DIATOMS AND BIOSTRATIGRAPHY AT EACH SITE

The presentation of the information for each sample in this report closely follows that used in the diatom reports for DSDP Legs 19 and 31 (Koizumi, 1973b, in press).

In Tables 1, 2, 3, and 4, the following abbreviations are used:

Abundance is recorded as B=barren, VR=very rare (less than 100 individuals on one slide, 18 × 18 mm), R=rare (101 to 1000 individuals on one slide), F=few (1001 to 2000 individuals on one slide), C=common (2001 to 4000 individuals on one slide), and A=abundant (more than 4001 individuals on one slide).

Preservation is reported as p=poor, m=moderate, and g=good based on the degree of destruction of the diatom valves.

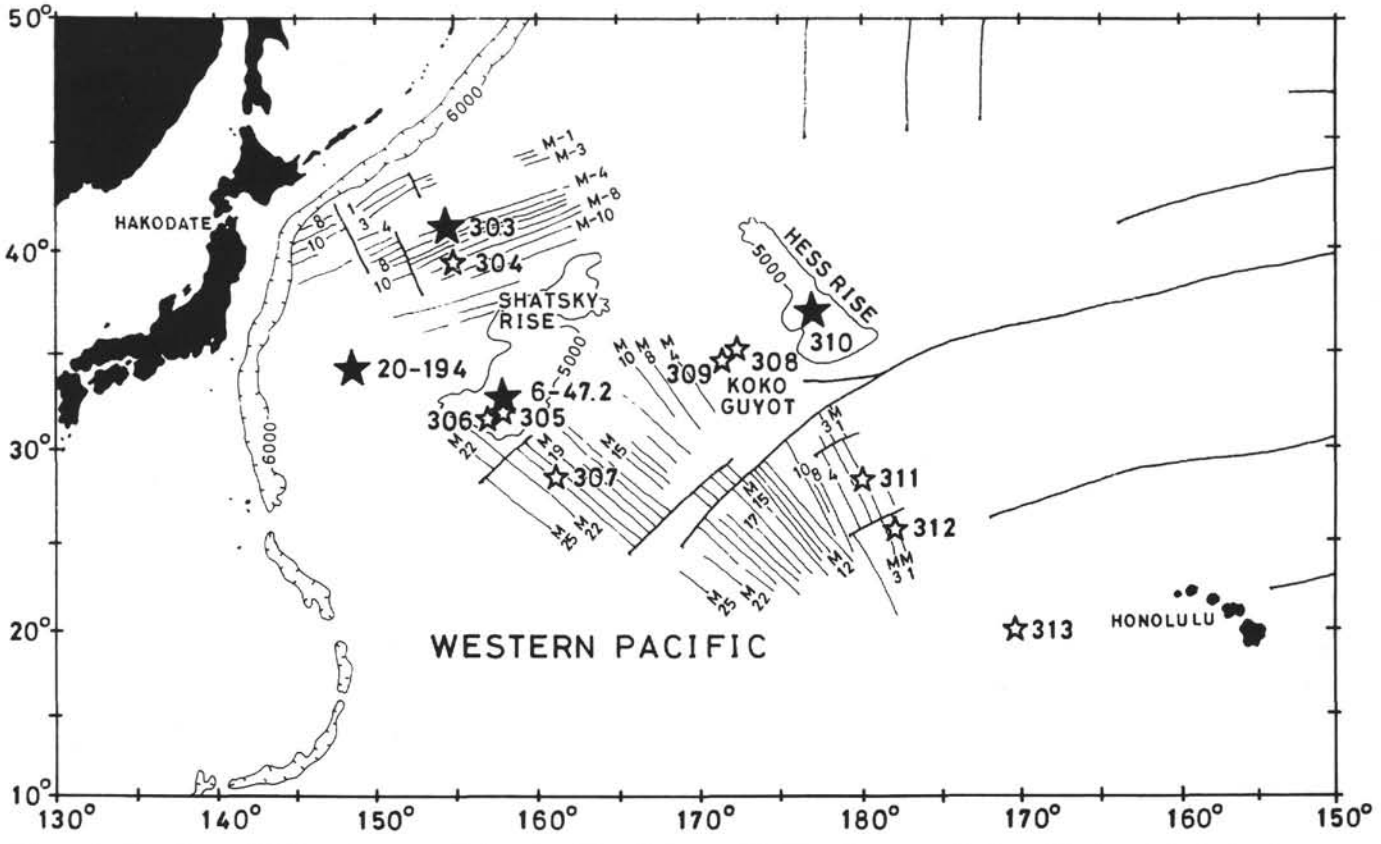

Figure 1. *Location of drilling sites occupied on Leg 32 and sites studied for this report (indicated by large black stars).*

Frequency grades for the occurrences of species are R=very rare (1 to 5 specimens), R=rare (6 to 19 specimens), F=few (20 to 39 specimens), C=common (40 to 59 specimens), A=abundant (60 to 99 specimens), and A=very abundant (more than 100 specimens). An italic letter in the tables indicates the specimens are believed to be reworked from older sediments.

Diatom zonations used in this report follow those proposed by Koizumi (1973b, in press) and by Burckle (1972).

Ages follow those proposed by Burckle (1972), Opdyke (1972), and Berggren (1974). The Miocene-Pliocene boundary in this report is placed at the top of geomagnetic epoch 5 (bottom of the Gilbert Reversed Magnetic Epoch) at an age of 5.10 m.y. B.P. This boundary is shifted by Berggren (1974) to the lower part of Gilbert Reversed Magnetic Epoch at an age of 4.95 to 5.00 m.y. B.P. The Pliocene-Pleistocene boundary is placed at the bottom in the Olduvai Event of the Matuyama Reversed Epoch at an age of about 1.8 m.y. B.P.

Figures 2 to 5 show the ranges of important taxa, the boundaries between diatom zones (named after Koizumi, 1973b, in press; and Burckle, 1972), the percentages of the cold and warm water species, and geologic age, against a vertical sclae of depth below the sediment surface at each site.

Site 303, Leg 32 (Table 1, Figure 2)

Site 303 is located on magnetic anomaly M-4 on the Japanese lineation pattern in 5609 meters of water (Figure 1). The cores used for this diatom study are from the upper part of sediment section, 0 to 211 meters below the sea floor (Cores 1 through 4). The sediments consist of diatom radiolarian ooze often rich in volcanic ash, and radiolarian-bearing pelagic clay composed predominantly of diatoms and radiolarians with some silicoflagellates and minor amounts of volcanic glass shards. Core 4 (117 to 126 m) shows a gradual transition between the upper part and the underlying one. It consists of zeolitic pelagic clay with downward decreasing amounts of radiolarians and diatoms.

Diatoms are abundant to common and well preserved in most samples from Cores 1 through 4 (0 to 183 m) except in the following samples: 303-1, CC; 303-4-3, 50-51 cm; and 303-4, CC, where they are rare to few and poorly to moderately preserved.

Diatoms from Core 1 (0 to 12 m) evidently belong in the *Denticula seminae* Zone and the *Pseudoeunotia doliolus* Zone. The uppermost part of Core 2 (approximately 62.5 m) is within the *Denticula seminae* v. *fossilis* Zone, and the remainder of Core 2 (65.5 to 71 m) is from the *Denticula seminae* v. *fossilis-Denticula kamtschatica* Zone and the *Nitzschia jouseae* Zone. Core 3 (117 to 126 m) belongs to the *Denticula kamtschatica* Zone and the *Thalassiosira convexa* Zone. The upper part of Core 4 (175 to 177.5 m) is from the *Denticula hustedtii* Zone, and the lower part (180.5 to 183 m) is from the *Denticula hustedtii-Denticula lauta* Zone.

Site 310, Leg 32 (Table 2, Figure 3)

Site 310 is located on the crest of Hess Rise in 3516 meters of water (Figure 1). Hole 310 was continuously cored from the sea floor to 193.5 meters below the sea floor (Cores 1 through 20). The upper 79 meters (Cores

TABLE 1
Abundance, Preservation, and Stratigraphic Distributions of Diatoms in Samples from Site 303 of Leg 32

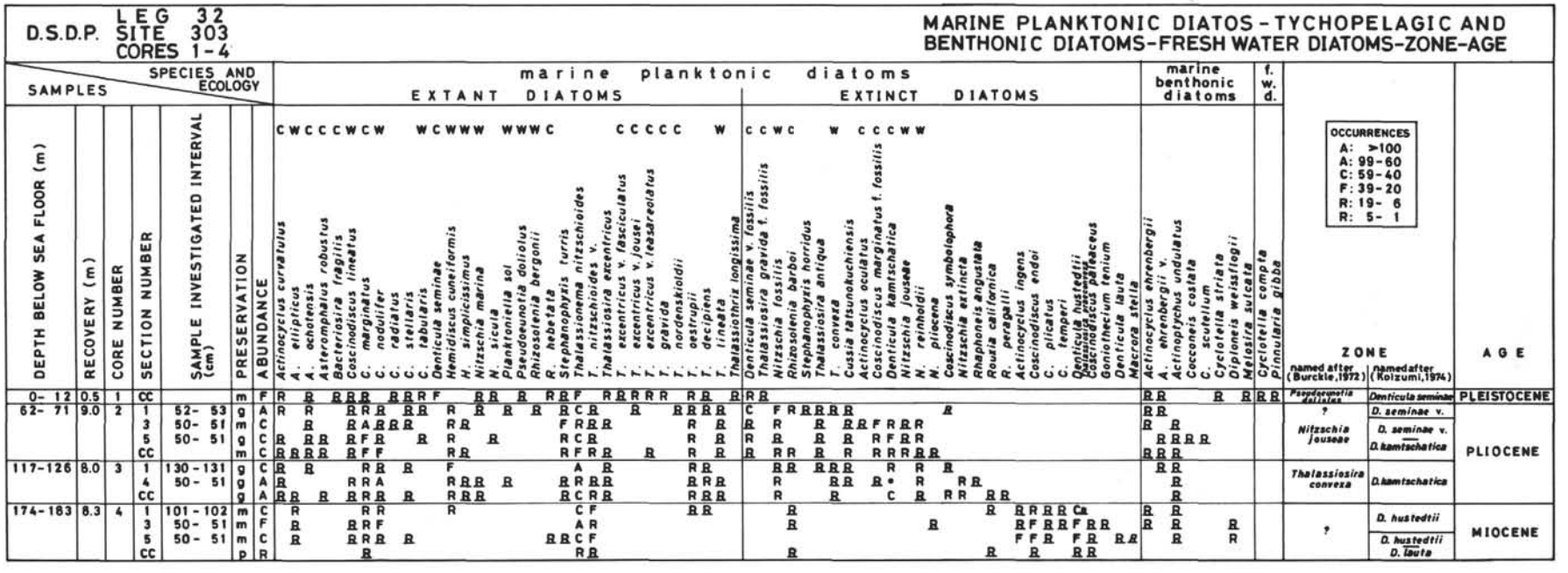

TABLE 2

Abundance, Preservation, and Stratigraphic Distributions of Diatoms in Samples from Site 310 of Leg 32

D.S.D.P. LEG 32 SITE 310 CORES 1-9

MARINE PLANKTONIC DIATOMS - TYCHOPELAGIC AND BENTHONIC DIATOMS - FRESHWATER DIATOMS - ZONE - AGE

SAMPLES: DEPTH BELOW SEA FLOOR (m)	RECOVERY (m)	CORE NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL (cm)	PRESERVATION	ABUNDANCE	marine planktonic diatoms: EXTANT DIATOMS	marine planktonic diatoms: EXTINCT DIATOMS	marine benthonic diatoms	f.w.d.	ZONE: named after (Burckle, 1972)	ZONE: named after (Koizumi, 1974)	AGE
0 - 5	6.5	1	1	10 - 11	m	F	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R	*Actinocyclus ehrenbergii* v. R		*Pseudoeunotia doliolus*	*Denticula seminae*	PLEISTOCENE
			4	149 - 150	m	C	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* F; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* F; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* C; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Nitzschia fossilis* R; *N. reinholdii* R; *Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R				
5.0 - 14.5	6.3	2	2	130 - 131	p	VR	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R			*Pseudoeunotia doliolus*	*Rhizosolenia curvirostris*	
			CC		p	R	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* R; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* R; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* R; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R; *Thalassiosira antiqua* R; *Nitzschia pliocena* R; *Denticula kamtschatica* R; *Thalassiosira zabelinae* R; *T. convexa* R		R		*Actinocyclus oculatus*
14.5 - 24.0	9.5	3	3	101 - 102	p	F	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R					
			CC		m	C	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* R; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* R; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* R; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Nitzschia fossilis* R; *N. reinholdii* R; *Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R; *Thalassiosira antiqua* R; *Nitzschia pliocena* R; *Denticula kamtschatica* R; *Thalassiosira zabelinae* R; *T. convexa* R; *Nitzschia jouseae* R; *Cussia tatsunokuchiensis* R; *Coscinodiscus nodulifer v. cyclopus* R; *C. symbolophora* R; *Nitzschia porteri* R; *N. cylindrica* R; *Actinocyclus ellipticus v. moronensis* R; *Coscinodiscus endoi* R; *C. vetustissimus* R; *Rouxia californica* R; *Thalassiosira praeconvexa* R				
24.0 - 33.5	9.0	4	2	101 - 102	p	F	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R	*Actinocyclus ehrenbergii* v. R		?	*D. seminae* v.	
			CC		p	F	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* R; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* R; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* R; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Nitzschia fossilis* R; *N. reinholdii* R; *Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R; *Thalassiosira antiqua* R; *Nitzschia pliocena* R; *Denticula kamtschatica* R; *Thalassiosira zabelinae* R; *T. convexa* R; *Nitzschia jouseae* R; *Cussia tatsunokuchiensis* R; *Coscinodiscus nodulifer v. cyclopus* R; *C. symbolophora* R; *Nitzschia porteri* R; *N. cylindrica* R; *Actinocyclus ellipticus v. moronensis* R; *Coscinodiscus endoi* R; *C. vetustissimus* R; *Rouxia californica* R; *Thalassiosira praeconvexa* R			*Nitzschia jouseae*	*D. seminae* v. — *D. kamtschatica*	PLIOCENE
33.5 - 43.0	9.4	5	3	101 - 102	p	R	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R	*Actinocyclus ehrenbergii* v. R				
			CC		p	R	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* R; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* R; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* R; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Nitzschia fossilis* R; *N. reinholdii* R; *Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R; *Thalassiosira antiqua* R; *Nitzschia pliocena* R; *Denticula kamtschatica* R; *Thalassiosira zabelinae* R; *T. convexa* R; *Nitzschia jouseae* R; *Cussia tatsunokuchiensis* R; *Coscinodiscus nodulifer v. cyclopus* R; *C. symbolophora* R; *Nitzschia porteri* R; *N. cylindrica* R; *Actinocyclus ellipticus v. moronensis* R; *Coscinodiscus endoi* R; *C. vetustissimus* R; *Rouxia californica* R; *Thalassiosira praeconvexa* R					
43.0 - 52.5	9.2	6	3	50 - 51	p	F	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R	*Actinocyclus ehrenbergii* v. R				
			CC		p	R	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* R; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* R; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* R; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Nitzschia fossilis* R; *N. reinholdii* R; *Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R; *Thalassiosira antiqua* R; *Nitzschia pliocena* R; *Denticula kamtschatica* R; *Thalassiosira zabelinae* R; *T. convexa* R; *Nitzschia jouseae* R; *Cussia tatsunokuchiensis* R; *Coscinodiscus nodulifer v. cyclopus* R; *C. symbolophora* R; *Nitzschia porteri* R; *N. cylindrica* R; *Actinocyclus ellipticus v. moronensis* R; *Coscinodiscus endoi* R; *C. vetustissimus* R; *Rouxia californica* R; *Thalassiosira praeconvexa* R				*D. kamtschatica*	
52.5 - 62.0	7.1	7	3	49 - 50	p	R	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R	*Actinocyclus ehrenbergii* v. R				
			CC		p	R	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* R; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* R; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* R; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Nitzschia fossilis* R; *N. reinholdii* R; *Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R; *Thalassiosira antiqua* R; *Nitzschia pliocena* R; *Denticula kamtschatica* R; *Thalassiosira zabelinae* R; *T. convexa* R; *Nitzschia jouseae* R; *Cussia tatsunokuchiensis* R; *Coscinodiscus nodulifer v. cyclopus* R; *C. symbolophora* R; *Nitzschia porteri* R; *N. cylindrica* R; *Actinocyclus ellipticus v. moronensis* R; *Coscinodiscus endoi* R; *C. vetustissimus* R; *Rouxia californica* R; *Thalassiosira praeconvexa* R					
62.0 - 71.5	9.5	8	3	101 - 102	p	R	*Actinocyclus curvatulus* R	*Rhizosolenia curvirostris* R	*Actinocyclus ehrenbergii* v. R		?	?	MIOCENE
			CC			B	*A. ellipticus* R; *A. ochotensis* R; *Asterolampra marylandica* R; *Asteromphalus robustus* R; *Coscinodiscus africanus* R; *C. lineatus* F; *C. marginatus* R; *C. nodulifer* R; *C. radiatus* R; *C. stellaris* R; *C. tabularis* R; *Denticula seminae* R; *Hemidiscus cuneiformis* R; *H. simplicissimus* R; *Nitzschia marina* R; *N. sicula* R; *Planktoniella sol* R; *Pseudoeunotia doliolus* R; *Rhizosolenia bergonii* R; *R. hebetata* R; *Roperia tesselata* R; *Stephanopyxis turris* F; *Thalassionema nitzschioides* R; *T. nitzschioides v.* R; *Thalassiosira decipiens* R; *T. excentricus* R; *T. excentricus v. leasareolatus* R; *T. gravida* R; *T. lineata* R; *T. oestrupii* R	*Nitzschia fossilis* R; *N. reinholdii* R; *Denticula seminae v. fossilis* R; *Actinocyclus oculatus* R; *Rhizosolenia barboi* R; *Thalassiosira antiqua* R; *Nitzschia pliocena* R; *Denticula kamtschatica* R; *Thalassiosira zabelinae* R; *T. convexa* R; *Nitzschia jouseae* R; *Cussia tatsunokuchiensis* R; *Coscinodiscus nodulifer v. cyclopus* R; *C. symbolophora* R; *Nitzschia porteri* R; *N. cylindrica* R; *Actinocyclus ellipticus v. moronensis* R; *Coscinodiscus endoi* R; *C. vetustissimus* R; *Rouxia californica* R; *Thalassiosira praeconvexa* R					
71.5 - 80.5	9.4	9	3	99 - 100		B							

OCCURRENCES
A: >100
A: 99-60
C: 59-40
F: 39-20
R: 19-6
R: 5-1

TABLE 3
Abundance, Preservation, and Stratigraphic Distributions of Diatoms in Samples from Site 47.2 of Leg 6

LEG 6
D.S.D.P. SITE 47·2
CORES 1 - 6

MARINE PLANKTONIC DIATOMS - TYCHOPELAGIC AND BENTHONIC DIATOMS - FRESH WATER DIATOMS - ZONE - AGE

SAMPLES / SPECIES AND ECOLOGY

marine planktonic diatoms — EXTANT DIATOMS

DEPTH BELOW SEA FLOOR (m)	RECOVERY (m)	CORE NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL (cm)	ABUNDANCE	PRESERVATION	*Actinocyclus curvatulus*	*A. ellipticus*	*A. ochotensis*	*Asteromphalus flabellatus*	*Bidduiphia aurita*	*Coscinodiscus africanus*	*C. angusto-lineatus*	*C. lineatus*	*C. marginatus*	*C. nodulifer*	*C. nodulifer v. cyclopus*	*C. radiatus*	*C. tabularis*	*Denticula seminae*	*Hemidiscus cuneiformis*	*H. simplicissimus*	*Nitzschia kolaczeckii*	*N. marina*	*N. sicula*	*Planktoniella sol*	*Pseudoeunotia doliolus*	*Rhizosolenia bergonii*	*Roperia tesselata*	*Stephanophyxis turris*	*Thalassionema nitzschioides*	*T. nitzschioides v.*	*Thalassiosira excentricus*	*T. gravida*	*T. lineata*	*T. oestrupii*
							C	W	C		C	W	W	W	C	W	W		W	C	W	W	W	W		W	W	W	W						C	W
9.1 - 18.3	4.9	1	2	100 - 101	R	m			R	R			R	R	R	R		R	R	R	R	R	R	R	R	R	R	R		R	R	R		R	R
18.3 - 27.4	9.1	2	1	140 - 141	R	m						R		R	R	F		R	R	R	R	R		R	R	R	R	R		R	R	R		R	R
			4	50 - 51	R	p					R		R	R	R	R			R		R	R		R	R	R	R	R			R		R	F	
			5	50 - 51	R	m	R		R	R			R	R	R	R			R		R	R	R	R			•	R	R		R	R	R			R
27.4 - 36.6	5.2	3	2	50 - 51	R	m		R						R	R	R			R		R				R	R	R			R	R	R			R
36.6 - 45.7	9.1	4	2	50 - 51	R	p		R						R	R	R	R		R		R	R			R			R			R	R	R		R	R
			6	50 - 51	R	p						R	R		R				R		R	R			R			R			R	R	R			
45.7 - 54.9	9.1	5	2	75 - 76	R	p	R			R			R		R	R			R		R	R			R			R			R	R	R			
			3	50 - 51	R	p	R						R	R	R	R			R		R	R			R			R			R	R	R		R	R
			6	50 - 51	VR	p										R	R		R		R							R				R				
54.9 - 64.0	3.3	6	1	25 - 26	VR	p							R		R	R			R												R	R	R			
			2	50 - 51	VR	p		R					R		R	R			R		R										R	R	R			

marine planktonic diatoms — EXTINCT DIATOMS

	Denticula seminae v. fossilis	*Actinocyclus oculatus*	*Rhizosolenia curvirostris*	*Nitzschia fossilis*	*N. reinholdii*	*Rhizosolenia barboi*	*Thalassiosira sp. a*	*Denticula hyalina*	*Rhizosolenia praebergonii*	*Nitzschia jouseae*	*N. pliocena*	*Thalassiosira convexa*	*Cussia tatsunokuchiensis*	*Denticula kamtschatica*	*Nitzschia cylindrica*	*Coscinodiscus plicatus*	*Denticula hustedtii*	*Thalassiosira praeconvexa*	*Denticula lauta*	*Coscinodiscus vetustissimus*
	c	c	c	c	w	c		w	w	w	w	c								
9.1 - 18.3	R	R	R																	
18.3 - 27.4		R		R	R															
				R	R	R														
27.4 - 36.6	•			F	R	R	R	R	•											
36.6 - 45.7	R			R	R	R				R	R	R	•		•	R		R		
				F		R				R	R	R	•	•			R	R		
45.7 - 54.9				F		R		R	R	R	R	R								
				F		R				R	R		R	R				R	R	
				R											R					
54.9 - 64.0				R											R	R	•			
				R											R	R	R	R		

	marine benthonic diatoms	f.w. d.
	Actinocyclus ehrenbergii	R
9.1 - 18.3	R R R R R	R
18.3 - 27.4	R R R R	
	R	
27.4 - 36.6	R R R	
36.6 - 45.7	R	
45.7 - 54.9	R	
	R R	
54.9 - 64.0	R	
	R	

	Actinoptychus undulatus	*Cyclotella striata*	*Diploneis bombus*	*Melosira sulcata*	*Triceratium cinnamomeum*	*Cyclotella comta*	*Stephanodiscus astrae*
9.1 - 18.3	R R R R					R	R
18.3 - 27.4	R R R			R			
27.4 - 36.6	R R R						
36.6 - 45.7							
45.7 - 54.9	R		R				
54.9 - 64.0							

OCCURRENCES
A: >100
A: 99 - 60
C: 59 - 40
F: 39 - 20
R: 19 - 6
R: 5 - 1

DEPTH BELOW SEA FLOOR (m)	ZONE named after (Burckle, 1972)	ZONE named after (Koizumi, 1974)	AGE
9.1 - 18.3	*Pseudoeunotia doliolus*	*Actinocyclus oculatus*	PLEISTOCENE
18.3 - 27.4			
27.4 - 36.6	*Rhizosolenia praebergonii*	*Denticula seminae v.*	PLIOCENE
36.6 - 45.7	*Nitzschia jouseae*	*D. seminae v. – D. kamtschatica*	
45.7 - 54.9		*Denticula kamtschatica*	
54.9 - 64.0	?	*Denticula hustedtii*	MIOCENE

TABLE 4
Abundance, Preservation, and Stratigraphic Distributions of Diatoms in Samples from Site 194 of Leg 20

D.S.D.P. LEG 20 SITE 194 CORES 1 - 2

MARINE PLANKTONIC DIATOMS - TYCHOPELAGIC AND BENTHONIC DIATOMS - FRESH WATER DIATOMS - ZONE - AGE

OCCURRENCES
Ā: >100
A: 99-60
C: 59-40
F: 39-20
R: 19-6
R̲: 5-1

Marine planktonic diatoms – EXTANT DIATOMS

DEPTH BELOW SEA FLOOR (m)	RECOVERY (m)	CORE NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL (cm)	PRESERVATION	ABUNDANCE	Actinocyclus ellipticus	A. ochotensis	Asteromphalus flabellatus	Biddulphia aurita	Coscinodiscus africanus	C. anguste-lineatus	C. lineatus	C. marginatus	C. nodulifer	C. nodulifer v. cyclopus	C. obscurus	C. ocurus iridis	C. radiatus	C. tabularis	Denticula seminae	Hemidiscus cuneiformis	H. simplicissimus	Nitzschia marina	Planktoniella sol	Pseudoeunotia doliolus	Rhizosolenia bergonii	Stephanopyxis turris	Thalassionema nitzschioides	T. nitzschioides v.	Thalassiosira excentricus	T. excentricus v. jouseae	T. lineata	T. oestrupii
ECOLOGY							W	C		C	W	W	W	C	W	W				W	C	W	W	W	W	W	W					C	W	
37.5-47.0	8.9	1	1	144-147	p	R		R̲		R̲		R̲	R̲	R̲	R̲			R̲	R	R̲	R̲			R	R̲	R̲	R̲	R̲	R	R	R̲	R̲	R̲	R
			6	121-123	p	VR					R̲			R̲	R̲						R̲			R̲	R̲	R̲			R̲	R̲				R̲
142.0-151.5	6.5	2	1	124-126	m	R						R̲			R	R̲	R̲			R̲		R̲	R	R̲	R̲				R	R̲	R̲			R̲
			5	90-92	g	C	R̲		R̲			R̲	R̲	R̲	R	R̲						R̲	R̲	R̲					R	R̲	R̲			

Marine planktonic diatoms – EXTINCT DIATOMS; marine benthonic diatoms; fresh water diatoms; ZONE; AGE

DEPTH BELOW SEA FLOOR (m)	CORE NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL (cm)	Denticula seminae v. fossilis	D. hyalina	Nitzschia fossilis	Thalassiosira nidulus	Cussia tatsunokuchiensis	Thalassiosira convexa	Denticula kamtschatica	Nitzschia jouseae	N. pliocena	Thalassiosira antiqua	T. praeconvexa	Denticula hustedtii	Kiesselavia carina	Denticula lauta	Actinocyclus ehrenbergii	Actinoptychus undulatus	Cyclotella striata	Diploneis bombus	Melosira sulcata	Rhaphoneis surirella	Achnanthes lanceolata	Cyclotella chaetoceras	C. comta	Eunotia sp.	Melosira granulata	M. islandica f. curvata	Pinnularia borealis	ZONE named after (Burckle, 1972)	ZONE named after (Koizumi, 1974)	AGE
ECOLOGY				C		W			W	C	W	W																					
37.5-47.0	1	1	144-147	R̲			R̲			R̲							R̲	R̲	R̲	R̲	R̲	R̲	R	R̲			R̲				*Pseudoeunotia doliolus*	?	PLEISTOCENE
		6	121-123	R̲	R̲	R̲													R̲	R̲		R̲				R̲		R̲	R̲	R̲			
142.0-151.5	2	1	124-126		R̲	R		R̲	R̲	R	R̲	R̲			R̲	R̲	R̲	R̲	R̲						R̲						*Nitzschia jouseae*	*Denticula kamtschatica*	PLIOCENE
		5	90-92		R̲	R		R̲	R̲	R̲			R̲	R̲				R	R̲	R̲					R			R̲	R̲		*Thalassiosira convexa*		

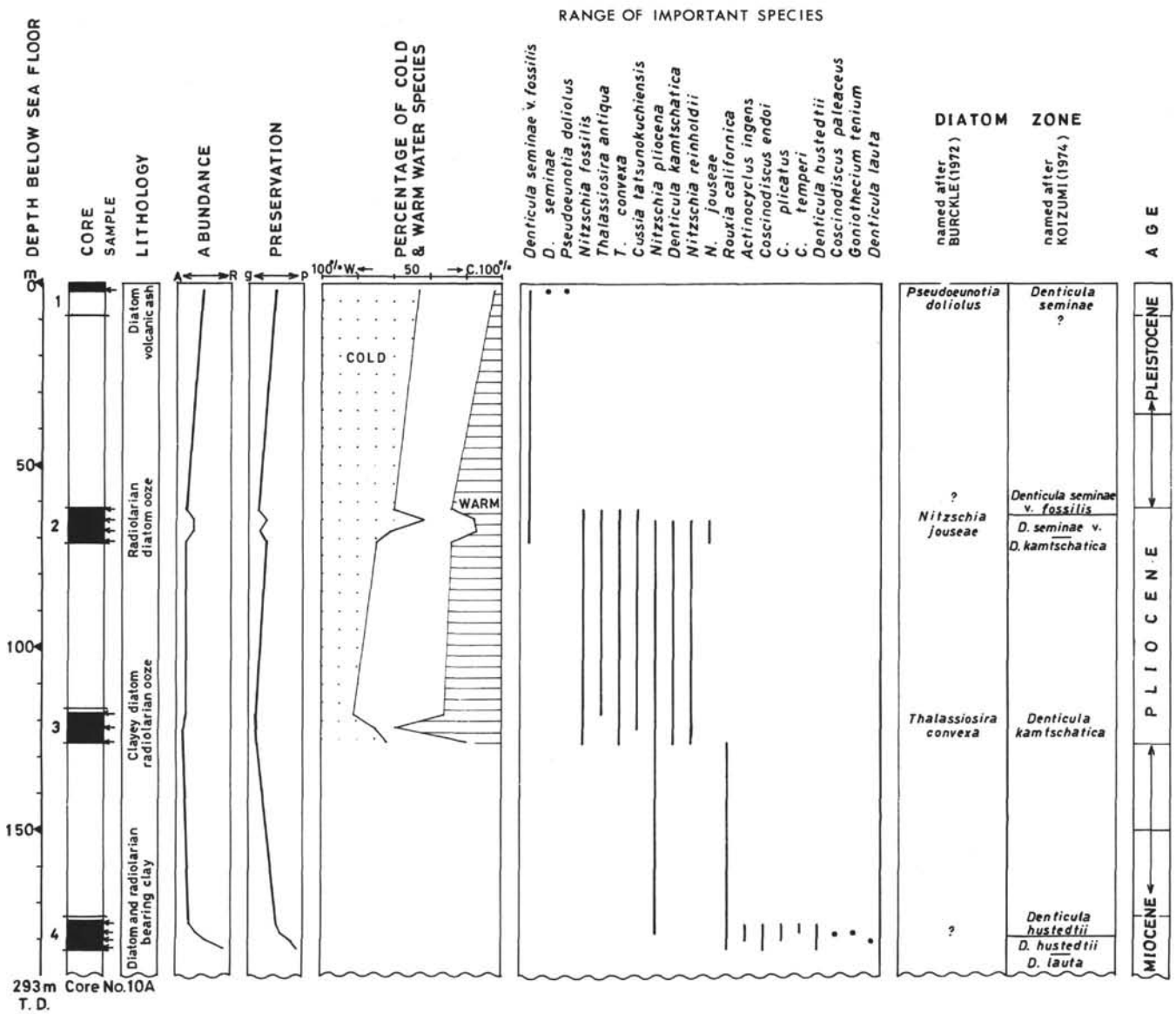

Figure 2. *Stratigraphic variation of the percentage of cold and warm water species and the ranges of selected important planktonic species in samples from Site 303 of Leg 32. Black areas in the core column represent cored sequences.*

1 through 9) consist of soft, pale brown radiolarian-bearing nanno ooze. The composition is rather constant and shows the predominance of biogenous, calcareous elements with abundant nannofossils and variable amounts of foraminifera decreasing regularly in the lower half of the upper part. The siliceous remains are generally common throughout.

Diatoms are rare to few and poorly preserved throughout the examined samples except in the following samples: 310-1-4, 149-150 cm and 310-3, CC, where they are common; and 310-2-2, 130-131 cm; 310-8, CC; and 310-9-3, 99-100 cm, where they are very rare or completely absent.

In Cores 1 through 3 (0 to 24 m) diatom assemblages represent the *Pseudoeunotia doliolus* Zone, but the top of Core 1 (310-1-1, 10-11 cm) contains the *Denticula seminae* Zone assemblage, the lower part of Core 1 to the upper part of Core 2 (6 to 7.8 m) the *Rhizosolenia curvirostris* Zone assemblage, and the core catcher of Core 2 to Core 3 (14 to 24 m) the *Actinocyclus oculatus* Zone assemblage without zonal breaks. The diatom assemblage of the upper part of Core 4 (26.5 m) belongs to the *Denticula seminae* v. *fossilis* Zone, those from the core catcher of Core 4 to the upper part of Core 6 (33 to 46.5 m) to the *Denticula seminae* v. *fossilis-Denticula kamtschatica* Zone, the core catcher of Core 6 to the upper part of Core 7 (52 to 56 m) to the *Denticula kamtschatica* Zone, and the core catcher of Core 7 to the upper part of Core 8 (61.5 to 66 m) to Miocene assemblages. Because of the absence of *Denticula hustedtii* and *Denticula lauta*, species that define the Miocene diatom zones of Koizumi (1973a, 1973b), these zones cannot be followed. In many samples from cores below Core 4 (24 to 75.5 m), guide species which define several zones

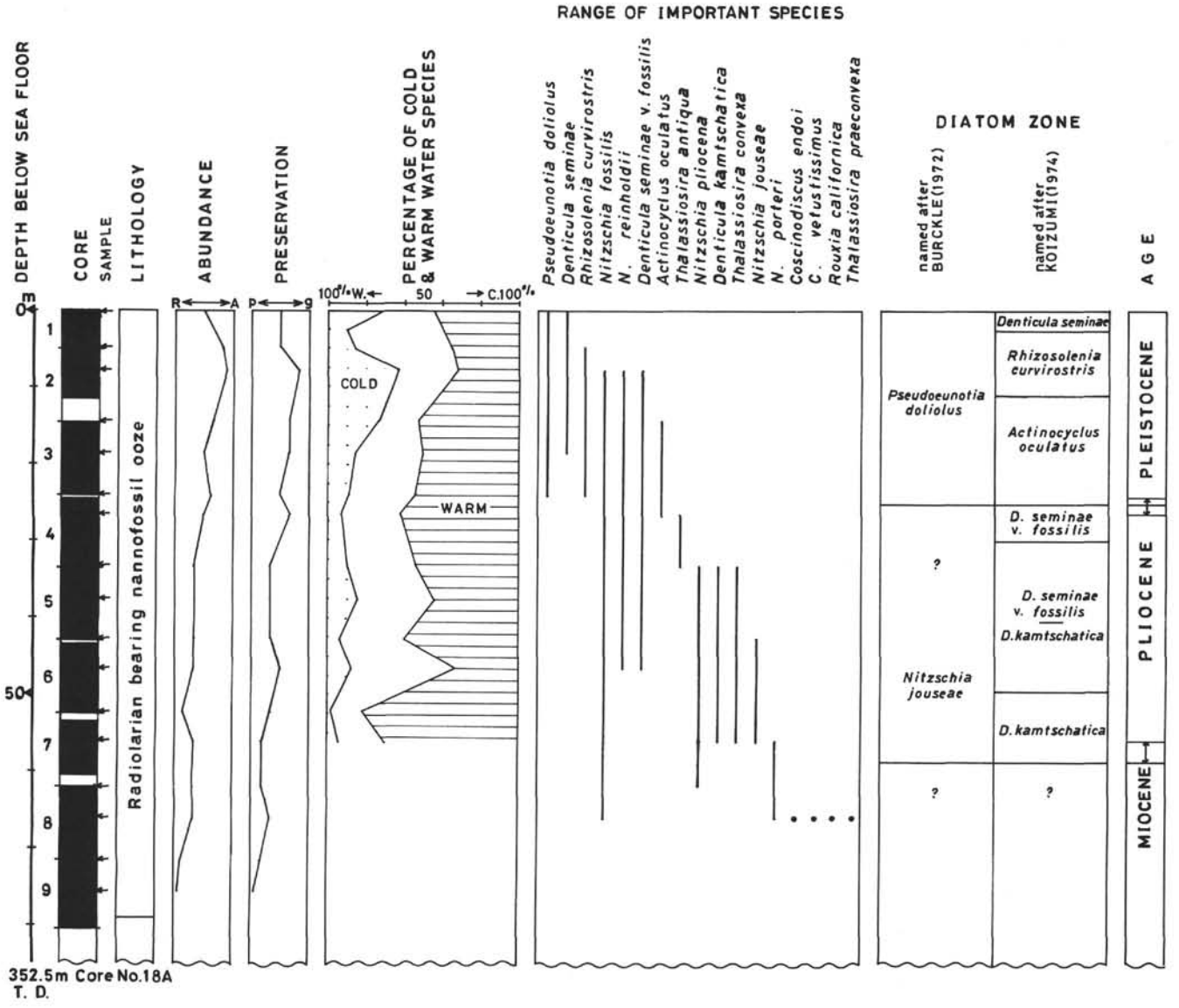

Figure 3. *Stratigraphic variation of the percentage of cold and warm water species and the ranges of selected important planktonic species in samples from Site 310 of Leg 32. Black areas in the core column represent cored sequences.*

proposed by Burckle (1972), such as *Rhizosolenia praebergonii*, *Nitzschia miocenica*, and *Nitzschia porteri*, are absent, as was the case at Site 303. The base of the *Nitzschia jouseae* Zone is found in 310-7-3, 49-50 cm.

Site 47, Hole 2, Leg 6 (Table 3, Figure 4)

Site 47, on the western part of Shatsky Rise at 2689 meters depth (Figure 1), was intended to establish a standard biostratigraphic reference section for the northwest Pacific. A total of 12 samples was available from the Neogene nanno chalk ooze section of Cores 1 through 6 (9.1 to 56.9 m).

Rare and moderately well to poorly preserved diatoms are present in Cores 1 through the upper part of Core 5 (11.6 to 49.2 m), and below that they are very rare and poorly preserved through the upper part of Core 6 (53.7 to 56.4 m).

Diatom assemblages from Cores 1 and 2 (9.1 to 27.4 m) belong to the *Actinocyclus oculatus* Zone and the *Pseudoeunotia doliolus* Zone, Core 3 (27.4 to 36.6 m) to the *Denticula seminae* v. *fossilis* Zone and the *Rhizosolenia praebergonii* Zone. Core 3 has the only occurrence of *Rhizosolenia praebergonii*, the guide species for zone, found in this study. Core 4 to the upper part of Core 5 (36.6 to 49.2 m) is assigned to the *Nitzschia jouseae* Zone of Burckle (1972), but the upper part of Core 4 (38.6 m) is from the *Denticula seminae* v. *fossilis-Denticula kamtschatica* Zone, and the lower part of Core 4 to the upper part of Core 5 (44.6 to 59.2 m) is from the *Denticula kamtschatica* Zone, the latter two zones being subdivisions of the *Nitzschia jouseae* Zone (Koizumi, in press). Samples from the lower part of Core 5 to the upper part of Core 6 (53.7 to 56.4 m) contain an assemblage from the late Miocene *Denticula hustedtii* Zone.

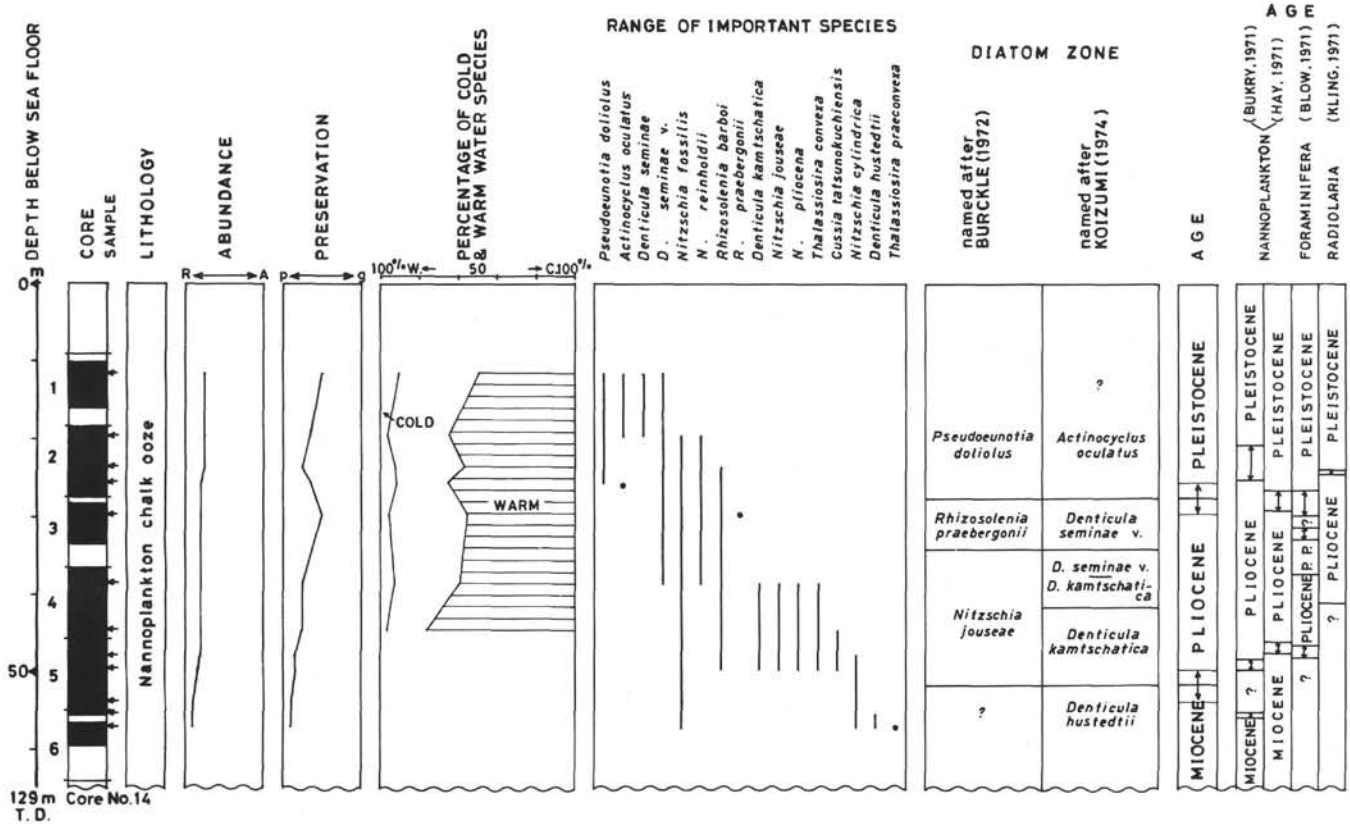

Figure 4. *Stratigraphic variation of the percentage of cold and warm water species and the ranges of selected important planktonic species in samples from Site 47.2 of Leg 6. Black areas in the core column represent cored sequences.*

Site 194, Leg 20 (Table 4, Figure 5)

Site 194 was drilled on the abyssal floor 360 miles east of the Japan trench (Figure 1). Four samples were available from the Neogene section of silty clay with thin stringers of volcanic ash, Cores 1 and 2 (37.5 to 151.5 m).

Very rare to rare and poorly preserved diatoms are present in most samples, because of abundant volcanic ash throughout those cores. However, in the sample 194-2-5, 90-92 cm, diatoms are common and well preserved.

Diatom assemblages in Core 1 (37.5 to 47 m) belong to the *Pseudoeunotia doliolus* Zone. Two samples examined from Core 2 (142 to 151.5 m) belong to the *Denticula kamtschatica* Zone of Koizumi (1973b, in press) and to the *Nitzschia jouseae* and *Thalassiosira convexa* zones, respectively, of Burckle (1972).

Displaced fresh water diatoms occur frequently throughout all the samples from this site.

OCCURRENCES OF ZONAL MARKER SPECIES AND BIOSTRATIGRAPHIC RESULTS

A comparison of zonal units between Koizumi (1973b, in press) and Burckle (1972) within the same strata shows generally close coincidence of the boundaries of zonal subdivisions for the Pliocene to Pleistocene interval of the northwestern Pacific Ocean. Table 5 presents a stratigraphically arranged listing of the earliest and latest occurrences of the key diatom zone taxa. The key taxa for the zonation of Koizumi (1973b, in press) are arranged on the left side and those of Burckle (1972) on the right side. In the "Event" column, T indicates the top of the range of a taxon and B its bottom. The level at which each event occurs is given in terms of core-section and, interval of samples is in centimeters. The lower part of the *Denticula kamtschatica* Zone is equivalent to the upper part of the *Thalassiosira convexa* Zone, the upper part of the *Denticula kamtschatica* Zone and the *Denticula seminae* v. *fossilis-Denticula kamtschatica* Zone to the *Nitzschia jouseae* Zone. The *Denticula seminae* v. *fossilis* Zone is comparable to the *Rhizosolenia praebergonii* Zone, but data are from only one site, and the *Actinocyclus oculatus* Zone, *Rhizosolenia curvirostris* Zone and *Denticula seminae* Zone correspond to the *Pseudoeunotia doliolus* Zone.

As shown in Figures 2 to 5, the absence of *Rhizosolenia praebergonii* as the guide species of uppermost Pliocene, except at Site 47.2, could be merely a result of sampling and not paleoecologic exclusion, because the species marks only short intervals in cores from warm water regions (Burckle, 1971, 1972) and from the northern Oga Peninsula (Koizumi, 1968). The coincidence of zonal units is not throughout the pre-Pliocene sediment of the studied samples. Some zonal marker species, such as *Nitzschia miocenica*, *Thalassiosira convexa*, and *Thalassiosira usatschevii*, are not present

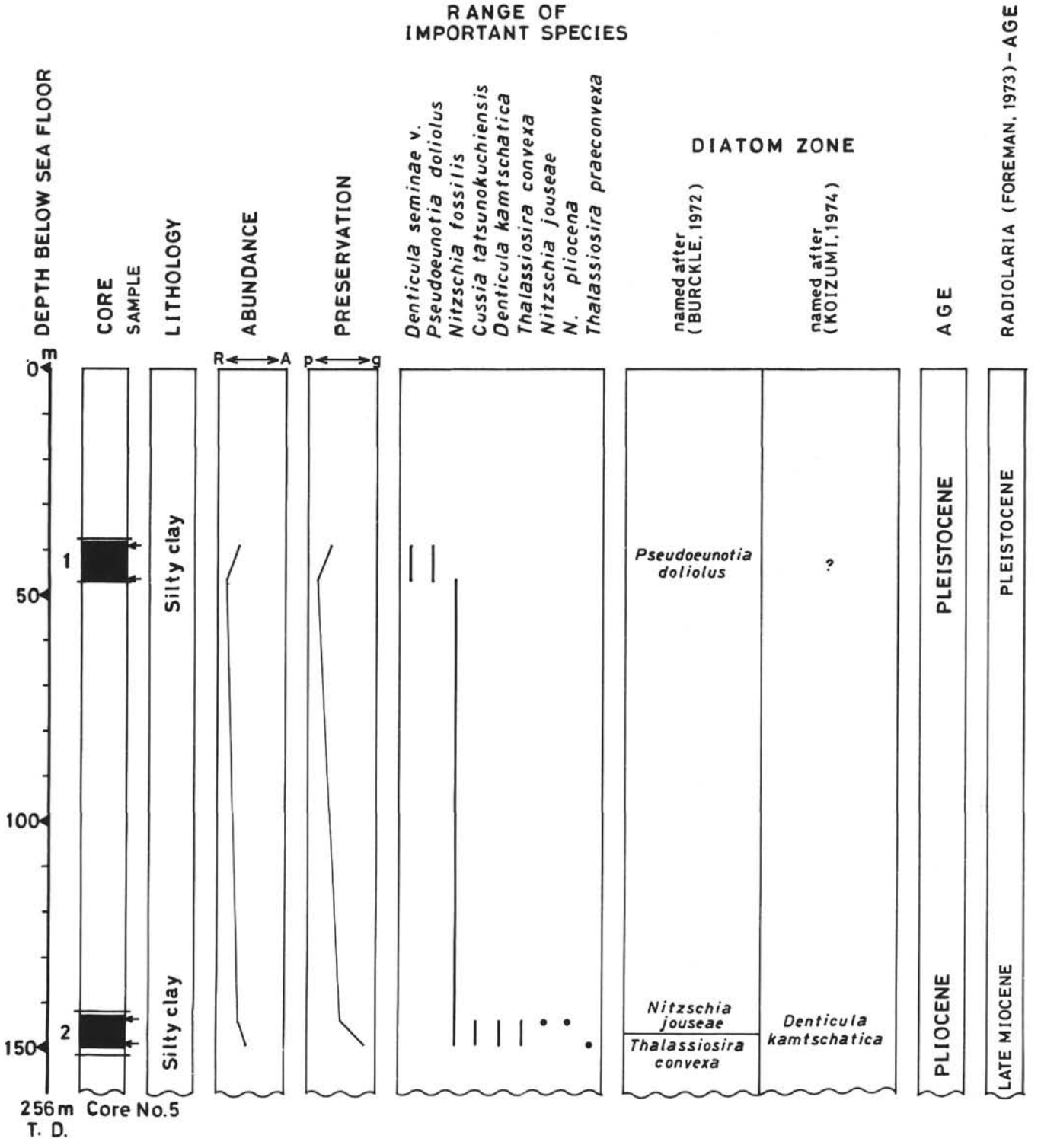

Figure 5. *The Ranges of selected important planktonic species in samples examined from Site 194 of Leg 20. Black areas in the core column represent cored sequences.*

through the Miocene sediment because of the preservation or geographic factors. These absences make the recognition of zones based on these species indistinguishable from adjacent zones. For instance, because most assemblages in southern sites (Sites 310 and 47.2) are strongly etched and dissolved, the lack of marker species may not necessarily be the result of paleoecologic exclusion. However, the absence of *Nitzschia cylindrica*, *Nitzschia miocenia*, *Nitzschia porteri*, and *Thalassiosira convexa* in the more northern site (Site 303) probably is due to the effect of either dissolution, because the above species are the less-resistant taxa, or paleoecologic-biogeographic exclusion.

A comparison of series (age) boundaries determined by diatoms examined for this report and calcareous nannofossils, pelagic foraminifera, and radiolarians, observ-

TABLE 5
Diatom Events Based on the Key Zonal Species of Sites 303, 310, 47.2, and 194

Event	303	310	47.2	194	Diatom Zone	Diatom Zone	303	310	47.2	194	Event
					Denticula seminae						
T *Rhizosolenia curvirostris*		1-4 149-150			*Rhizosolenia curvirostris*						
T *Actinocyclus oculatus*		2. CC			*Actinocyclus oculatus*	*Pseudoeunotia doliolus*	1, CC	3, CC	2-5, 50-51	1-6, 121-123	B *Pseudoeunotia doliolus*
T *Thalassiosira antiqua*					*Denticula seminae* v.	*Rhizosolenia praebergonii*			3-2, 50-51		B *Rhizosolenia praebergonii*
T *Denticula kamtschatica*	2-3 50-51	4, CC	4-2, 50-51	2-1, 124-126	*Denticula seminae v.– Denticula kamtschatica*						
B *Denticula seminae*	2, CC	6-3, 50-51	4-2, 50-51			*Nitzschia jouseae*	2, CC	7-3, 49-50	5-3, 50-51		B *Nitzschia jouseae*
B *Denticula kamtschatica*	3, CC	7-3, 49-50	5-3, 50-51	2-5, 90-92	*Denticula kamtschatica*	*Thalassiosira convexa*	3 CC	7-3, 49-50	5-2, 75-76		B *Thalassiosira convexa*
T *Denticula hustedtii*	4-1, 101-102		6-1, 25-26		*Denticula hustedtii*						
T *Denticula lauta*	4-5, 50-51				*D. hustedtii – D. lauta*	?					

ed in a richly fossiliferous, continuously cored, section from Site 47.2 is presented in the right side of Figure 4. The comparison shows generally close coincidence of series boundaries. All these four groups of microfossils are thought to be the products of planktonic unicellular organisms that have undergone concurrent stress in the same physical environment, probably resulting in significant morphologic changes at roughly similar times (Bukry et al., 1971).

PALEOCLIMATIC INTERPRETATION

Climatic fluctuations based on the percentage of cold and warm water species, can be interpreted for the Holocene to early Pliocene interval at Sites 303, 310, and 47.2 (Figures 2 to 5). Site 194 is not suitable because of very few samples available. In general, the lower part of the Pliocene to the middle part of the Pleistocene at each site show a gradual increase in the percentages of cold water species as the percentages of warm water species decrease. This tendency is typified at Site 310, where the percentage of cold water species maximizes at the lower part of the *Rhizosolenia curvirostris* Zone (about 0.85 m.y. B.P.). This agrees with the results in the northern North Pacific, DSDP Leg 19 (Koizumi, 1973b), and in the Sea of Japan, DSDP Leg 31 (Koizumi, in press).

SYSTEMATIC SECTION, FLORAL REFERENCES

This section provides bibliographic references to the taxa mentioned in this report. The taxa are arranged alphabetically, separately under the marine planktonic, marine tychopelagic and benthonic, and fresh water diatoms. The taxa that are treated by Hustedt (1930, 1962a, 1962b) are referred directly to those works. For the taxa that are not treated by Hustedt, references are made as far as possible to the original description. Additional references are selected from remarks and illustrations which were helpful for this report. Among those listed here, most of the marine planktonic species which are useful for the diatom zonation are illustrated and their plate and figure numbers are shown in parentheses.

Marine Planktonic Diatoms

Actinocyclus curvatulus Jan., *in* Schmidt, 1878: Hustedt, 1962a, p. 538, fig. 307; Hustedt, 1958, p. 129, pl. 8, fig. 82, 83; Koizumi, 1968, p. 207, pl. 32, fig. 1, 2; Koizumi, 1973b, p. 831, pl. 1, fig. 1-6; Koizumi, in press, p. 812, pl. 2, fig. 7-10. (Plate 1, Figures 1, 2)

Actinocyclus ellipticus Grun., 1881: Hustedt, 1962a, p. 533, fig. 303. (Plate 3, Figures 1-3)

Actinocyclus ellipticus Grun. var. *moronensis* (Deby) Kolbe, 1954: p. 21, pl. 3, fig. 29, 30.

Actinocyclus ingens Ratt., Rattray, 1890: p. 149, pl. 11, fig. 7; Sheshukova-Poretzkaya, 1967, p. 194, pl. 29, fig. 8, pl. 30, fig. 1a-e; Koizumi, 1968, p. 207, pl. 32, fig. 5, 6; Kanaya, 1971, p. 554, pl. 40.6, fig. 1-8; Koizumi, 1973b, p. 831, pl. 1, fig. 13, 14, pl. 2, fig. 1, 2.

Actinocyclus ochotensis Jousé, 1968: p. 17, pl. 2, fig. 2-5; Donahue, 1970, p. 135, pl. 2, fig. 2-5; Koizumi, 1973b, p. 831, pl. 2, fig. 3-7; Schrader, 1973a, p. 701, pl. 18, fig. 8, 17, pl. 19, fig. 6; Koizumi, in press, p. 812, pl. 2, fig. 11-13, (Plate 3, Figures 12, 13)

Actinocyclus oculatus Jousé, 1968: p. 18, pl. 2, fig. 6, 7; Koizumi, 1968, p. 208, pl. 32, fig. 11-14; Donahue, 1970, p. 135, pl. 2, fig. 6, 7; Koizumi, 1973b, p. 831, pl. 2, fig. 8, 9; Koizumi, in press, p. 812, pl. 2, fig. 14-17.

Asterolampra marylandica Ehr., 1845: Hustedt, 1962a, p. 485, fig. 270, 271; Scheshukova-Poretzkaya, 1967, p. 189, pl. 29, fig. 3, (Plate 3, Figure 5)

Asteromphalus flabellatus (Bréb.) Grev., 1859: Hustedt, 1962a, p. 498, fig. 279; Koizumi, 1968, p. 209, pl. 32, fig. 16.

Asteromphalus robustus Castr., 1875: Hustedt, 1962a, p. 496, fig. 278; Sheshukova-Poretzkaya, 1967, p. 190, pl. 29, fig. 2; Schrader, 1973a, p. 702, pl. 21, fig. 4, 5. (Plate 3, Figure 4)

Bacteriosira fragilis Gran, 1900: Hustedt, 1962a, p. 544, fig. 310; Sheshukova-Poretzkaya, 1967, p. 202, pl. 33, fig. 3a-b; Schrader, 1973a, p. 702, pl. 16, fig. 7; Koizumi, in press, p. 812, pl. 2, fig. 5, 6.

Biddulphia aurita (Lyng.) Bréb. and God., 1838: Hustedt, 1962a, p. 846, fig. 501; Sheshukova-Poretzkaya, 1967, p. 214, pl. 34, fig. 5.

Coscinodiscus africanus Jan., *in* Schmidt, 1878: Hustedt, 1962a, p. 428, fig. 231. (Plate 2, Figures 1, 2)

Coscinodiscus anguste-lineatus Schmidt, 1878: Hustedt, 1962a, p. 391, fig. 203. (Plate 2, Figures 7-8)

Coscinodiscus endoi Kanaya, 1959: p. 76, pl. 3, fig. 8-11; Koizumi 1968, p. 211, pl. 32, fig. 21, 22; Koizumi, 1973b, p. 831, pl. 2, fig. 10; Schrader, 1973a, p. 702, pl. 7, fig. 14, 21, pl. 20, fig. 1, 2. (Plate 2, Figure 16)

Coscinodiscus lineatus Ehr., 1938: Hustedt, 1962a, p. 392, fig. 204; Koizumi, 1968, pl. 32, fig. 26 (Plate 2, Figures 5, 6)

Coscinodiscus marginatus Ehr., 1843: Hustedt, 1962a, p. 416, fig. 223; Sheshukova-Poretzkaya, 1967, p. 156, pl. 11, fig. 9, pl. 17, fig. 4a-B, pl. 18, fig. 1a-2, 1e; Koizumi, in press p. 814, pl. 3, fig. 6. (Plate 2, Figure 18)

Coscinodiscus marginatus Ehr., forma *fossilis* Jousé, 1961: p. 68, pl. 3, fig. 7, 8; Koizumi, 1973b, p. 832, pl. 3, fig. 12-14; Schrader, 1973a, p. 703, pl. 20, fig. 12; Koizumi, in press, p. 814, pl. 3, fig. 7.

Coscinodiscus nodulifer Schmidt, 1878: Hustedt, 1962a, p. 426, fig. 229; Kolbe, 1954, p. 33, pl. 3, fig. 35-37; Kanaya, 1971, p. 555, pl. 40.3, fig. 1-4; Koizumi, in press, p. 814, pl. 3, fig. 11, 12. (Plate 1, Figures 3-10)

Coscinodiscus nodulifer Schmidt var. *cyclopus* Jousé, 1971: p. 14, pl. 1, fig. 1-5. (Plate 1, Figures 11, 12)

Coscinodiscus obscurus Schmidt, 1878: Hustedt, 1962a, p. 418, fig. 224a-b; Sheshukova-Poretzkaya, 1967, p. 164, pl. 23, fig. 1.

Coscinodiscus oculus-iridis Ehr., 1839: Hustedt, 1962a, p. 454, fig. 252; Sheshukova-Poretzkaya, 1967, p. 160, pl. 21, fig. 1; Koizumi 1968, p. 211, pl. 33, fig. 5, 6.

Coscinodiscus plicatus Grun., Grunow, 1884: p. 86, pl. 3, fig. 10, 27; Kolbe, 1954, p. 34, no illustration; Kanaya, 1971, p. 555, pl. 40.4, fig. 4-6; Schrader, 1973a, p. 703, pl. 6, fig. 23. (Plate 2, Figures 21, 22)

Coscinodiscus radiatus Ehr., 1839: Hustedt, 1962a, p. 240, fig. 225; Hanna, 1970, p. 185, fig. 4, 8, 17.

Coscinodiscus stellaris Rop., 1858: Hustedt, 1962a, p. 396, fig. 207; Koizumi, 1968, p. 212, pl. 33, fig. 11.

Coscinodiscus symbolophorus Grun., Grunow, 1884: p. 82, pl. 4, fig. 3-6; Sheshukova-Poretzkaya, 1967, p. 167, pl. 22, fig. 3a-b; Schrader, 1973a, p. 703, pl. 22, fig. 8, 9.

Coscinodiscus tabularis Grun., 1884: Hustedt, 1962a, p. 427, fig. 230; Koizumi, 1968, p. 212, pl. 33, fig. 10. (Plate 2, Figures 14, 15)

Coscinodiscus temperi Brun, *in* Brun and Tempère, 1889: p. 33, pl. 8, fig. 2; Koizumi, 1968, p. 212, pl. 32, fig. 28; Koizumi, 1973c, p. 134, pl. 20, fig. 9a-b; Schrader, 1973a, p. 704, pl. 6, fig. 18, 19, pl. 7, fig. 1-5, 8-9. (Plate 3, Figures 6, 7)

Coscinodiscus vetustissimus Pant., 1886: Hustedt, 1962a, p. 412, fig. 220; Kanaya, 1971, p. 555, pl. 40.2, fig. 1-5. (Plate 1, Figures 13, 14)

Cussia praepaleacea (Schrader) Schrader, 1974: p. 543, fig. 1 (8). (Plate 4, Figures 36, 37)

Cussia tatsunokuchiensis (Koizumi) Schrader, 1974: p. 543, fig. 1 (6-7). (Plate 4, Figures 33-35)

Denticula hustedtii Simonsen and Kanaya, 1961: p. 501, pl. 1, fig. 19-25; Kanaya, 1971, p. 555, pl. 40.5, fig. 13, 14; Koizumi, 1973b, p. 832, pl. 5, fig. 18-23; Schrader, 1973a, p. 704, pl. 2, fig. 28-34, 36-47. (Plate 4, Figures 48-49)

Denticula hyalina Schrader, 1973: 1973a, p. 704, pl. 1, fig. 12-22; Schrader, 1973b, p. 418, pl. 1, fig. 10, 22; Koizumi, in press, p. 810, pl. 1, fig. 21-26.

Denticula kamtschatica Zabelina, 1934: Simonsen and Kanaya, 1961, p. 503, pl. 1, fig. 14-18; Koizumi, 1968, p. 213, pl. 34, fig. 7-10; Koizumi, 1972, p. 350, pl. 42, fig. 12, 13; Koizumi, 1973b, p. 832, pl. 5, fig. 14-17; Schrader, 1973a, p. 705, pl. 2, fig. 1-13; Schrader, 1973b, p. 418, pl. 1, fig. 7, 8; Koizumi, in press, p. 810, pl. 1, fig. 13-20. (Plate 4, Figure 47)

Denticula lauta Baill., 1854: Simonsen and Kanaya, 1961, p. 500, pl. 1, fig. 1-8; Koizumi, 1968, p. 213, pl. 34, fig. 11a-12b; Kanaya, 1971, p. 555, pl. 40.5, fig. 11; Koizumi, 1973b, p. 832, pl. 5, fig. 24-28; Schrader, 1973a, p. 705, pl. 2, fig. 14-25, 35; Schrader, 1973b, p. 419, pl. 1, fig. 11, 20, 23, 24.

Denticula seminae Simonsen and Kanaya, 1961: p. 503, pl. 1, fig. 26-30; Koizumi, 1972, p. 350, pl. 42, fig. 5a-6; Koizumi, 1973b, p. 832, pl. 5, fig. 1-13; Schrader, 1973a, p. 705, pl. 1, fig. 1-11, 36, 47; Schrader, 1973b, p. 420, pl. 1, fig. 1-4; Koizumi, in press, p. 810, pl. 1, fig. 1-3.

Denticula seminae Simonsen and Kanaya var. *fossilis* Schrader, 1973: 1973b, p. 420, pl. 1, fig. 5, 6; Koizumi, in press, p. 810, pl. 1, fig. 4-12. (Plate 4, Figures 44-46)

Goniothecium tenue Brun, 1894: p. 77, pl. 5, fig. 5, 6; Sheshukova-Poretzkaya, 1967, p. 232, pl. 39, fig. 6a-b, pl. 40, fig. 5a-b; Koizumi, 1973b, p. 833, pl. 7, fig. 7-9.

Hemidiscus cuneiformis Wall., 1860: Hustedt, 1962a, p. 904, fig. 542; Koizumi, 1968, p. 215, pl. 34, fig. 17, 18; Kanaya, 1971, p. 556, pl. 40.3, fig. 5, 6; Schrader, 1973a, p. 706, pl. 24, fig. 14; Koizumi, in press, p. 817, pl. 4, fig. 2. (Plate 3, Figures 10, 11)

Hemidiscus simplicissimus Hanna and Grant, 1926: p. 147, pl. 16, fig. 13; Schrader, 1973a, p. 706, pl. 24, fig. 12, 13; Koizumi, in press, p. 817, pl. 4, fig. 1. (Plate 3, Figures 8, 9)

Kisseleviella carina Sheshk., Sheshukova-Poretzkaya, 1962: p. 207, fig. 2a-d, 1a-b; Sheshukova-Poretzkaya, 1967, p. 236, pl. 40, fig. 6a-B, pl. 41, fig. 5a-B; Koizumi, 1973b, p. 833, pl. 7, fig. 3, 4.

Macrora stella (Azpeitia) Hanna, 1932: p. 196, pl. 12, fig. 7; Schrader, 1973a, p. 706, pl. 12, fig. 21-24. (Plate 2, Figure 17)

Nitzschia cylindrica Burckle, 1972: p. 239, pl. 2, figs. 1-6; Schrader, 1973a, p. 707, pl. 5, fig. 27, 32, 33; Schrader, 1974, p. 546, fig. 5 (23-30).

Nitzschia extincta Koz. and Sheshuk., *in* Sheshukova-Poretzkaya, 1967: p. 303, pl. 47, fig. 12; Koizumi, 1972, p. 351, pl. 42, fig. 10a-11b; Koizumi, 1973c, p. 134, pl. 20, fig. 16, 17.

Nitzschia fossilis (Fuengelli) Kanaya, *in* Kanaya and Koizumi, 1970: p. 59; Koizumi, 1972, p. 352, pl. 42, fig. 14a-15c; Kobayashi et al., 1971, p. 1059, fig. 5, 7; Schrader, 1973a, p. 707, pl. 4, fig. 9-11, 24, 25; Koizumi, in press, p. 810, pl. 1, fig. 46. (Plate 4, Figures 5-12)

Nitzschia jouseae Burckle, 1972: p. 240, pl. 2, fig. 17-21; Schrader, 1973a, p. 707, pl. 4, fig. 20, 21; Kasarina and Demidenko, 1974, p. 88, pl. 3, fig. 12. Synonyms: As *Nitzschia pliocena* (Brun) Mertz, Jousé, 1971, p. 16, pl. 4, fig. 1-5. (Plate 4, Figures 18-27)

Nitzschia kolaczeckii Grun., 1867: Kolbe, 1955, p. 174, pl. 2, fig. 22, 23; Hasle, 1960, p. 24, pl. 5, fig. 50b-c.

Nitzschia marina Grun., *in* Cleve and Grunow, 1880: p. 70; Van Heurck, 1880, pl. 57, fig. 26, 27; Kolbe, 1954, p. 40, pl. 3, fig. 38-40.

Nitzschia pliocena (Brun) Kanaya, *in* Kanaya and Koizumi, 1970: p. 59. Remarks: This species is distinguished from *Nitzschia reinholdii* Kanaya by the coarser transapical costae, 9-10 in 10μ, and the two rows of rounded pores in the intercostal membranes. (Plate 4, Figures 28-32)

Nitzschia porteri Frenguelli, 1949: p. 116, pl. 1, fig. 33, 34; Burckle, 1972, no description, pl. 2, fig. 16; Schrader, 1973a, p. 707, pl. 5, fig. 35, 36, 43, 44, 39-41; Schrader, 1974, p. 548, fig. 5 (31-32); Jousé, 1974, pl. 5, fig. 18-22. (Plate 4, Figures 38-43)

Nitzschia reinholdii Kanaya, *in* Kanaya and Koizumi, 1970: p. 58; Koizumi, 1972, p. 351, pl. 42, fig. 16a-c; Schrader, 1973a, p. 708, pl. 4, fig. 1-9; Koizumi, in press, p. 810, pl. 1, fig. 47, 48. (Plate 4, Figures 13-17)

Nitzschia sicula (Cast.) Hust., Hustedt, 1958: p. 180, fig. 128-132; Hasle, 1960, p. 26, fig. 16, pl. 7, fig. 64, 65.

Planktoniella sol (Wall.) Schütt, 1893: Hustedt, 1962a, p. 465, fig. 295; Hasle, 1960, p. 11, pl. 3, fig. 19, 20; Gerloff, 1970, p. 203, pl. 1-14, fig. 1-51.

Pseudoeunotia doliolus (Wall.) Grun., 1880: Hustedt, 1962b, p. 258, fig. 737; Kolbe, 1954, p. 43, pl. 3, fig. 41; Burckle, 1972, pl. 3, fig. 7; Kobayashi et al., 1971, p. 1059, fig. 5, 6; Schrader, 1973a, p. 708, pl. 4, fig. 1-8; Koizumi, in press, p. 810, pl. 1, fig. 41-45. (Plate 4, Figures 1-4)

Rhizosolenia barboi Brun, 1894: Schrader, 1973a, p. 709, pl. 24, fig. 4, 7. (Plate 4, Figures 52, 53)

Rhizosolenia bergonii Perag., 1892: Hustedt, 1962a, p. 575, fig. 327; Koizumi, 1972, p. 353, pl. 42, fig. 7; Burckle, 1972, pl. 3, fig. 4; Schrader, 1973a, p. 709, pl. 9, fig. 1-5, 10, 12, 22, 23, pl. 10, fig. 24, 29. (Plate 4, Figures 50, 51)

Rhizosolenia curviostris Jousé, 1968: p. 19, pl. 3, fig. 1-3; Donahue, 1970, p. 135, pl. 1, fig. a; Koizumi, 1973b, p. 833, pl. 5, fig. 29-31; Schrader, 1973a, p. 709, pl. 24, fig. 5, 6, 8, 9; Koizumi, in press, p. 810, pl. 1, fig. 35-37.

Rhizosolenia hebetata (Bail.) Gran forma *hiemalis* Gran, 1904: Hustedt, 1962a, p. 590, fig. 337; Koizumi, 1973b, p. 833, pl. 5, fig. 34, 35; Schrader, 1973a, p. 709, pl. 9, fig. 11, 13-17, 19-21, 24, 25; Koizumi, in press, p. 810, pl. 1, fig. 31, 32, 34.

Rhizosolenia praebergonii Muchina, 1965: p. 24, pl. 2, fig. 3, 4; Koizumi, 1968, p. 217, pl. 34, fig. 20a-21b; Burckle, 1972, pl. 3, fig. 1-3; Kobayashi et al., 1971, p. 1059, fig. 5.5; Kasarina and Demidenko, 1974, p. 88, pl. 3, fig. 14.

Roperia tesselata (Roper) Grun., *in* Van Heurck, 1881: Hustedt, 1962a, p. 523, fig. 297; Schrader, 1973a, p. 710, pl. 19, fig. 3, 4, 8, 9; Koizumi, in press, p. 814, pl. 3, fig. 15, 16. (Plate 2, Figures 3, 4)

Rouxia californica Perag., *in* Tempère and Peragallo, 1910: p. 117; Hanna, 1930, p. 186, pl. 14, fig. 6, 7; Schrader, 1973a, p. 710, pl. 3, fig. 18-20, 22, 26; Koizumi, in press, p. 810, pl. 1, fig. 52.

Rouxia peragalli Brun and Herib., *in* Heribaud, 1893: Hanna, 1930, p. 180, pl. 14, fig. 1, 5; Sheshukova-Poretzkaya, 1967, p. 294, pl. 43, fig. 17; Koizumi, 1968, p. 217, pl. 35, fig. 1, 2; Koizumi, 1973b, p. 833, pl. 7, fig. 10.

Stephanopyxis horridus Koizumi, 1972: p. 348, pl. 42, fig. 1a-2b; Koizumi, 1973b, p. 833, pl. 6, fig. 1-4; Koizumi, in press, p. 817, pl. 4, fig. 3, 4. (Plate 3, Figures 14, 15)

Stephanopyxis turris (Grev. and Arn.) Ralfs, *in* Pritchard, 1861: Hustedt, 1962a, p. 304, fig. 140; Koizumi, 1973b, p. 833, pl. 6, fig. 13-16.

Thalassionema nitzschioides Grun., 1881: Hustedt, 1962b, p. 244, fig. 723; Schrader, 1973a, p. 712, pl. 23, fig. 2, 6, 8-10, 12, 13, 26, 29, 34; Koizumi, 1973c, p. 134, pl. 20, fig. 24, 25; Koizumi, in press, p. 810, pl. 1, fig. 50, 51.

Thalassionema nitzschioides Grun. vars. Remarks: The following three varieties are presented; *Thalassionema nitzschioides* Grun. var. *inflata* Heiden and Kolbe, 1928: p. 564, pl. 35, fig. 116, *Thalassionema nitzschioides* Grun. var. *incurvata* Heiden and Kolbe, 1928: p. 564, pl. 35, fig. 117, and *Thalassionema nitzschioides* Grun. var. *parva* Heiden and Kolbe, 1928: p. 564, pl. 35, fig. 118.

Thalassiosira antiqua (Grun.) Cl., Cleve-Euler, 1941: p. 173, fig. 4, 5, 74-84; Cleve-Euler, 1951, p. 72, fig. 119a; Sheshukova-Poretzkaya, 1967, p. 143, pl. 14, fig. 3a, 6; Koizumi, 1973b, p. 834, pl. 7, fig. 12; Schrader, 1973a, p. 712, pl. 11, fig. 25, pl. 25, fig. 19; Koizumi, 1973c, p. 134, pl. 20, fig. 12, 13; Koizumi, in press, p. 817, pl. 4, fig. 9. (Plate 3, Figure 16)

Thalassiosira convexa Muchina, 1965: p. 22, pl. 11, fig. 1, 2; Koizumi, 1972, p. 353, pl. 43, fig. 15a-16b; Burckle, 1972, pl. 2, fig. 22, 23; Kobayashi et al., 1971, p. 1059, fig. 5.3a-5.3b; Koizumi, 1973b, p. 834, pl. 7, fig. 13-15; Schrader, 1973a, p. 712, pl. 11, fig. 37, 38; Koizumi, in press, p. 817, pl. 4, fig. 15-20 (Plate 3, Figures 17-20)

Thalassiosira decipiens (Grun.) Joerg., 1905: Hustedt, 1962a, p. 322, fig. 158; Sheshukova-Poretzkaya, 1964, p. 74, pl. 1, fig. 2; Koizumi, 1973b, p. 834, pl. 7, fig. 16-18; Schrader, 1973a, p. 712, pl. 11, fig. 8, 9, 34, 35, pl. 16, fig. 12; Koizumi, 1973c, p. 134, pl. 20, fig. 6; Koizumi, in press, p. 817, pl. 4, fig. 10-14.

Thalassiosira eccentricus (Ehr.) Cl., Cleve, 1904: Sheshukova-Poretzkaya, 1967, p. 141, pl. 14, fig. 4; Schrader, 1973a, p. 712, pl. 25, fig. 17, pl. 16, fig. 5, 6; Fryxell and Hasle, 1972, p. 297, pl. 1-4, fig. 1a-18. Synonyms: As *Coscinodiscus excentricus* Ehr., 1839: Hustedt, 1962a, p. 388, fig. 201; Koizumi, 1973b, p. 831, pl. 2, fig. 11, 12.

Thalassiosira eccentricus (Ehr.) Cl. var. *jousei* (Kanaya). Synonyms: As *Coscinodiscus excentricus* Ehr. var. *jousei* Kanaya, *in* Kanaya and Koizumi, 1966: p. 125; Koizumi, 1973b, p. 832, pl. 3, fig. 1-6; Koizumi, in press, p. 814, pl. 3, fig. 1-4.

Thalassiosira eccentricus (Ehr.) Cl. var. *leasareolatus* (Kanaya). Synonyms: As *Coscinodiscus excentricus* Ehr. var. *leasareolatus* Kanaya, *in* Kanaya and Koizumi, 1966: p. 125; Koizumi, 1973b, p. 832, pl. 3, fig. 7-11; Koizumi, in press, p. 814, pl. 3, fig. 5.

Thalassiosira gravida Cl., Cleve, 1896: Hustedt, 1962a, p. 325, fig. 161; Hasle, 1968, p. 196, fig. 3, 4; Koizumi, 1972, p. 353, pl. 43, fig. 11a-11b; Koizumi, 1973b, p. 834, pl. 7, fig. 19-21; Schrader, 1973a, p. 712, pl. 14, fig. 3-8.

Thalassiosira gravida Cl. forma *fossilis* Jousé, 1961: p. 63, pl. 1, fig. 9; Sheshukova-Poretzkaya, 1967, p. 147, pl. 15, fig. 1a-B; Koizumi, 1972, p. 353, pl. 43, fig. 10; Koizumi, 1973b, p. 834, pl. 7, fig. 22-24; Koizumi, in press, p. 819, pl. 5, fig. 7-12.

Thalassiosira lineata Jousé, 1968: p. 13, pl. 1, fig. 1, 2; Koizumi, 1973b, p. 834, pl. 7, fig. 28, 29; Koizumi, 1973c, p. 134, pl. 20, fig. 7, 8; Koizumi, in press, p. 819, pl. 5, fig. 22. (Plate 2, Figures 9-12)

Thalassiosira nidulus (Temp. and Brun) Jousé, 1961: p. 63, pl. 3, fig. 4, 5; Sheshukova-Poretzkaya, 1967, p. 140, pl. 11, fig. 8a-8c, pl. 14, fig. 1a-1c; Koizumi, 1972, p. 354, pl. 43, fig. 6; Koizumi, 1973b, p.

834, pl. 7, fig. 25, 26; Schrader, 1973a, p. 712, pl. 11, fig. 1-7; Koizumi, in press, p. 817, pl. 4, fig. 27, 28.

Thalassiosira nordenskiöldi Cl., 1875: Hustedt, 1962a, p. 321, fig. 157; Hasle, 1968, p. 196, fig. 2, 4, 8; Koizumi, 1972, p. 354, pl. 43, fig. 8; Koizumi 1973b, p. 834, pl. 8, fig. 4; Schrader, 1973a, p. 712, pl. 14, fig. 9-12; Koizumi, in press, p. 819, pl. 4, fig. 24.

Thalassiosira oestrupi (Ostf.) Proskina-Lavrenko, 1956: Hasle, 1960, p. 8, pl. 1, fig. 5-7; Jousé, 1968, p. 13, pl. 1, fig. 3-7; Koizumi, 1968, p. 219, pl. 35, fig. 24, 25; Koizumi, 1973b, p. 834, pl. 7, fig. 27; Schrader, 1973a, p. 712, pl. 11, fig. 16-22, 26-33, 36, 39-45; Koizumi, in press, p. 819, pl. 5, figs. 3, 4. (Plate 2, Figure 13)

Thalassiosira praeconvexa Burckle, 1972: p. 242, pl. 2, fig. 7-9; Schrader, 1973a, p. 712, pl. 11, fig. 10-15; Schrader, 1974, p. 557, fig. 2 (7-10); Kasarina and Demidenko, 1974, p. 88, pl. 3, fig. 7, 8. (Plate 3, Figures 21-28)

Thalassiosira zabelinae Jousé, 1961: p. 66, pl. 2, fig. 1-7; Sheshukova-Poretzkaya, 1967, p. 149, pl. 16, fig. 2a-2d; Koizumi, 1968, p. 219, pl. 35, fig. 27a-28b; Koizumi, 1972, p. 354, pl. 43, fig. 17a-b; Koizumi, 1973b, p. 834, pl. 8, fig. 10-12; Schrader, 1973a, p. 712, pl. 14, fig. 1-2; Koizumi, in press, p. 819, pl. 5, fig. 13-17.

Thalassiosira sp. a Remarks: This species is similar to *Thalassiosira olgaea* Kasarina and Demidenko, 1974: no description, pl. 2, fig. 9, 10.

Thalassiothrix longissima Cl. and Grun., 1880: Hustedt, 1962a, p. 247, fig. 726; Sheshukova-Poretzkaya, 1967, p. 250, pl. 42, fig. 11; Hasle and Mendiola, 1967, p. 114, fig. 20: Koizumi, 1973b, p. 834, pl. 8, fig. 16; Schrader, 1973a, p. 713, pl. 23, fig. 7, 17, 18.

Marine Tychopelagic and Benthonic Diatoms

Actinocyclus ehrenbergii Ralfs, *in* Pritchard, 1861: Hustedt, 1962a, p. 525, fig. 298-302; Schrader, 1973a, p. 701, pl. 19, fig. 1; Koizumi, 1973c, p. 134, pl. 20, fig. 10, 11.

Actinocyclus ehrenbergii Ralfs vars. Remarks: The following three varieties are presented; *Actinocyclus ehrenbergii* Ralfs var. *sparsa* (Greg.) Hust., Hustedt, 1962a, p. 528, fig. 300; *Actinocyclus ehrenbergii* Ralfs var. *crassa* (Smith) Hust., Hustedt, 1962a, p. 529, fig. 301, and *Actinocyclus ehrenbergii* Ralfs var. *tenella* (Bréb.) Hust., Hustedt, 1962a, p. 530, fig. 302.

Actinoptychus undulatus (Bail.) Ralfs, *in* Pritchard, 1861: Hustedt, 1962a, p. 475, fig. 264; Sheshukova-Poretzkaya, 1967, p. 184, pl. 27, fig. 1a-1e, pl. 28, fig. 1a-1b; Koizumi, 1973c, p. 134, pl. 20, fig. 1a-3b; Schrader, 1973a, p. 702, pl. 22, fig. 4, 5, 12, 15.

Cocconeis costata Greg., 1855: Hustedt, 1962b, p. 332, fig. 785; Sheshukova-Poretzkaya, 1967, p. 262, pl. 44, fig. 4a-B.

Cocconeis scutellum Ehr., 1938: Hustedt, 1962b, p. 337, fig. 790; Sheshukova-Poretzkaya, 1967, p. 264, pl. 44, fig. 7.

Cyclotella striata (Kütz.) Grun., 1880: Hustedt, 1962a, p. 344, fig. 176.

Diploneis bombus Ehr., 1844: Hustedt, 1962b, p. 704, fig. 1086.

Diploneis weissflogi (Sch.) Cl., 1894: Hustedt, 1962b, p. 703, fig. 1085.

Melosira sulcata (Ehr.) Kütz., 1844: Hustedt, 1962a, p. 276, fig. 119; Sheshukova-Poretzkaya, 1967, p. 126, pl. 10, fig. 5, pl. 11, fig. 4a-4b; Hanna, 1970, p. 190, fig. 50, 51, 53.

Rhaponeis angustata Pant., Pantocsek, 1886: p. 33, pl. 11, fig. 97, pl. 30, fig. 313; Sheshukova-Poretzkaya, 1967, p. 241, pl. 41, fig. 8a-8b, pl. 43, fig. 2; Koizumi, 1973c, p. 134, pl. 20, fig. 21, 22.

Fresh Water Diatoms

Achnanthes lanceolata (Bréb.) Grun., 1880; Hustedt, 1962b, p. 408, fig. 863; Patrick and Reimer, 1966, p. 269, pl. 18, fig. 1-10.

Cyclotella chaetoceras Lemmerm., 1900: Hustedt, 1930, p. 100, fig. 74; Hustedt, 1962a, p. 344, fig. 175.

Cyclotella comta (Ehr.) Kütz., 1849: Hustedt, 1930, p. 103, fig. 69; Hustedt, 1962a, p. 354, fig. 183.

Eunotia sp. a Remarks: No attempts have been made to identify a species of the genus *Eunotia* Ehr., 1837: Hustedt, 1962b, p. 264, fig. 740-779, found at 20-194-1-1, 144-147 cm. The genus *Eunotia* is characteristic of fresh water biofacies.

Gomphonema olivaceum (Lyngb.) Kütz., 1844: Hustedt, 1930, p. 378, fig. 719.

Melosira granulata (Ehr.) Ralfs, *in* Pritchard, 1861: Hustedt, 1930, p. 87, fig. 44; Hustedt, 1962a, p. 248, fig. 104.

Melosira islandica Mull. forma *curvata vel spiralis* Müll., O.Müller, 1906: Hustedt, 1962a, p. 253, fig. 106.

Pinnularia borealis Ehr., 1841: Hustedt, 1930, p. 326, fig. 597; Patrick and Reimer, 1966, p. 618, pl. 58, fig. 13.

Pinnularia gibba Ehr., 1871: Hustedt, 1930, p. 327, fig. 600.

Stephanodiscus astraea (Ehr.) Grun., 1880: Hustedt, 1930, p. 110, fig. 85; Hustedt, 1962a, p. 368, fig. 193.

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This investigation was supported by the U.S. National Science Foundation through the Deep Sea Drilling Project. I thank Dr. R.L. Larson of the Lamont-Doherty Geological Observatory of Columbia University and Dr. R. Moberly of the Hawaii Institute of Geophysics, Co-Chief Scientists, for inviting me to contribute to the Initial Reports of DSDP Leg 32; Dr. J.V. Gardner of the Deep Sea Drilling Project at Scripps Institution of Oceanography for assistance in technical and editorial questions; Dr. D. Bukry of the U.S. Geological Survey, La Jolla, California for assistance in paleontological questions; Dr. H. Okada of the Kagoshima University for making the DSDP Leg 20 samples available for this report; and Dr. K. Nakaseko of the Osaka University for encouragement during this investigation.

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PLATE 1

Magnification 1000×, except Figure 7

Figures 1, 2 — *Actinocyclus curvatulus* Jan. Slide no. 1254, 32μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figures 3, 4 — *Coscinodiscus nodulifer* Schmidt. Slide no. 1211, 37μ in diameter, from 303-3-1, 130-131 cm, *Denticula kamtschatica* Zone and *Thalassiosira convexa* Zone, lower Pliocene.

Figures 5, 6 — *Coscinodiscus nodulifer* Schmidt. Slide no. 1219, 27μ in diameter, from 303-4-3, 50-51 cm, *Denticula hustedtii* Zone, upper Miocene.

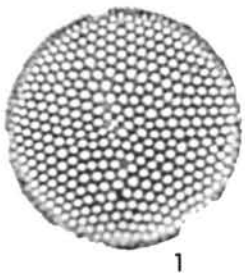
Figures 7, 8 — *Coscinodiscus nodulifer* Schmidt. Slide no. 1245, 84μ in diameter, from 310-6-3, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene. ×700 on Figure 7.

Figures 9, 10 — *Coscinodiscus nodulifer* Schmidt. Slide no. 1209, 55μ in diameter, from 303-2, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 11, 12 — *Coscinodiscus nodulifer* Schmidt var. *cyclopus* Jousé. Slide no. 1254, 50μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figures 13, 14 — *Coscinodiscus vetustissimus* Pant. Slide no. 1253, 46μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

PLATE 1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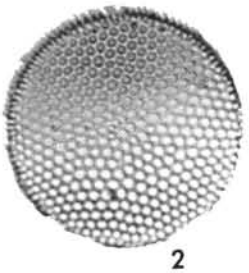
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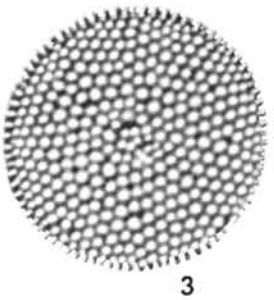
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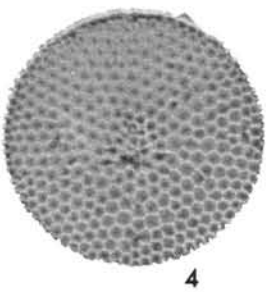
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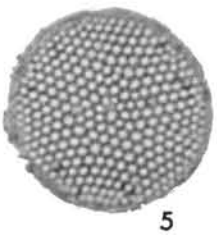
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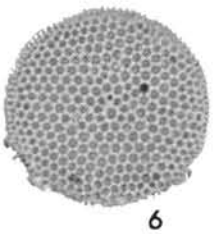
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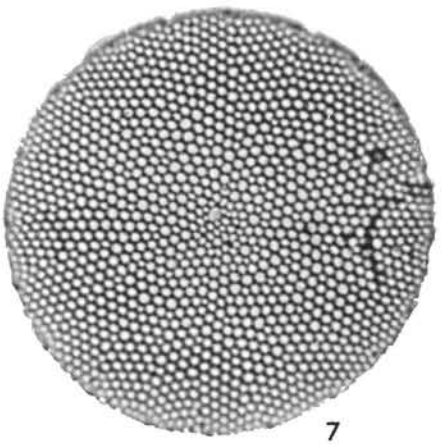
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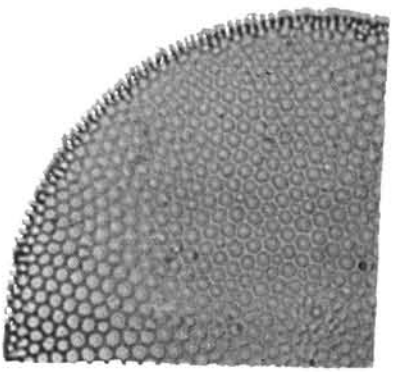
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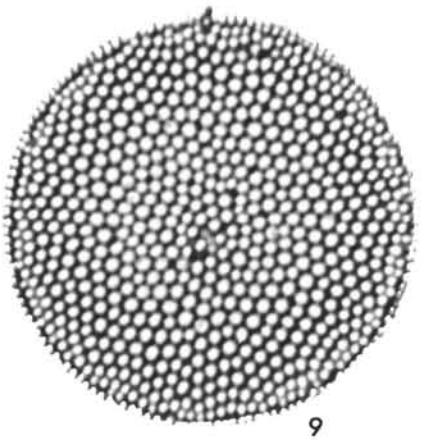
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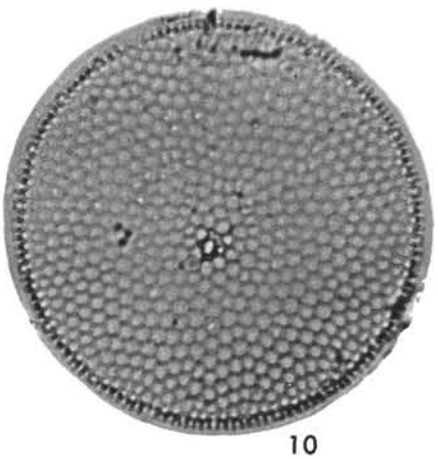
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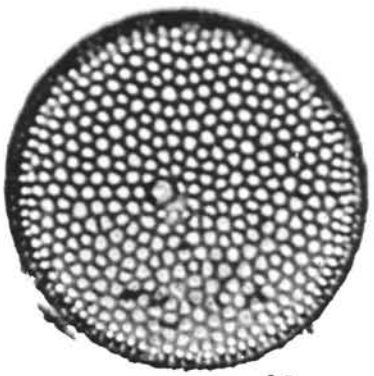
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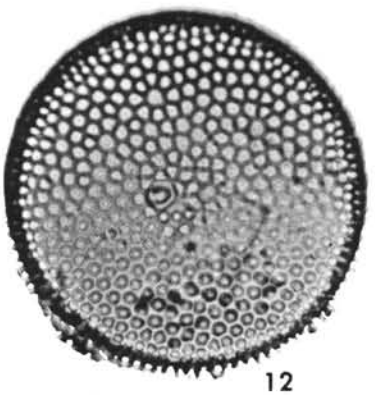
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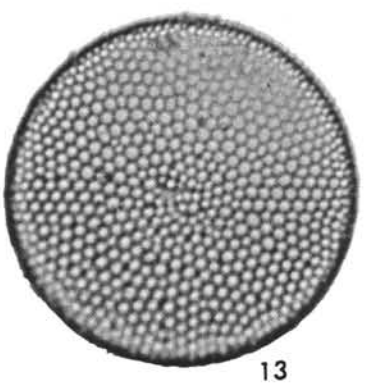
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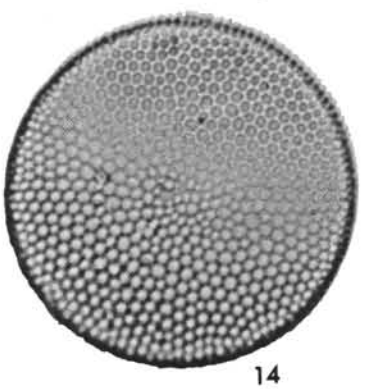
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PLATE 2

Magnification 1000×, except Figure 2

Figures 1, 2 — *Coscinodiscus africanus* Jan. Slide no. 1227, 61μ in diameter from 310-1-4, 149-140 cm, *Rhizosolenia curvirostris* Zone and *Pseudoeunotia doliolus* Zone, middle Pleistocene. ×700 on Figure 2.

Figures 3, 4 — *Roperia tesselata* (Roper) Grun. Slide no. 1231, 40μ in diameter, from 310-2, CC, *Actinocyclus oculatus* Zone and *Pseudoeunotia doliolus* Zone, lower Pleistocene.

Figures 5, 6 — *Coscinodiscus lineatus* Ehr. Slide no. 1207, 55μ in diameter, from 303-2-5, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 7, 8 — *Coscinodiscus anguste-lineatus* Schmidt. Slide no. 1203, 15μ in diameter, from 303-2-1, 52-53 cm, *Denticula seminae* var. *fossilis* Zone, upper Pliocene.

Figures 9, 10 — *Thalassiosira lineata* Jousé. Slide no. 1239, 34μ in diameter, from 310-4, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone, middle Pliocene.

Figures 11, 12 — *Thalassiosira lineata* Jousé. Slide no. 1227, 46μ in diameter, from 310-1-4, 149-150 cm, *Rhizosolenia curvirostris* Zone and *Pseudoeunotia doliolus* Zone, lower Pleistocene.

Figure 13 — *Thalassiosira oestrupi* (Ostf.) Proskina-Lavrenko. Slide no. 1254, 23μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figures 14, 15 — *Coscinodiscus tabularis* Grun. Slide no. 1254, 33μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figure 16 — *Coscinodiscus endoi* Kanaya. Slide no. 1217, 21μ in diameter, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

Figure 17 — *Macrora stella* (Azpeitia) Hanna. Slide no. 1221, 20μ in diameter, from 303-4-5, 50-51 cm, *Denticula hustedtii-Denticula lauta* Zone, upper Miocene.

Figure 18 — *Coscinodiscus marginatus* Ehr. Slide no. 1217, 45μ in diameter, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

Figures 19, 20 — *Coscinodiscus plicatus* Grun. Slide no. 1213, 31μ in diameter, from 303-4-3, 50-51 cm, *Denticula hustedtii* Zone, upper Miocene.

Figures 21, 22 — *Coscinodiscus plicatus* Ehr. Slide no. 1217, 55μ in diameter, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

PLATE 2

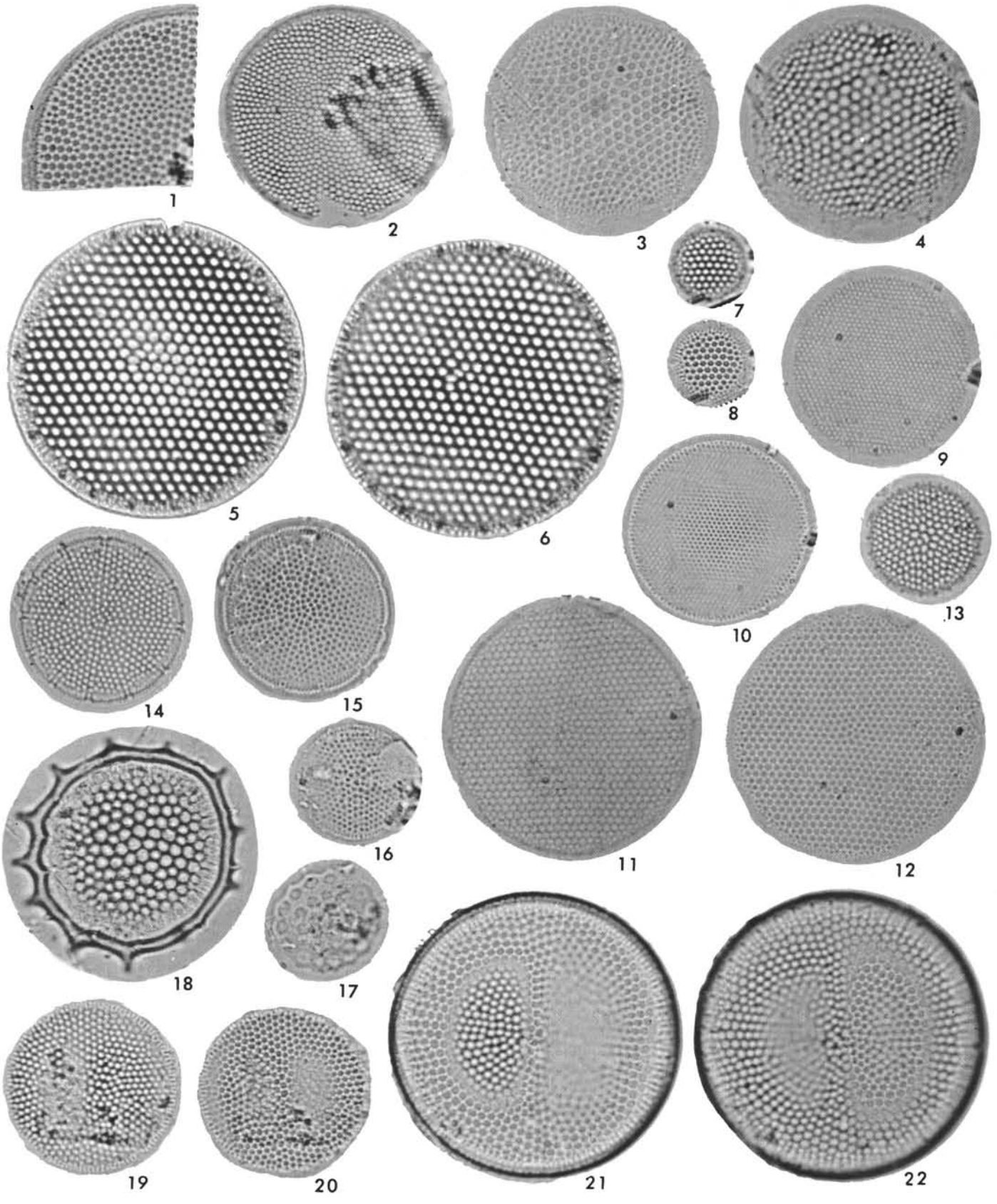


PLATE 3

Magnification 1000×

Figure 1 — *Actinocyclus ellipticus* Grun. Slide no. 1245, 60μ in length, from 310-6-3, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figure 2 — *Actinocyclus ellipticus* Grun. Slide no. 1217, 38μ in length, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

Figure 3 — *Actinocyclus ellipticus* Grun. Slide no. 1253, 38μ in length, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figure 4 — *Asteromphalus robustus* Castr. Slide no. 1207, 50μ in length, from 303-2-5, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figure 5 — *Asterolampra marylandica* Ehr. Slide no. 1254, broken specimen, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

Figures 6, 7 — *Coscinodiscus temperi* Brun. Slide no. 1217, 32μ in length, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

Figure 8 — *Hemidiscus simplicissimus* Hanna and Grant. Slide no. 1253, 34μ in length, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figure 9 — *Hemidiscus simplicissimus* Hanna and Grant. Slide no. 1249, 30μ in length, from 310-7-3, 49-50 cm, *Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, lower Pliocene.

Figures 10, 11 — *Hemidiscus cuneiformis* Wall. Slide no. 1211, 46μ in length, from 303-3-1, 130-131 cm, *Denticula kamtschatica* Zone and *Thalassiosira convexa* Zone, lower Pliocene.

Figures 12, 13 — *Actinocyclus ochotensis* Jousé. Slide no. 1207, 30μ in diameter, from 303-2-5, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 14, 15 — *Stephanopyxis horridus* Koizumi. Slide no. 1203, 27μ in diameter, from 303-2-1, 52-53 cm, *Denticula seminae* var. fossilis Zone, upper Pliocene.

Figure 16 — *Thalassiosira antiqua* (Grun.) Cl. Slide no. 1209, 29μ in diameter, from 303-2, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jousea* Zone, middle Pliocene.

Figures 17, 18 — *Thalassiosira convexa* Much. Slide no. 1243, 29μ in diameter, from 310-5, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 19, 20 — *Thalassiosira convexa* Much. Slide no. 1203, 38μ in diameter, from 303-2-1, 52-53 cm, *Denticula seminae* var. *fossilis* Zone, upper Pliocene.

Figures 21, 22 — *Thalassiosira praeconvexa* Burckle. Slide no. 1250, 20μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figures 23, 24 — *Thalassiosira praeconvexa* Burckle. Slide no. 1211, 19μ in diameter, from 303-3-1, 130-131 cm, *Denticula kamtschatica* Zone and *Thalassiosira convexa* Zone, lower Pliocene.

Figures 25, 26 — *Thalassiosira praeconvexa* Burckle. Slide no. 1253, 18μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figures 27, 28 — *Thalassiosira praeconvexa* Burckle. Slide no. 1253, 15μ in diameter, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

PLATE 3

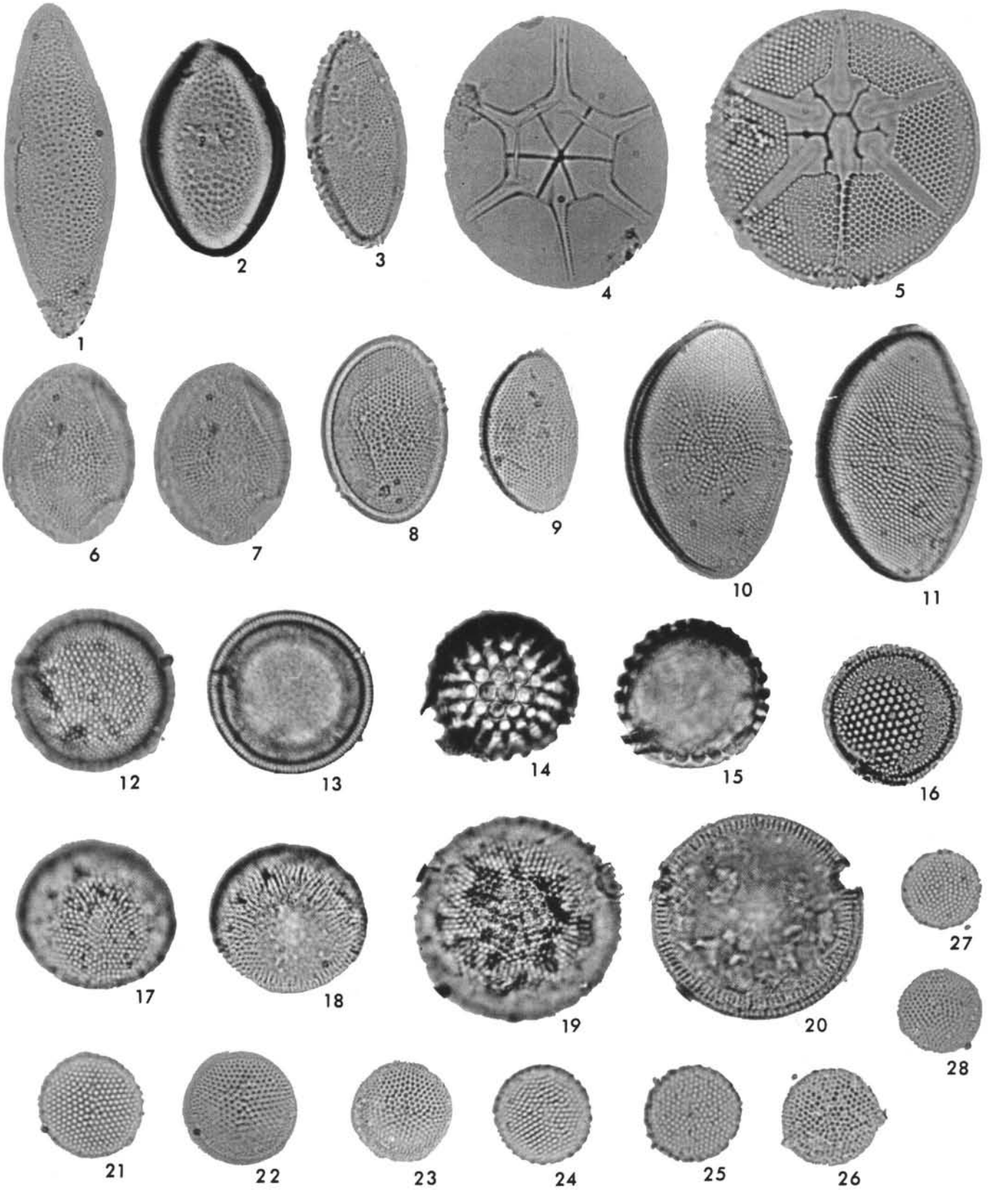


PLATE 4

Magnification 1000×

Figures 1, 2 — *Pseudoeunotia doliolus* (Wall.) Grun. Slide no. 1225, 37μ in length, from 310-1-1, 10-11 cm, *Denticula seminae* Zone and *Pseudoeunotia doliolus* Zone, upper Pleistocene.

Figures 3, 4 — *Pseudoeunotia doliolus* (Wall.) Grun. Slide no. 1227, 44μ in length, from 310-1-4, 149-150 cm, *Rhizosolenia curvirostris* Zone and *Pseudoeunotia doliolus* Zone, middle Pleistocene.

Figures 5, 6 — *Nitzschia fossilis* (Fuengelli) Kanaya. Slide no. 1203, 88μ in length, from 303-2-1, 52-53 cm, *Denticula seminae* var. *fossilis* Zone, upper Pliocene.

Figures 7, 8 — *Nitzschia fossilis* (Fuengelli) Kanaya. Slide no. 1213, 43μ in length, from 303-3-4, 50-51 cm, *Denticula kamtschatica* Zone and *Thalassiosira convexa* Zone, lower Pliocene.

Figures 9, 10 — *Nitzschia fossilis* (Fuengelli) Kanaya. Slide no. 1249, 37μ in length, from 310-7-3, 49-50 cm, *Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, lower Pliocene.

Figures 11, 12 — *Nitzschia fossilis* (Fuengelli) Kanaya. Slide no. 1245, 68μ in length, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figure 13 — *Nitzschia reinholdii* Kanaya. Slide no. 1231, 61μ in length, from 310-2, CC, *Actinocyclus oculatus* Zone and *Pseudoeunotia doliolus* Zone, lower Pleistocene.

Figures 14, 15 — *Nitzschia reinholdii* Kanaya. Slide no. 1233, 79μ in length, from 310-3-3, 101-102 cm, *Actinocyclus oculatus* Zone and *Pseudoeunotia doliolus* Zone, lower Pleistocene.

Figures 16, 17 — *Nitzschia reinholdii* Kanaya. Slide no. 1243, 63μ in length, from 310-5, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 18, 19 — *Nitzschia jouseae* Burckle. Slide no. 1205, 21μ in length, from 303-2-3, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 20, 21 — *Nitzschia jouseae* Burckle. Slide no. 1209, 25μ in length, from 303-2, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 22, 23 — *Nitzschia jouseae* Burckle. Slide no. 1243, 26μ in length, from 310-5, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 24, 25 — *Nitzschia jouseae* Burckle. Slide no. 1249, 16μ in length, from 310-7-3, 49-50 cm, *Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, lower Pliocene.

Figures 26, 27 — *Nitzschia jouseae* Burckle. Slide no. 1248, 28μ in length, from 310-6, CC, *Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, lower Pliocene.

Figures 28, 29 — *Nitzschia pliocena* (Brun) Kanaya. Slide no. 1209, 56μ in length, from 303-2, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figure 30 — *Nitzschia pliocene* (Brun) Kanaya. Slide no. 1248, 38μ in length, from 310-6, CC, *Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, lower Pliocene.

Figures 31, 32 — *Nitzschia pliocena* (Brun) Kanaya. Slide no. 1219, 51μ in length, from 303-4-3, 50-51 cm, *Denticula hustedtii* Zone, upper Miocene.

Figure 33 — *Cussia tatsunokuchiensis* (Koizumi) Schrader. Slide no. 1207, 25μ in length, from 303-2-5, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 34, 35 — *Cussia tatsunokuchiensis* (Koizumi) Schrader. Slide no. 1246, 31μ in length, from 310-6-3, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschtica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figures 36, 37 — *Cussia praepaleacea* (Schrader) Schrader. Slide no. 1219, 49μ in length, from 303-4-3, 50-51 cm, *Denticula hustedtii* Zone, upper Miocene.

Figure 38 — *Nitzschia porteri* Frenguelli. Slide no. 1253, 40μ in length, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figure 39 — *Nitzschia porteri* Frenguelli. Slide no. 1253, 28μ in length, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figures 40, 41 — *Nitzschia porteri* Frenguelli. Slide no. 1254, 31μ in length, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figure 42 — *Nitzschia porteri* Frenguelli. Slide no. 1253, 18μ in length, from 310-8-3, 101-102 cm, undefined zone, upper Miocene.

Figure 43 — *Nitzschia porteri* Frenguelli. Slide no. 1249, 15μ in length, from 310-7-3, 49-50 cm, *Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, lower Pliocene.

Figure 44 — *Denticula seminae* var. *fossilis* Schrader. Slide no. 1240, 19μ in length, from 310-4, CC, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone, middle Pliocene.

Figure 45 — *Denticula seminae* var. *fossilis* Schrader. Slide no. 1245, 17μ in length, from 310-6-3, 50-51 cm, *Denticula seminae* var. *fossilis-Denticula kamtschatica* Zone and *Nitzschia jouseae* Zone, middle Pliocene.

Figure 46 — *Denticula seminae* var. *fossilis* Schrader. Slide no. 1203, 24μ in length, from 303-2-1, 52-53 cm, *Denticula seminae* var. *fossilis* Zone, upper Pliocene.

Figure 47 — *Denticula kamtschatica* Zabelina. Slide no. 1213, 24μ in length, from 303-3-4, 50-51 cm, *Denticula kamtschatica* Zone and *Thalassiosira convexa* Zone, lower Pliocene.

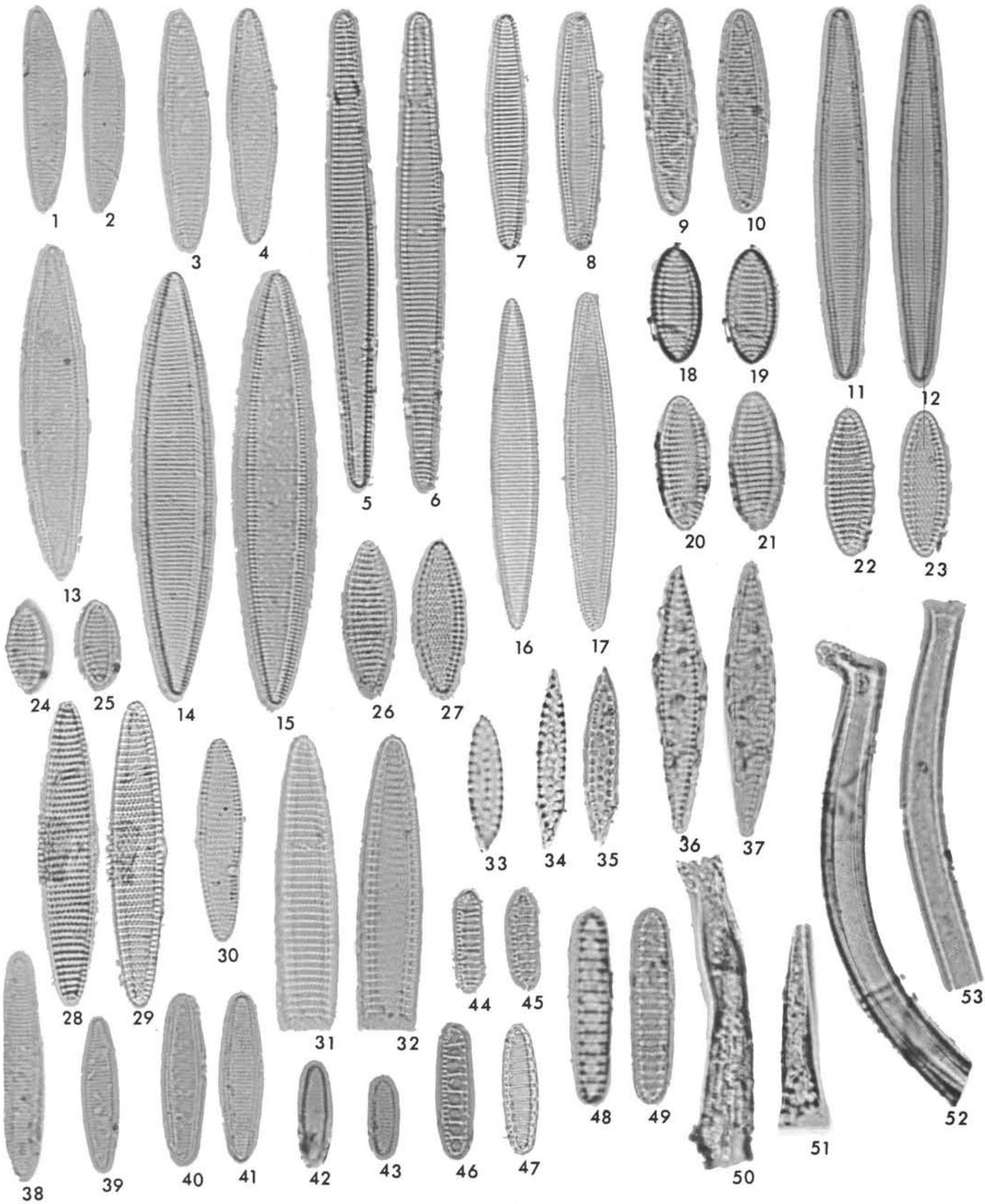
Figures 48, 49 — *Denticula hustedtii* Simonsen and Kanaya. Slide no. 1217, 35μ in length, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

Figures 50,51 — *Rhizosolenia bergonii* Perag. Slide no. 1231, broken specimen, from 310-2, CC, *Actinocyclus oculatus* Zone and *Pseudoeunotia doliolus* Zone, lower Pleistocene.

Figure 52 — *Rhizosolenia barboi* Brun. Slide no. 1203, broken specimen, from 303-2-1, 52-53 cm, *Denticula seminae* var. *fossilis* Zone, upper Pliocene.

Figure 53 — *Rhizosolenia barboi* Brun. Slide no. 1217, broken specimen, from 303-4-1, 101-102 cm, *Denticula hustedtii* Zone, upper Miocene.

PLATE 4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