

13. NEOGENE DIATOMS FROM THE EMPEROR SEAMOUNT CHAIN, LEG 55, DEEP SEA DRILLING PROJECT

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INTRODUCTION

Leg 55 of the Deep Sea Drilling Project started from Honolulu, Hawaii, on 23 July 1977 and terminated at Yokohama, Japan on 6 September, 1977. Eleven holes were drilled at 4 sites; a multiple re-entry hole was drilled on Suiko Seamount (Figure 1). As originally planned, Leg 55 had two objectives: (1) drilling at least two sites on the Emperor Seamount chain, and (2) drilling a third site in Mesozoic Pacific crust in anomaly M-1 on the oceanic side of the Kuril trench. The proposed site in Mesozoic crust, however, was abandoned for logistical reasons. Because the principal objective of Leg 55 was to test the "hot-spot" hypothesis of the origin of the Hawaiian and Emperor chains, the recovery of sedimentary sequences for diatoms was not of primary importance. Drilling on Suiko Seamount (Site 433), however, yielded pelagic sediments which consist mostly of skeletons of diatoms, radiolarians, and foraminifers, without the terrigenous material such as sand, silt, and volcanic ash.

Eighty-two samples from the 11 holes drilled on Leg 55 were examined for diatoms. The entire upper Neogene section of the northernmost site (433) contains abundant and moderately well preserved diatoms. Regrettably, diatoms are very rare throughout the samples from Quaternary sediments of the southern sites (Sites 430 to 432), owing to the lower primary production in the warm-water area; no diatoms were recovered in any samples from sediments older than lower Neogene from the northernmost site.

PREPARATION OF SAMPLES

All samples examined were taken on board D/V *Glomar Challenger* from suitable levels in the core sections. The sample spacing in critical intervals was sufficiently close that stratigraphic first and last occurrences of selected species were determined with reasonable accuracy.

Original wet material of about 1 gram weight was dropped into a 200-ml beaker of boiling hydrogen peroxide solution (H_2O_2 , 15%). Upon cooling, hydrochloric acid was added to make an acid solution (approximately 25% in HCl by volume) that was then boiled. After boiling for about 5 minutes, the beaker was filled with distilled water and allowed to stand for 4 hours. Then the residue was separated by decanting the acid water in the beaker. The beaker was filled again with distilled water, and this decanting process was repeated four times.

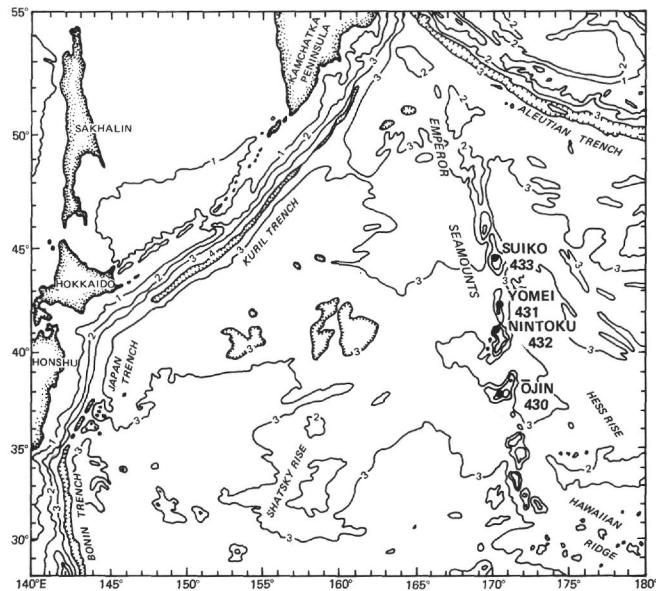


Figure 1. Location of drilling sites occupied on DSDP Leg 55, the northwestern Pacific Ocean. Contour depths are in kilometers (from map "Topography of North Pacific" by T. E. Chase, H. W. Menard, and J. Mammerickx, Institute of Marine Resources, Geologic Data Center, Scripps Institution of Oceanography, 1971).

The residue was stirred while adding distilled water. After about 10 seconds, when clastic grains and volcanic glass sank to the lower part or the bottom of the beaker, approximate quantities of the suspension containing diatom valves were taken with a 1-ml pipette from the middle part of the water column in the beaker, and placed on a square cover glass (18 × 18 mm in size). The cover glass was dried on a hot plate at moderate temperature (about 60° to 80°C) and then mounted on a slide glass using Aroclor No. 4465 (refractive index 1.66).

METHOD OF STUDY

Investigations were carried out using a Carl Zeiss Standard RA microscope with a lens combination of kpl W12.5 × and Plan Oil 100 × /1.25. All diatom species were identified and counted throughout the samples from Sites 430, 431, and 432 (Tables 1 to 3). The single count of 200 specimens was done for the samples from Site 433 (Table 4). The microscope work was completed by adding 200 more specimens in order to know the oc-

TABLE 1
Neogene Diatoms

DSDP, Leg 55, Site 430												
Hole	Depth Below Sea Floor (m)	Recovery (m)	Core	Section	Sample Interval (cm)	Abundance	Preservation	<i>Asteromphalus robustus</i>	<i>Coscinodiscus marginatus</i>	<i>Pseudaeonita doliohus</i>	<i>Thalassionema nitzschioides</i>	<i>Thalassiosira eccentrica</i>
	2.5-4.5	7.7	2	3	10-20 30-35 CC	VR VR B	p p	1	1	1	1	<i>T. oestrupii</i>
A	0-5.5	1.0	1	1	25-30 CC CC	VR B B	p		2		2	<i>T. tabularis</i>
	19.0-28.5										2	<i>Thalassiothrix longissima</i>
											7	Total Specimens
											3	P.d.
											2	Diatom Zone
											3	Plei.
											3	Chronostigraphy

TABLE 2
Neogene Diatoms

TABLE 3
Neogene Diatoms

currences of the marine planktonic species selected by Koizumi (1973a, 1975a, c) and Burckle (1972, manuscript) for the Neogene diatom zonation of the North Pacific Ocean. Additions to the regular counting are shown by a black circle in the distribution chart (Table 4).

Abundance is recorded as follows: B = barren; VR = very rare (less than 100 individuals on one slide, 18 x 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 recorded as follows: p = poor, m = moderate, and g = good, according to the degree of destruction of the diatom valves.

Diatom zonations follow those proposed by Koizumi (1975a, c) and Burckle (1972, manuscript). The age assignments for these diatom zones follow Koizumi (1977) and Burckle and Opdyke (1977).

In this paper, the Miocene/Pliocene boundary is placed at the top of Geomagnetic Epoch 5 (bottom of the Gilbert Reversed Magnetic Epoch), at an age of 5.10 m.y., and 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.

SITE 430

(lat 37° 58.88 'N, long 170° 35.45 'E, depth 1464 m)

Stratigraphic Setting

Three holes were drilled on a lagoonal sediment pond of Ōjin Seamount (Figure 1). Hole 430 was abandoned because of caving, after recovering three cores of Quaternary to Eocene pebbly mudstone. Core 1 of Hole 430 had zero recovery. At Hole 430A, the drill penetrated 47.5 meters of Quaternary and upper Paleocene calcareous ooze and sand. A punch core at Hole 430B resulted in very poor recovery of Quaternary watery ooze.

Diatoms and Age

Diatoms are very few in two samples and absent in the core-catcher sample from Core 2 of Hole 430. Diatoms are present, but very rare, in only one sample from Core 1 of Hole 430A (Table 1).

Diatom-bearing samples of Site 430 belong to the *Pseudoeunotia doliolus* Zone (Recent to early Brunhes Normal Epoch; 0 to 0.63 m.y.B.P.) of Burckle (1972; in Burckle and Opdyke, 1977).

SITE 431

(lat 42° 25.44 'N, long 170° 32.68 'E, depth 1714.5 m)

Stratigraphic Setting

Two holes were drilled on a faulted terrace of Yōmei Seamount (Figure 1). At both Hole 431 and Hole 431A, drilling was ended after the recovery of only two cores, owing to the loss of the bottom hole assembly.

Diatoms and Age

Diatoms are very few in two samples from Core 1 of Hole 431 and in three samples from Core 1 of Hole 431A. They are completely absent in two samples from Core 2, Hole 431A (Table 2). No marine tychopelagic to benthic species or fresh-water species were observed in any of the samples. Diatom-bearing samples at Site 431 belong to the *Denticula seminae* Zone (Recent to late Brunhes Normal Epoch; 0 to 0.25 m.y.B.P.) of Koizumi (1973a, 1975a) and the *Pseudoeunotia doliolus* Zone.

SITE 432

(lat 41° 20.03 'N, long 170° 74 'E, depth 1320 m)

Stratigraphic Setting

Two holes were drilled on a terrace deposit atop Nin-toku Seamount (Figure 1). At Hole 432, the lower bottom sub sheared off while we were attempting to take Core 2. Hole 432A was washed down to a sub-bottom depth of 36 meters, and 3.52 meters (Cores 1 and 2) of well-consolidated Paleocene calcite-cemented conglomerate and sandstone, underlain by a thin red clay above basalt, was recovered.

Diatoms and Age

Diatoms are very few in four samples from Core 1 of Hole 432. The assemblages represent the *Denticula seminae* Zone and the *Pseudoeunotia doliolus* Zone (Table 3). All other samples are barren of diatoms.

SITE 433

(lat 44° 46.60 'N, long 170° 01.26 'E, depth 1874 m)

Stratigraphic Setting

Four holes, including a multiple re-entry hole, were drilled at the southwestern flank of the central ridge of Suiko Seamount (Figure 1). At Hole 433, a 5.0-meter core of Pleistocene to upper Pliocene diatom-nannofossil ooze was taken. Hole 433A was continuously cored, and penetrated 163.5 meters of sedimentary rocks. The sedimentary section consists of five lithologic units: (1) Pleistocene to upper Pliocene foraminiferal nannofossil ooze from 0 to 5.0 meters (Core 1); (2) lower Pliocene through upper Miocene diatom-nannofossil ooze to marly siliceous nannofossil ooze from 5.0 to 43.0 meters (Cores 2 to 5); (3) upper Miocene calcareous ooze to calcareous chalk from 43.0 to 52.0 meters (Sections 1 to 6 of Core 6); (4) middle to lower Miocene tuffaceous sandy mud from 52.0 to 52.5 meters (Section 7 of Core 6); and (5) Paleocene carbonate sand and sandy mud from 52.5 to 163.5 meters (CC of Core 6 to Core 19). Hole 433B was washed to a depth of 128.5 meters sub-bottom, and cored in the lower 34.5 meters of sedimentary rocks of reef carbonate, sorted sandstone, and calcarenites ranging from lower Eocene to upper Paleocene. Hole 433C was washed to a depth of 163.0 meters sub-bottom and penetrated 4.5 meters of Paleocene calcarenite and reef carbonate sand, and 383.0 meters of basalt.

Abundance and Preservation of Diatoms

In general, common and moderately preserved diatoms are continuously present throughout the upper 52.3 meters of siliceous and calcareous ooze and calcareous chalk from Cores 1 to 6 of Hole 433A, except in the core-catcher sample of Core 6 which is barren of diatoms. Diatoms are poorly preserved in Cores 3 and 4,

TABLE 4
Neogene Diatoms

and they are rare to few and badly preserved in the lowermost part of Core 6 (51.64 to 52.3 m). All samples taken from below Core 7 of Hole 433A and from Hole 433B are barren of diatoms.

Marine tychopelagic species occur frequently throughout the upper Miocene section of Core 6 (Table 4, Figure 2).

Age, Biostratigraphy, and Paleoceanography

Five diatom zones were recognized with zonal breaks (Table 5). The *Denticula seminae* Zone assemblage in a Sample 1-1, 73–75 cm is followed by the *Rhizosolenia curvirostris* Zone assemblage in Sample 1-2, 8–10 cm of Hole 433. After the absence of two zonal assemblages,

TABLE 4 - *Continued*

those of the *Actinocyclus oculatus* Zone and the *Denticula seminae* var. *fossilis* Zone, the *Denticula seminae* var. *fossilis*-*Denticula kamtschatica* Zone assemblage was observed in Samples 1-2, 108-110 cm to 3,CC. In Hole 433A, the uppermost *Denticula seminae* Zone assemblage was not found, owing to a lack of sediments representing this zone. The same two zones that are missing in Hole 433 are also absent between Samples 1-1, 18-20 cm and 1-1, 65-67 cm. The *Denticula kam-*

tschatica Zone assemblage occurs in the interval between Samples 2, CC and 6-6, 53–54 cm. Older reworked middle Miocene species from the *Denticula lauta* Zone assemblage are common in two samples, 6-6, 114–115 cm and 6-6, 138–140 cm, which originally belonged to the *Denticula kamtschatica* Zone. This interval, therefore, is the mixed zone of both *Denticula kamtschatica* Zone and *Denticula lauta* Zone assemblages. Below the mixed interval, the *Denticula lauta* Zone assemblage

TABLE 4 - *Continued*

DSDP, Leg 55, Site 433											
Hole	Depth Below Sea Floor (m)	Recovery (m)	Core	Section	Sample Interval (cm)	Abundance	Preservation	Planktoniella sol	Pseudoeunotia doliolus	Rhizosolenia barboi	R. bergeronii
	0-5.0	5.0	1	1	73-75	C	c		●	15	
			2	2	8-10	R	c		5	20	15
			3	3	108-110	A	g		7	1	11
					90-92	A	g		6	●	2
					CC	A	g			1	●
A	0-5.0	1.7	1	1	4-13	F	p		●	1	6
					18-20	R	p		14	19	15
					65-67	F	c		12	6	6
					CC	F	c		7	●	
	5.0-14.5	2.4	2	1	27-29	F	c		5	3	
			2	2	120-122	C	c		6	2	
					28-30	C	c		3	1	1
					CC	C	c		4	1	
14.5-24.0	14.5-24.0	8.0	3	1	8-10	A	p		1	3	1
			2	2	8-10	A	p		●	6	●
			3	3	8-10	C	p		1	●	
			4	4	18-20	F	p		3	4	
			5	5	8-10	F	p		2	5	●
			6	6	8-10	F	p		2	8	
					CC	C	p		1	5	2
	24.0-33.5	8.7	4	1	8-10	C	p	1	1	12	6
			2	2	8-10	C	p	2	1	6	5
			3	3	8-10	F	p	1	2	1	●
			4	4	8-10	F	p	1	1	15	2
			5	5	8-10	C	p	2	2	14	1
			6	6	8-10	C	c	1	2	10	4
33.5-43.0	33.5-43.0	8.6	5	1	8-10	A	c	4	2	16	6
			2	2	8-10	F	c	11	5	2	22
			3	3	8-10	F	c	11	5	2	1
			4	4	8-10	C	c	5	3	9	15
			5	5	8-10	F	c	5	2	15	3
			6	6	8-10	A	g	12	4	3	1
					CC	R	c	4	2	6	1
43.0-52.5	43.0-52.5	9.5	6	1	8-10	A	g	●	●	2	2
			2	2	8-10	C	gg	8	3	4	3
			3	3	8-10	C	gg	8	●	2	2
			4	4	8-10	C	gg	5	2	5	3
			5	5	8-10	C	gg	7	2	5	3
			6	6	8-10	C	g	7	1	4	1
					53-54	C	g	15	8	2	●
					114-115	F	p		1	3	49
					138-140	F	p		5	2	3
			7	7	6-7	F	p		2	1	10
					27-29	R	p		5	5	15

was recognized in the interval between Samples 6-7, 6-7 cm and 6-7, 27-29 cm, without two zonal assemblages, the *Denticula hustedtii* Zone and *Denticula hustedtii-Denticula lauta* Zone assemblages.

Figure 3 represents the ranges of selected marine planktonic diatom species and the boundaries between diatom zones, corresponding to depth below the sediment surface at Site 433. The occurrences of a number of species have been directly compared with the paleomagnetic time-scale (Burckle, 1972, manuscript; Bur-

ckle and Opdyke, 1977) and various radiometric dates (Koizumi, 1977). These absolute ages of diatom events were used to construct the curve of sediment accumulation rates at Site 433 (Figure 4).

Three hiatuses are shown in Figure 4. The Pliocene/Pleistocene hiatus is represented in Core 1 of Hole 433 and Core 1 of Hole 433A. The time gap over the boundary is calculated at about 1.7 m.y. This hiatus is marked by occurrence of sandy diatom-nannofossil ooze at a sub-bottom depth of from 1.30 to 2.15 meters.

TABLE 4 – *Continued*

The boundary unconformity could be attributed to sub-bottom erosion of the top of the seamount by cold bottom currents. The Miocene/Pliocene hiatus was also identified between Cores 3 and 4, where its duration was about 0.8 m.y. Another gap in Core 6 spans an interval of about 9.0 m.y., encompassing most of the late Miocene and the whole middle Miocene. The hiatus is also marked by occurrences of calcareous chalk and marly siliceous ooze at a sub-bottom depth of from 52.0 to 52.5 meters. These unconformities are assumed to

have been caused by increased bottom water activity associated with global cooling in the latest Miocene to earliest Pliocene.

An abrupt change in sedimentation occurred about 4.4 m.y. ago. The accumulation rate for the upper 4.6 meters of Pliocene sediment was about 4.3 meters/m.y., whereas the estimated rate of accumulation for the lowermost Pliocene section between 6.8 and 23.8 meters was 53.0 meters/m.y. The sediments were deposited, therefore, about 12 times faster in the earliest Pliocene

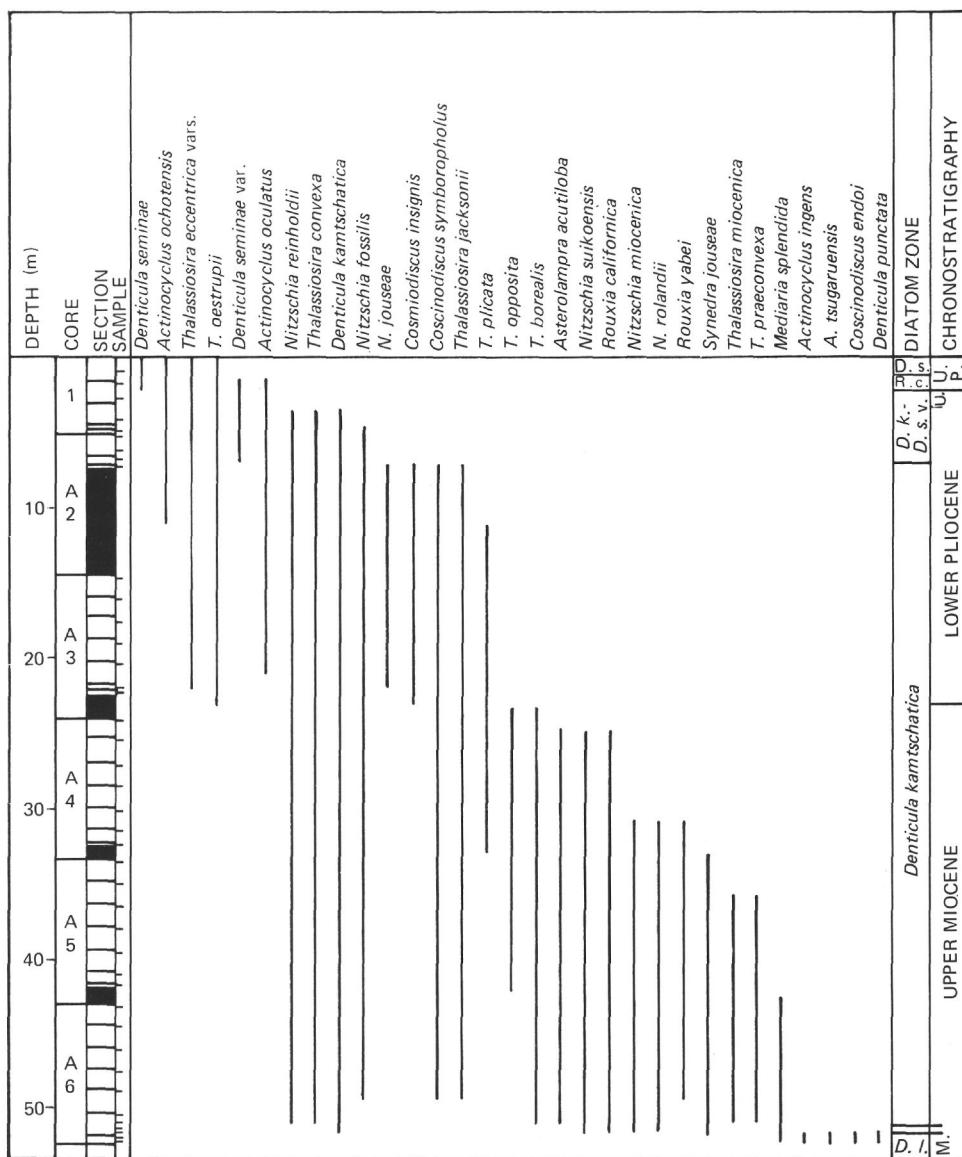


Figure 2. Chronostratigraphic positions of samples, based on accumulation rates (Figure 4), and paleoceanographic cycles at Site 433.

than during the later Pliocene. The calculated rate of deposition for the uppermost Miocene sediments is 30 meters/m.y., which is comparable to the lowest Pliocene rates.

Td (diatom temperature) values (Kanaya and Koizumi, 1966) were calculated for each sample on the basis of the species assigned to cold or warm water (Figure 2). They are shown as *Td'* because the calculation involved extinct species. The abrupt increases in the diatom temperature curve are found both below and above the Miocene/Pliocene boundary. The trend of the curve is not shown near the boundary, because of the absence of samples due to the hiatus. The significant cooling, however, is recorded in the uppermost Miocene sections throughout the North Pacific region.

DESCRIPTIONS OF FOUR NEW DIATOM SPECIES

Genus *NITZSCHIA* Hassal (1845)

Nitzschia suikoensis Koizumi, n. sp.
(Plate 1, Figures 1-6)

Description: Valves linear-elliptic to elliptic with bluntly rounded apices, 25–60 μ long, 6–7 μ wide. Transapical striae straight in the middle of the valves, curved near the apices, 12–15 in 10 μ , punctuation not visible in the normal light microscope. Keel very eccentric, fibulae 6–8 in 10 μ , without a central nodule.

Holotype: Plate 1, Figures 3 and 4, 41 μ in length, from DSDP Leg 55, Sample 443A-5-5, 8–10 cm, North Pacific Ocean.

Paratype: Plate 1, Figures 1 and 2, 30 μ in length, from DSDP Leg 55, Sample 443A-6-6, 8–10 cm, North Pacific Ocean.

Discussion: No similar species were found in the literature. The new species is named for Suiko Seamount in the Emperor Seamount chain.

TABLE 5
Neogene Diatoms

Chronostratigraphy	Hole	430	430A	431	431A	432	433	433A
Diatom Zone								
Pleistocene	<i>Denticula seminae</i>	2-3, 10-20 cm 2-5, 30-35 cm	1-1, 25-30 cm	1-1, 64-66 cm 1,CC	1-1, 5-8 cm 1-1, 145-148 cm	1-1, 12-13 cm 1-4, 20-21 cm	1-1, 73-75 cm	
	<i>Rhizosolenia curvirostris</i>						1-2, 8-10 cm	1-1, 4-13 cm 1-1, 18-20 cm
	<i>Actinocyclus oculatus</i>							
Pliocene	<i>Denticula seminae v. fossilis</i>							
	<i>Denticula seminae v. fossilis</i>						1-2, 108-110 cm 1,CC	1-1, 65-67 cm 2-2, 28-30 cm
	<i>Denticula kamtschatica</i>							2,CC 6-6, 53-54 cm
Miocene	<i>Denticula kamtschatica</i>							
	<i>Denticula hustedtii</i>							
	<i>Denticula hustedtii</i>							
<i>Denticula lauta</i>								6-7, 6-7 cm 6-7, 27-29 cm

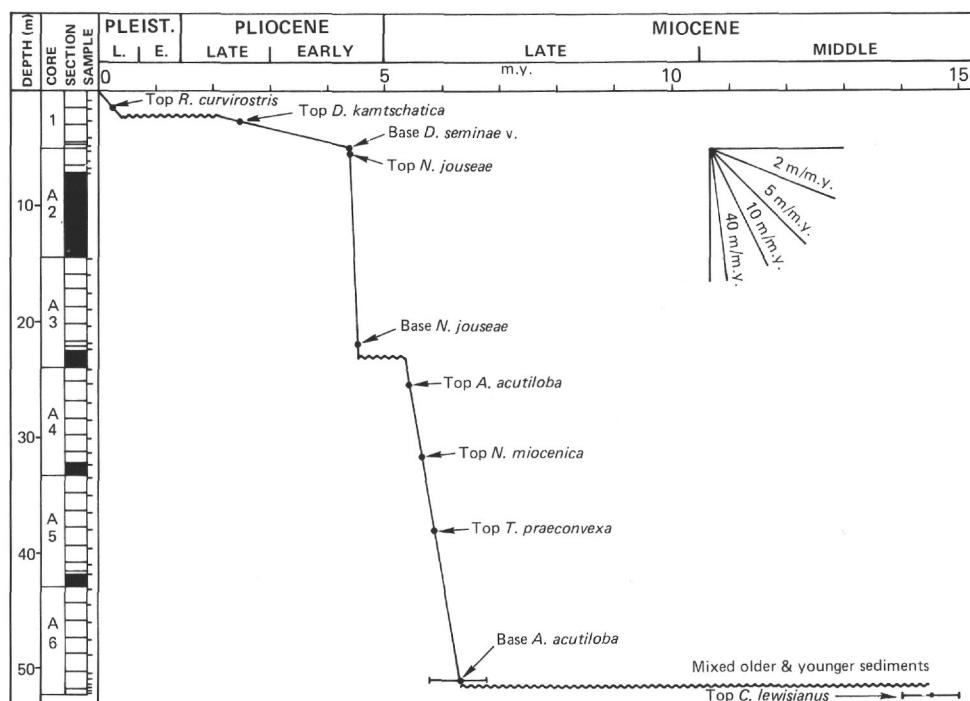


Figure 3. Stratigraphic ranges of selected marine planktonic diatom species and zonal subdivisions at Site 443. Black area in the section column shows unrecovered interval.

Occurrences: Up to now found only in the upper Miocene sediment from DSDP Hole 433A.

Genus THALASSIOSIRA Cleve (1873) emend. Hasle (1973)

Thalassiosira borealis Koizumi, n. sp.
(Plate 1, Figures 7-10)

Synonyms: *Thalassiosira decipiens* (Grun.) Jörg., Sheshukova-Poretskaya, 1967, pl. 4, fig. 5, pl. 14, fig. 2; *Thalassiosira decipiens* (?) Jörg., Schrader, 1973a, pl. 16, fig. 12; *Thalassiosira nativa* Sheshuk., Koizumi, 1975a, pl. 4, fig. 21, 22.

Description: Valves circular, 15-25 μ in diameter, slightly curved, with rounded margins. Some small mucilage pores present in the

depressed center. Areolae hexagonal, decreasing in size from the center to the margin, 8-12 in 10 μ midway. Areolae arranged in slightly curved tangential rows with secondary sculpture of outwardly concave rows in outer border. One row of conspicuous marginal processes surround the inner edge of margin, about 4 in 10 μ .

Holotype: Plate 1, Figure 7, 17 μ in diameter, from DSDP Leg 55, Sample 443A-6-3, 8-10 cm, North Pacific Ocean.

Paratype: Plate 1, Figure 8, 21 μ in diameter, from DSDP Leg 55, Sample 433A-5-5, 8-10 cm, North Pacific Ocean.

Discussion: This species is similar to *Thalassiosira decipiens* (Grun.) Jörg., but differs by the presence of some mucilage pores in the center and of conspicuous marginal processes, and to *Thalassiosira burcklini* Schrader, 1974, p. 916, pl. 1, fig. 21-26, from which

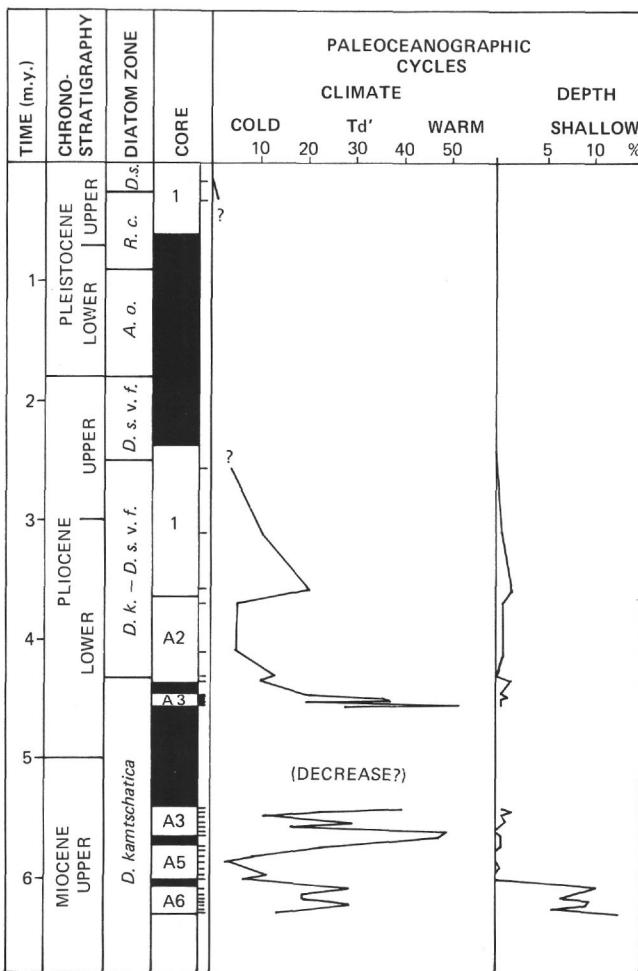


Figure 4. Accumulation rates of Neogene sediments at Site 433. Black area in the section column shows unrecovered interval.

it differs by the finer areolation, the arrangement of areolae, and the presence of marginal processes. This species is also distinguished from *Thalassiosira nativa* Sheshukova-Poretsky, 1967, p. 145, pl. 14, fig. 7a-B, by the larger form and the presence of marginal processes.

Occurrences: *Thalassiosira borealis* occurs in upper Miocene to lower Pliocene sediments from DSDP Sites 173, 302, 433, and land sections of Sakhalin and Kamchatka.

***Thalassiosira jacksonii* Koizumi and Barron, n. sp.**
(Plate 1, Figures 11-14)

Synonyms: *Coscinodiscus symbolophorus* Grun., Sheshukova-Poretsky, 1967, pl. 1, fig. 3, pl. 22, fig. 3; *Thalassiosira antarctica* Comber, Schrader, 1974, pl. 3, fig. 10-13; *Thalassiosira* sp. b, Schrader and Fenner, 1976, pl. 17, fig. 5, 10.

Description: Valves circular, slightly convex, depressed in the center, with narrow margin. Diameter 13-30 μ . Areolae circular, arranged in radial fascicles, within each fascicle parallel to the longest radial row. Areolae are also arranged weakly concave outward near the margin. Areolae slightly large and somewhat sparse in the center, smaller and denser outward, 13-18 in 10 μ midway. A mucilage pore present in the hyaline central area. One row of marginal processes surrounds the inner edge of margin, 6-7 in 10 μ . All other rows of marginal spines to striae were barely distinguishable in the normal light microscope.

Holotype: Plate 1, Figure 12, 16 μ in diameter, from DSDP Leg 55, Sample 433A-4-5, 8-10 cm, North Pacific Ocean.

Paratype: Plate 1, Figure 14, 20 μ in diameter, from DSDP Leg 55, Sample 443A-1, CC, North Pacific Ocean.

Discussion: This species differs, by the presence of a mucilage pore in the hyaline center, from *Thalassiosira antarctica* Comber, 1896: Hendey, 1937, p. 237; Hustedt, 1958, p. 108, pl. 3, fig. 1-3; Hasle and Heimdal, 1968, p. 357, fig. 1-21, and by the areolation in radial to bifurcate rows and by the flat to slightly convex valve surface from *Thalassiosira gracilis* (Karst.) Hustedt, 1958: p. 109, fig. 4-7; Fenner, Schrader and Wienigk, 1976, p. 780, pl. 9, fig. 12-20. The new species is named for the late Dr. Dale E. Jackson, former senior researcher in marine geology, U.S. Geological Survey at Menlo Park, who served as co-chief scientist of DSDP Leg 55.

Occurrences: *Thalassiosira jacksonii* occurs in the Pliocene to upper Miocene sediments from DSDP Sites 238, 348, 433, 438, and land sections of Hokkaido and Sakhalin.

***Thalassiosira opposita* Koizumi, n. sp.**
(Plate 1, Figures 15-17)

Description: Valves flat to slightly curved, depressed in the center, with rounded margin. Diameter of valves 17-30 μ . Areolae arranged in straight to slightly curved, nearly parallel rows. Areolae become smaller outward, about 16 in 10 μ midway. Hyaline central area with two opposite processes surrounded by slightly large and conspicuous areolae. One concentric row of strutted processes present about halfway from center to margin. One row of marginal processes surrounds the inner edge of margin, about 7 in 10 μ . Valve margin radially striated, about 20 striae in 10 μ .

Holotype: Plate 1, Figure 16, 29 μ in diameter, from DSDP Leg 55, Sample 433A-6-4, 8-10 cm, North Pacific Ocean.

Paratype: Plate 1, Figure 15, 20 μ in diameter, from DSDP Leg 55, Sample 433A-6-4, 8-10 cm, North Pacific Ocean.

Discussion: This species is most characterized by the presence of opposite central processes. No similar species were found in the literature.

Occurrences: Up to now found only in the upper Miocene sediment from DSDP Hole 433A.

EMENDED DESCRIPTIONS OF TWO DIATOM SPECIES

Genus DENTICULA Kützing (1884)

***Denticula kamtschatica* Zabelina (1934), emend. Koizumi**
(Plate 2, Figures 1-10)

Synonyms: *Nitzschia rolandii* Schrader, Harper, 1977, pl. 3, fig. 9, 10.

Description: Simonsen and Kanaya, 1961, p. 503, pl. 1, fig. 14-18.

Emended description: The number of pseudosepta in 10 μ has been expanded to 5-8. Pseudosepta irregularly branch near the raphe.

Discussion: This species is represented by specimens having 6-8 pseudosepta in 10 μ in the DSDP Leg 55 samples, as well as other DSDP samples; Schrader, 1973a, pl. 2, fig. 3-13, DSDP Sites 173 and 178; Koizumi, 1973a, pl. 5, fig. 15, DSDP Site 183; Koizumi, 1975a, pl. 1, fig. 13-16, 19, 20, DSDP Sites 301 and 302. They cannot be distinguished from the type form, because of the presence of intermediate form in the number of pseudosepta in 10 μ .

Genus NITZSCHIA Hassall (1845)

***Nitzschia rolandii* Schrader (1973), emend. Koizumi**
(Plate 2, Figures 15-20)

Description: Schrader, 1973a, p. 708, pl. 26, fig. 3, 4, pl. 5, fig. 31, 42.

Emended description: Valves linear to linear-lanceolate with parallel sides and bluntly rounded ends, 10-45 μ in length, 3-6 μ in width. Transapical striae 10-12 in 10 μ , punctuation not visible in the normal light microscope. Transapical striae regularly branch near the keel, mostly share branches to one another.

Discussion: Harper (1977) referred specimens resembling *Denticula kamtschatica* to *Nitzschia rolandii* emend. Harper. However, two forms of them are considered to be *Denticula kamtschatica* by the expanded number of pseudosepta in 10 μ and the irregular branching pattern of pseudosepta. This species, in DSDP Hole 433A samples, is more similar to the illustration of paratype than one of holotype by Schrader (1973a).

FLORAL REFERENCES

The references are given for those taxa mentioned in this report. The taxa are arranged alphabetically, separately under the marine

planktonic and marine tychopelagic to benthic diatoms. The taxa that were treated by Hustedt (1930, 1959) are referred directly to his work. For the taxa that were not treated by Hustedt, references, as far as possible, are made to the original descriptions. Additional references are selected from remarks and illustrations which were helpful for the present work. Marine planktonic diatoms which are important for the biostratigraphy and taxonomy are illustrated.

Marine Planktonic Diatoms

- Actinocyclus curvatus* Jan., in Schmidt, 1878: Hustedt, 1930, p. 538, fig. 307; Koizumi, 1973a, p. 831, pl. 1, fig. 1-6.
- Actinocyclus divisus* (Grun.) Hustedt, 1958: p. 129, pl. 8, fig. 81; Koizumi, 1973a, p. 831, pl. 1, fig. 7-12.
- Actinocyclus ellipticus* Grun., in Van Heurck, 1883: Hustedt, 1930, p. 533, fig. 303; Schrader, 1974, p. 908, pl. 17, fig. 4, 5, 16. [Plate 1, Figure 19.]
- Actinocyclus ellipticus* Grun. forma *lanceolata* Kolbe, 1954: p. 20, pl. 3, fig. 27; Schrader, 1974, p. 908, pl. 17, fig. 2. [Plate 1, Figure 20.]
- Actinocyclus ellipticus* Grun. var. *elongatus* (Grun.) Kolbe, 1954: p. 20, pl. 3, fig. 28, 31; Schrader, 1974, p. 908, pl. 17, fig. 3. [Plate 1, Figure 21.]
- Actinocyclus ingens* Rattray, 1890: p. 149, pl. 11, fig. 7; Kanaya, 1971, p. 554, pl. 40.6, fig. 1-8; Koizumi, 1973a, p. 831, pl. 1, fig. 13, 14, pl. 2, fig. 1, 2. **Remarks:** Two kinds of specimens were found, those with the concentric undulation of the valve surface and those with valves almost flat. Separation into two different taxa has not been done, because they show a continuous transition from one extreme to another.
- Actinocyclus ochotensis* Jousé, 1968: p. 17, pl. 2, fig. 2-5; Koizumi, 1973a, p. 831, pl. 2, fig. 8, 9.
- Actinocyclus oculatus* Jousé, 1968: p. 18, pl. 2, fig. 6, 7; Koizumi, 1973a, p. 831, pl. 2, fig. 8, 9.
- Actinocyclus tsugaruensis* Kanaya, 1959: p. 99, pl. 8, fig. 5-8.
- Asterolampra acutiloba* Forti, in Tempère and Peragallo, 1912: Schrader, 1974, p. 911, pl. 9, fig. 7, 8. [Plate 1, Figure 18.]
- Asterolampra grevillei* (Wall.) Greville, 1860: Hustedt, 1930, p. 489, fig. 274; Schrader, 1974, p. 911, pl. 8, fig. 5.
- Asterolampra marylandica* Ehr., 1844: Hustedt, 1930, p. 485, fig. 270, 271; Schrader, 1974, p. 912, pl. 8, fig. 2. [Plate 2, Figure 24.]
- Asteromphalus darwinii* Ehr., 1844: Greville, 1860, p. 116, pl. 4, fig. 12, 13; Hanna, 1970, p. 180, fig. 90. **Synonyms:** *Asteromphalus robustus* Castr., Sheshukova-Poretzkaya, 1967, pl. 29, fig. 2; *Asteromphalus cf. robustus* Castr., Schrader, 1973a, pl. 21, fig. 7. [Plate 2, Figure 26.]
- Asteromphalus flabellatus* (Bréb.) Grev., 1859: Hustedt, 1930, p. 498, fig. 279; Schrader, 1974, p. 912, pl. 8, fig. 3.
- Asteromphalus hookeri* Ehr., 1844: Hustedt, 1958, p. 127, pl. 8, fig. 88-90; Schrader, 1973a, p. 702, pl. 21, fig. 6. [Plate 2, Figure 23.]
- Asteromphalus hungaricus* Pantocsek, 1889: p. 111, pl. 30, fig. 436, pl. 31, fig. 451. [Plate 2, Figure 25.]
- Asteromphalus robustus* Castr., 1875: Hustedt, 1930, p. 496, fig. 278; Koizumi, 1975b, p. 876, pl. 3, fig. 5.
- Coscinodiscus curvatus* Grun., in Schmidt, 1878: Hustedt, 1930, p. 406, fig. 214; Fenner, Schrader, and Wienigk, 1976, p. 773, pl. 6, fig. 3-10. **Remarks:** Valves nearly flat, 15-30 μ in diameter. Valve surface divided into sectors bounded by curved rows, the areolae running parallel to the lateral row of each sector. At the outer end of the long curved row of areolae, marginal process always situated. Areolae are irregularly distributed in the central area, slightly smaller near margin, 8-13 in 10 μ midway. [Plate 2, Figures 21, 22.]
- Coscinodiscus endoi* Kanaya, 1959: p. 76, pl. 3, fig. 8-11; Schrader, 1973a, p. 702, pl. 7, fig. 14, 21, pl. 20, fig. 1, 2.
- Coscinodiscus lewisiyanus* Greville, 1866: p. 78, pl. 8, fig. 8-10; Kanaya, 1971, p. 555, pl. 40.5, fig. 4-6; Schrader, 1973a, p. 703, pl. 8, fig. 1-6, 10, 15.
- Coscinodiscus marginatus* Ehr., 1843: Hustedt, 1930, p. 416, fig. 223; Koizumi, 1975b, p. 876, pl. 2, fig. 18. **Remarks:** *Coscinodiscus marginatus* Ehr. forma *fossilis* Jousé, 1961, p. 68, pl. 3, fig. 7, 8; Koizumi, 1973a, p. 832, pl. 3, fig. 12-14, is included here.
- Coscinodiscus nodulifer* Schmidt, 1878: Hustedt, 1930, p. 426, fig. 229; Koizumi, 1975b, p. 876, pl. 1, fig. 3-10.
- Coscinodiscus oculatus-iris* Ehr., 1839: Hustedt, 1930, p. 454, fig. 252.
- Coscinodiscus radiatus* Ehr., 1839: Hustedt, 1930, p. 240, fig. 225.
- Coscinodiscus stellaris* Rop., 1858: Hustedt, 1930, p. 395, fig. 207; Schrader, 1973a, p. 704, pl. 26, fig. 7.
- Coscinodiscus symbolophorus* Grunow, 1884: p. 82, pl. 4, fig. 3-6; Schrader, 1973a, p. 703, pl. 22, fig. 8, 9. **Synonyms:** *Coscinodiscus stellaris* Rop. var. *symbolophorus* (Grun.) Jörg., Koizumi, 1973a, p. 832, pl. 4, fig. 5, 6.
- Coscinodiscus tabularis* Grun., 1884: Hustedt, 1930, p. 427, fig. 230; Koizumi, 1975b, p. 876, pl. 2, fig. 14, 15.
- Cosminodiscus insignis* Jousé, 1961: p. 67, pl. 2, fig. 8; Koizumi, 1973a, p. 832, pl. 4, fig. 7-11.
- Denticula hyalina* Schrader, 1973: 1973a, p. 704, pl. 1, fig. 12-22; Koizumi, 1975a, p. 799, pl. 1, fig. 21-26.
- Denticula lauta* Bail., 1854: Simonsen and Kanaya, 1961, p. 500, pl. 1, fig. 1-8; Schrader, 1973a, p. 705, pl. 2, fig. 14-25, 35. [Plate 2, Figures 11, 12.]
- Denticula punctata* Schrader, 1973: 1973a, p. 705, pl. 1, fig. 25-30, pl. 3, fig. 16, 17. [Plate 2, Figures 13, 14.]
- Denticula seminae* Simonsen and Kanaya, 1961: p. 503, pl. 1, fig. 26-30; Koizumi, 1973a, p. 832, pl. 5, fig. 1-4.
- Denticula seminae* Simonsen and Kanaya var. *fossilis* Schrader, 1973: 1973b, p. 420, pl. 1, fig. 5, 6; Koizumi, 1975c, p. 621, pl. 1, fig. 3, 4. **Synonyms:** *Denticula seminae* Simonsen and Kanaya, Koizumi, 1973a, p. 832, pl. 5, fig. 5-13.
- Hemidiscus cuneiformis* Wall., 1860: Hustedt, 1930, p. 904, fig. 542; Koizumi, 1975a, p. 802, pl. 4, fig. 2.
- Mediaria splendida* Sheshukova-Poretzkaya, 1962: p. 210, fig. 2, 5; Koizumi, 1973a, p. 832, pl. 7, fig. 5, 6.
- Nitzschia fossilis* (Frenguelli) Kanaya, in Kanaya and Koizumi, 1970: p. 59; Koizumi and Kanaya, 1976, p. 155, pl. 1, fig. 11-14.
- Nitzschia jouseae* Burckle, 1972: p. 240, pl. 2, fig. 17-21; Schrader, 1974, p. 915, pl. 7, fig. 14-23; Koizumi, 1975b, p. 877, pl. 4, fig. 18-27. [Plate 3, Figures 9, 10.]
- Nitzschia kolaczeckii* Grun., 1867: Kolbe, 1955, p. 174, pl. 2, fig. 22, 23; Hasle, 1960, p. 24, pl. 5, fig. 50b, 50c.
- Nitzschia marina* Grun., in Cleve and Grunow, 1880: p. 70; Kolbe, 1954, p. 40, pl. 3, fig. 38-40; Schrader, 1973a, p. 707, pl. 4, fig. 17-19.
- Nitzschia miocenica* Burckle, 1972: p. 240, pl. 2, fig. 10-15; Schrader, 1974, p. 915, pl. 5, fig. 10, 11. [Plate 3, Figures 15-18.]
- Nitzschia oceanica* Hasle, 1972: p. 115; Hasle, 1965, p. 11, pl. 1, fig. 15-19, pl. 2, fig. 6-9, pl. 3, fig. 1, 2, pl. 16, fig. 1, 2 as *Fragilaropsis oceanica* (C1.) Hasle. [Plate 3, Figures 11-14.]
- Nitzschia reinholdii* Kanaya, in Kanaya and Koizumi, 1970: p. 58; Koizumi and Kanaya, 1976, p. 155, pl. 1, fig. 15-18.
- Nitzschia sicula* (Cast.) Hustedt, 1958: p. 180, fig. 128-132; Hasle, 1960, p. 26, pl. 7, fig. 64, 65, 16.
- Planktoniella sol* (Wall.) Schütt, 1893: Hustedt, 1930, p. 465, fig. 295; Gerloff, 1970, p. 203, pl. 1-14, fig. 1-51.
- Pseudoeunotia doliolus* (Wall.) Grun., 1880: Hustedt, 1959, p. 258, fig. 737; Koizumi and Kanaya, 1976, p. 155, pl. 1, fig. 9, 10.
- Rhizosolenia barboi* Brun, 1894: Schrader, 1973a, p. 709, pl. 24, fig. 4, 7; Koizumi, 1975b, p. 877, pl. 4, fig. 52, 53. **Synonyms:** *Rhizosolenia curvirostris* Jousé, Koizumi, 1975a, pl. 1, fig. 19. *Rhizosolenia curvirostris* Jousé var. *inermis* Jousé, Koizumi, 1973a, p. 833, pl. 5, fig. 32, 33.
- Rhizosolenia bergenii* Perag., 1892: Hustedt, 1930, p. 575, fig. 327; Koizumi and Kanaya, 1976, p. 155, pl. 1, fig. 20, 21.
- Rhizosolenia curvirostris* Jousé, 1968: p. 19, pl. 3, fig. 2; Koizumi, 1973a, p. 833, pl. 5, fig. 29-31.
- Rhizosolenia hebetata* (Bail.) Gran forma *hiemalis* Gran, 1904: Hustedt, 1930, p. 590, fig. 337; Koizumi, 1973a, p. 833, pl. 5, fig. 34, 35.
- Rhizosolenia styliformis* Brig., 1858: Hustedt, 1930, p. 584, fig. 333; Koizumi, 1975a, p. 802, pl. 1, fig. 33.
- Rhizosolenia* sp. a Koizumi, 1968: p. 217, pl. 34, fig. 22a, 22b; Koizumi, 1975a, p. 802, pl. 1, fig. 33. **Remarks:** Thickened walls of spine twisted.
- Rhizosolenia* sp. e Koizumi, 1968: p. 217, pl. 34, fig. 26; Koizumi, 1973a, p. 833, pl. 5, fig. 39. **Remarks:** Apical process slightly bent, with a cavity expanded in the middle part of the process.

Rhizosolenia sp. f Koizumi. **Synonyms:** *Rhizosolenia hebetata* (Bail.) Gran forma *hiemalis* Gran, Koizumi, 1975a, p. 802, pl. 1, fig. 32. **Remarks:** Spine of apical process entirely twisted.

Roperia tessellata (Roper.) Grun., in Van Heurck, 1880: Hustedt, 1930, p. 523, fig. 297; Koizumi, 1975b, p. 877, pl. 2, fig. 3, 4.

Rouxia californica Perag., in Tempère and Peragallo, 1910: p. 117, Hanna, 1930, p. 186, pl. 14, fig. 6, 7; Koizumi, 1975a, p. 802, pl. 1, fig. 52.

Rouxia naviculoides Schrader, 1973: 1973a, p. 710, pl. 3, fig. 27–32.

Rouxia yabei Hanna, 1930: p. 185, pl. 15, fig. 2–4; Schrader, 1973a, p. 710, pl. 3, fig. 21, 23.

Stephanopyxis turris (Grev. and Arn.) Ralfs, in Pritchard, 1861: Hustedt, 1930, p. 304, fig. 140; Koizumi, 1973a, p. 833, pl. 6, fig. 13–16.

Synedra jouseana Sheshukova-Poretskaya, 1962: p. 208, fig. 4; Koizumi, 1973a, p. 833, pl. 6, fig. 17.

Thalassionema nitzschiooides Grun., 1881: Hustedt, 1959, p. 244, fig. 725; Koizumi, 1975a, p. 803, pl. 1, fig. 50, 51.

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

Thalassiosira antiqua (Grun.) Cleve-Euler, 1941: p. 173, fig. 4, 5, 74–84; Koizumi, 1975a, p. 803, pl. 4, fig. 9.

Thalassiosira aff. borealis Koizumi. **Remarks:** Valves almost flat, with rounded margins. Diameter of valves 18–33 μ . Areolae form irregular radial rows, secondary more or less concave outwardly, giving irregularly sectorial pattern. Areolae about 8 in 10 μ , nearly same size on entire valve. One row of inconspicuous marginal processes near the valve margin. A more thorough study is necessary to establish the relationship among *Thalassiosira borealis* Koizumi (this paper), *Thalassiosira burcklini* Schrader, 1974, p. 916, pl. 1, fig. 21–26, and *Thalassiosira* aff. *borealis* Koizumi. [Plate 1, Figures 15–17.]

Thalassiosira convexa Mukhina, 1965: p. 22, pl. 11, fig. 1, 2; Koizumi, 1975a, p. 803, pl. 4, fig. 15–20. **Remarks:** *Thalassiosira convexa* Mukhina var. *aspinosa* Schrader, 1974, p. 916, pl. 2, fig. 8, 9, 13a–21, is included here.

Thalassiosira decipiens (Grun.) Jörg., 1905: Hustedt, 1930, p. 322, fig. 158; Koizumi, 1973a, p. 834, pl. 7, fig. 16–18.

Thalassiosira eccentrica (Ehr.) Cleve, 1904: Sheshukova-Poretskaya, 1967, p. 141, pl. 14, fig. 4; Fryxell and Hasle, 1972, p. 297, pl. 1–4, fig. 1a–18. **Synonyms:** *Coscinodiscus excentricus* Ehr., Koizumi, 1973a, pl. 2, fig. 11, 12.

Thalassiosira eccentrica (Ehr.) Cl. var. *fasciculata* (Hust.). **Synonyms:** *Coscinodiscus excentricus* Ehr. var. *fasciculata* Hust., Koizumi, 1975a, pl. 2, fig. 20. **Remarks:** The pattern of radial bundles is more conspicuous than others as a primary sculpture.

Thalassiosira eccentrica (Ehr.) Cl. var. *jousei* (Kanaya). **Synonyms:** *Coscinodiscus excentricus* Ehr. var. *jousei* Kanaya, Koizumi, 1973a, pl. 3, fig. 1–6.

Thalassiosira eccentrica (Ehr.) Cl. var. *leasareolatus* (Kanaya). **Synonyms:** *Coscinodiscus excentricus* Ehr. var. *leasareolatus* Kanaya, Koizumi, 1973a, pl. 3, fig. 7, 11; Koizumi, 1975a, pl. 3, fig. 5. **Remarks:** The meshwork of areolae is loose in the center of the valves and a few smaller areolae are present in the hyaline center.

Thalassiosira gravida Cl., 1896: Hustedt, 1930, p. 325, fig. 161; Koizumi, 1973a, p. 834, pl. 7, fig. 19–21.

Thalassiosira gravida Cl. var. *fossilis* Jousé, 1961: p. 63, pl. 1, fig. 9; Koizumi, 1973a, p. 834, pl. 7, fig. 22–24.

Thalassiosira hyalina (Grun.) Gran, 1897: Hustedt, 1930, p. 323, fig. 159; Koizumi, 1973a, p. 834, pl. 8, fig. 1, 2.

Thalassiosira leptopus (Grun.) Hasle and Fryxell, 1977: p. 20, fig. 1–14. **Synonyms:** *Coscinodiscus lineatus* Ehr., Koizumi, 1975b, pl. 2, fig. 5, 6.

Thalassiosira lineata Jousé, 1968: p. 13, pl. 1, fig. 1, 2; Koizumi, 1975b, p. 877, pl. 2, fig. 9–12.

Thalassiosira miocenica Schrader, 1974: p. 916, pl. 22, fig. 1–5, 11–13.

Thalassiosira oestrupii (Ostf.) Proshkina-Lavrenko, 1956: Hasle, 1960, p. 8, pl. 1, fig. 5–7; Koizumi, 1975a, p. 803, pl. 5, fig. 3, 4.

Thalassiosira plicata Schrader, 1974: p. 917, pl. 3, fig. 1, 2, 4–7, 9.

Synonyms: *Actinocyclus cf. curvatulus* Jan., Schrader, 1974, pl. 3, fig. 3. **Remarks:** In the DSDP Leg 55 materials, aerolae are smaller, 14–17 in 10 μ midway and a few subangular areolae present in the plicated central area.

Thalassiosira praeconvexa Burckle, 1972: p. 242, pl. 2, fig. 7–9; Koizumi, 1975b, p. 878, pl. 3, fig. 21–28.

Thalassiothrix longissima Cl. and Grun., 1880: Hustedt, 1930, p. 247, fig. 726; Hasle and de Mendiola, 1967, p. 114, fig. 20.

Marine Tychopelagic-Benthic Diatoms

Actinocyclus ehrenbergii Ralfs, in Pritchard, 1861: Hustedt, 1930, p. 525, fig. 298–302; Koizumi, 1973b, p. 134, pl. 20, fig. 10, 11.

Actinocyclus ehrenbergii Ralfs var. *tenella* (Bréb.) Hustedt, 1930: p. 530, fig. 302; Schrader, 1974, p. 908, pl. 20, fig. 1, 3.

Actinoptychus undulatus (Bail.) Ralfs, in Pritchard, 1861: Hustedt, 1930, p. 475, fig. 264; Koizumi, 1973b, p. 134, pl. 20, fig. 1a–3b.

Cocconeis costata Greg., 1855: Hustedt, 1959, p. 332, fig. 785; Sheshukova-Poretskaya, 1967, p. 262, pl. 44, fig. 4a–4B.

Diploneis bombus Ehr., 1844: Hustedt, 1959, p. 704, fig. 1086.

Rhabdonema japonicum Tem. and Brun, in Brun and Tempère, 1889: p. 53, pl. 1, fig. 6; Sheshukova-Poretskaya, 1967, p. 258, pl. 43, fig. 14, pl. 44, fig. 1a–1; Hanna, 1970, p. 192, fig. 47, 92, 93, 95.

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PLATE 1
(Magnification 1500 \times)

- Figures 1-6 *Nitzschia suikoensis* Koizumi, n. sp.
 1, 2. Slide no. 3679, 30 μ in length, from DSDP Sample 433A-6-6,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (Paratype).
 3, 4. Slide no. 3659, 41 μ in length, from DSDP Sample 433A-5-5,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (Holotype).
 5, 6. Slide no. 3659, 60 μ in length, from DSDP Sample 433A-5-5,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figures 7-10 *Thalassiosira borealis* Koizumi, n. sp.
 7. Slide no. 3669, 17 μ in diameter, from DSDP Sample 433A-6-3,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (Holotype).
 8. Slide no. 3659, 21 μ in diameter, from DSDP Sample 433A-5-5,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (Paratype).
 9, 10. Slide no. 3671, 18 μ in diameter, from DSDP Sample 433A-6-4,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figures 11-14 *Thalassiosira jacksonii* Koizumi and Barron, n. sp.
 11. Slide no. 3669, 15 μ in diameter, from DSDP Sample 433A-6-3,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 12. Slide no. 3643, 16 μ in diameter, from DSDP Sample 433A-4-5,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (Holotype).
 13. Slide no. 3643, 20 μ in diameter, from DSDP Sample 433A-4-5,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 14. Slide no. 3695, 20 μ in diameter, from DSDP Sample 433-1,
 CC, *Denticula kamtschatica-Denticula seminae* var. *fossilis*
 Zone, Pliocene (Paratype).
- Figures 15-17 *Thalassiosira opposita* Koizumi, n. sp.
 15. Slide no. 3645, 20 μ in diameter, from DSDP Sample 433A-4-6,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (Paratype).
 16. Slide no. 3671, 29 μ in diameter, from DSDP Sample 433A-6-4,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (Holotype).
 17. Slide no. 3643, 17 μ in diameter, from DSDP Sample 433A-4-5,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figure 18 *Asterolampra acutiloba* Forti.; Slide no. 3667, 40 μ in diameter
 from DSDP Sample 433A-6-2, 8-10 cm, *Denticula kamtschatica*
 Zone, upper Miocene.
- Figure 19 *Actinocyclus ellipticus* Grun.; Slide no. 3649, 35 μ in length, from
 DSDP Sample 433A-5-1, 8-10 cm, *Denticula kamtschatica* Zone,
 upper Miocene.
- Figure 20 *Actinocyclus ellipticus* Grun. f. *lanceolata* Kolbe; Slide no. 3645,
 52 μ in length, from DSDP Sample 433A-4-6, 8-10 cm, *Denticula*
 kamtschatica Zone, upper Miocene.
- Figure 21 *Actinocyclus ellipticus* Grun. v. *elongatus* (Grun.) Kolbe; Slide no.
 3645, 86 μ in length, from DSDP Sample 433A-4-6, 8-10 cm, *Den-*
 ticula kamtschatica Zone, upper Miocene.

PLATE 1

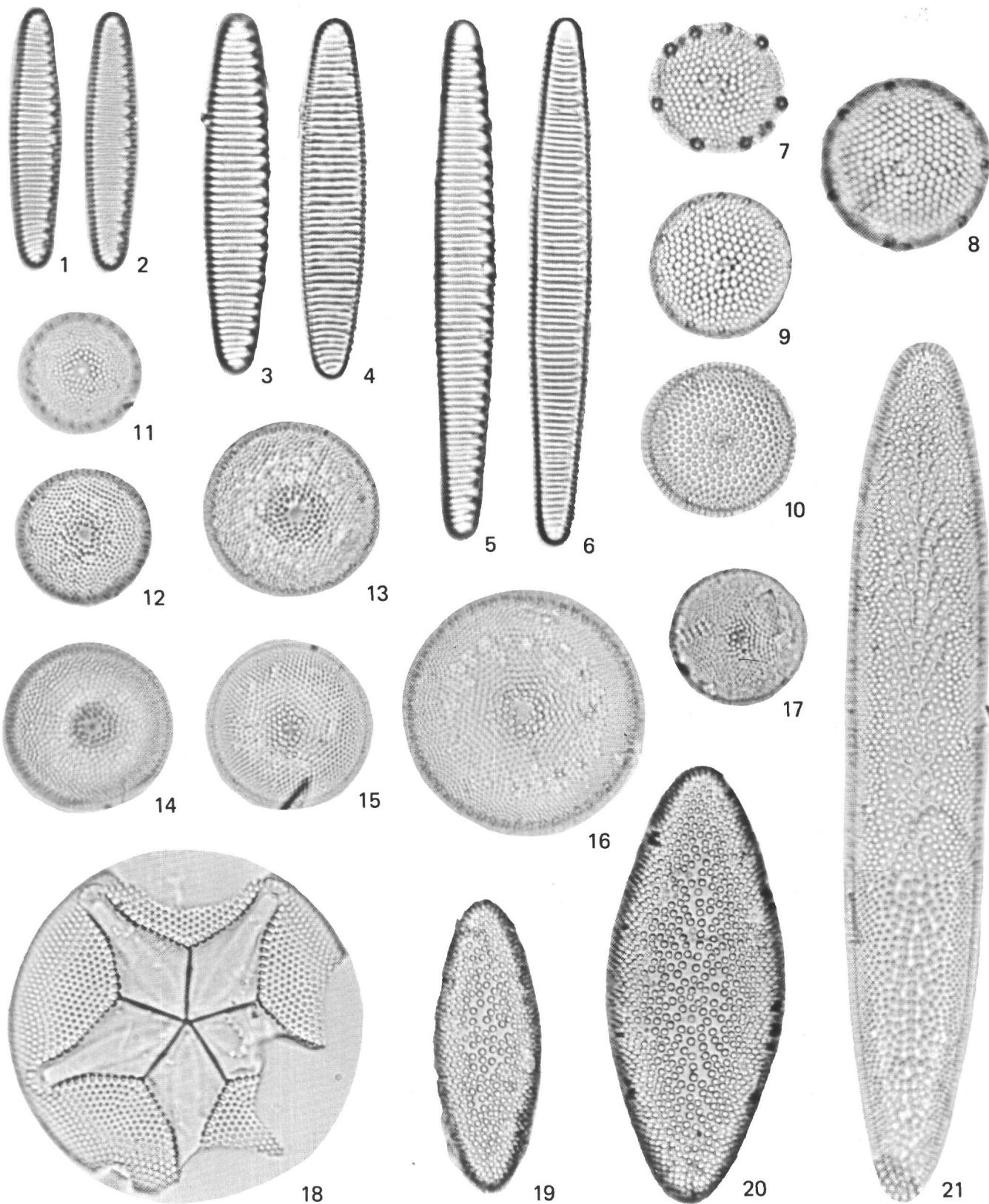


PLATE 2
(Magnification 1500 \times)

- Figures 1-10 *Denticula kamtschatica* Zabelina, (emend.) Koizumi
1. Slide no. 3659, 15 μ in length, from DSDP Sample 433A-5-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (pseudosepta 5 in 10 μ).
 2. Slide no. 3659, 19 μ in length, from DSDP Sample 433A-5-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (pseudosepta 4 in 10 μ).
 3. Slide no. 3659, 15 μ in length, from DSDP Sample 433A-5-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (pseudosepta 7 in 10 μ).
 4. Slide no. 3615, 17 μ in length, from DSDP Sample 433A-2-2, 28-30 cm, *Denticula kamtschatica-Denticula seminae* v. *fossilis* Zone, lower Pliocene (pseudosepta 6-7 in 10 μ).
 5. Slide no. 3659, 19 μ in length, from DSDP Sample 433A-5-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene (pseudosepta 7 in 10 μ).
 6. Slide no. 3647, 30 μ in length, from DSDP Sample 433A-4,CC, *Denticula kamtschatica* Zone, upper Miocene (pseudosepta 6-7 in 10 μ).
 7. Slide no. 3619, 12 μ in length, from DSDP Sample 433A-3-1, 8-10 cm, *Denticula kamtschatica* Zone, lower Pliocene (pseudosepta 7 in 10 μ).
 8. Slide no. 3615, 12 μ in length, from DSDP Sample 433A-2-2, 28-30 cm, *Denticula kamtschatica-Denticula seminae* v. *fossilis* Zone, lower Pliocene (pseudosepta 7-8 in 10 μ).
 9. Slide no. 3613, 28 μ in length, from DSDP Sample 433A-2-1, 27-29 cm, *Denticula kamtschatica-Denticula seminae* v. *fossilis* Zone, lower Pliocene (pseudosepta 8 in 10 μ).
 10. Slide no. 3615, 25 μ in length, from DSDP Sample 433A-2-2, 28-30 cm, *Denticula kamtschatica-Denticula seminae* v. *fossilis* Zone, lower Pliocene (pseudosepta 7 in 10 μ).
- Figures 11, 12 *Denticula lauta* Bail.; Slide no. 3734, 23 μ in length, from DSDP Sample 433A-6-7, 6-7 cm, *Denticula lauta* Zone, middle Miocene.
- Figures 13, 14 *Denticula punctata* Schrader; Slide no. 3734, 22 μ in length, from DSDP Sample 433A-6-7, 6-7 cm, *Denticula lauta* Zone, middle Miocene.
- Figures 15-20 *Nitzschia rolandii* Schrader, (emend.) Koizumi
- 15, 16. Slide no. 3651, 39 μ in length, from DSDP Sample 433A-5-2, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 - 17, 18. Slide no. 3659, 15 μ in length, from DSDP Sample 433A-5-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 - 19, 20. Slide no. 3665, 20 μ in length, from DSDP Sample 433A-6-1, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figures 21, 22 *Coscinodiscus curvatulus* Grun.
21. Slide no. 3671, 17 μ in diameter, from DSDP Sample 443A-5-2, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 22. Slide no. 3619, 23 μ in diameter, from DSDP Sample 433A-3-1, 8-10 cm, *Denticula kamtschatica* Zone, lower Miocene.
- Figure 23 *Asteromphalus hookeri* Ehr.; Slide no. 3617, 34 μ in diameter, from DSDP Sample 433A-6-1, 8-10 cm, *Denticula kamtschatica* Zone, lower Pliocene.
- Figure 24 *Asterolampra marylandica* Ehr.; Slide no. 3665, 55 μ in diameter, from DSDP Sample 433A-5-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figure 25 *Asteromphalus hungaricus* Pant.; Slide no. 3659, broken specimen, from DSDP Sample 433A-5-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figure 26 *Asteromphalus darwinii* Ehr.; Slide no. 3619, 53 \times 66 μ in size, from DSDP Sample 433A-3-1, 8-10 cm, *Denticula kamtschatica* Zone, lower Pliocene.

PLATE 2

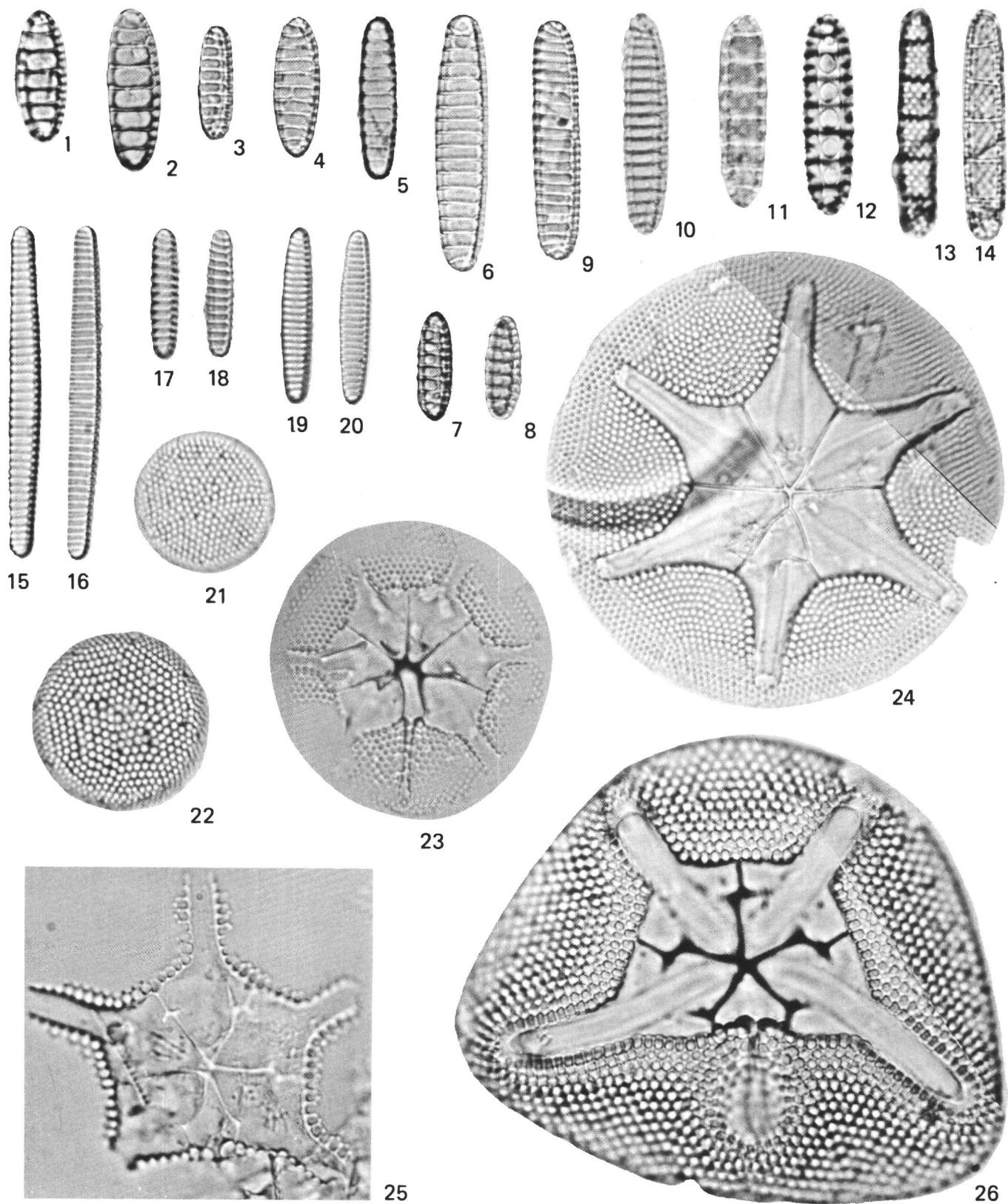


PLATE 3
(Magnification 1500 \times)

- Figures 1-8 *Nitzschia miocenica* Burckle
 1, 2. Slide no. 3665, 17 μ in length, from DSDP Sample 433A-6-1,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 3, 4. Slide no. 3679, 17 μ in length, from DSDP Sample 433A-6-6,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 5, 6. Slide no. 3649, 35 μ in length, from DSDP Sample 433A-5-1,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 7, 8. Slide no. 3651, 32 μ in length, from DSDP Sample 433A-5-2,
 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figures 9-10 *Nitzschia jouseae* Burckle; Slide no. 3617, 29 μ in length, from
 DSDP Sample 433A-2, CC, *Denticula kamtschatica* Zone, lower
 Pliocene.
- Figures 11-14 *Nitzschia* cf. *oceanica* Hasle
 11, 12. Slide no. 3645, 31 μ in length, from DSDP Sample
 433A-4-6, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 13, 14. Slide no. 3653, 22 μ in length, from DSDP Sample
 433A-5-3, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figures 15-18 *Thalassiosira miocenica* Schrader
 15, 16. Slide no. 3679, 18 μ in diameter, from DSDP Sample
 433A-6-6, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 17, 18. Slide no. 3665, 20 μ in diameter, from DSDP Sample
 433A-6-1, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figures 19-21 *Thalassiosira preeconvexa* Schrader
 19, 20. Slide no. 3730, 17 μ in diameter, from DSDP Sample
 433A-6-6, 53-54 cm, *Denticula kamtschatica* Zone, upper Miocene.
 21. Slide no. 3730, 13 μ in diameter, from DSDP Sample 433A-6-6,
 53-54 cm, *Denticula kamtschatica* Zone, upper Miocene.
- Figures 22-25 *Thalassiosira plicata* Schrader
 22, 23. Slide no. 3625, 29 μ in diameter, from DSDP Sample
 433A-3-4, 18-20 cm, *Denticula kamtschatica* Zone, lower Pliocene.
 24, 25. Slide no. 3621, 36 μ in diameter, from DSDP Sample
 433A-3-2, 8-10 cm, *Denticula kamtschatica* Zone, lower Pliocene.
- Figures 26-29 *Thalassiosira* aff. *borealis* Koizumi
 26, 27. Slide no. 3665, 18 μ in diameter, from DSDP Sample
 433A-6-1, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.
 28, 29. Slide no. 3643, 26 μ in diameter, from DSDP Sample
 433A-4-5, 8-10 cm, *Denticula kamtschatica* Zone, upper Miocene.

PLATE 3

