Rea, D.K., Basov, I.A., Scholl, D.W., and Allan, J.F. (Eds.), 1995
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 145

2. OLIGOCENE AND EARLY MIDDLE MIOCENE DIATOM BIOSTRATIGRAPHY OF HOLE 884B[1]

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ABSTRACT

An Oligocene through early Miocene diatom zonation is proposed for the North Pacific based on the stratigraphic documentation and illustration of diatom taxa from Hole 884B on the eastern flank of Detroit Seamount in the northwest Pacific. The Hole 884B section is unique in the North Pacific because it contains a nearly continuous record of diatom sedimentation covering the last 30 m.y. Paleomagnetic stratigraphy is available for the last 19–20 m.y. of that record.

The successive FOs of *Rocella vigilans* (~30.2 Ma), *Cavitatus rectus* (~29.6 Ma), *Rocella gelida* (~28.3 Ma), *Thalassiosira praefraga* sp. nov. (~24.0 Ma), *Thalassiosira fraga* (20.3 Ma), *Crucidenticula sawamurae* (18.4 Ma), and *Crucidenticula kanayae* (16.9 Ma) are the basis for proposing partial range zones with the same successive names. The *Denticulopsis praelauta, D. lauta,* and *D. hyalina* zones are recognized in the overlying lower middle Miocene sediments in Hole 884B. One new species, *Thalassiosira praefraga* A. Gladenkov et Barron sp. nov., is proposed.

INTRODUCTION

Although the late early Miocene to Quaternary diatom biostratigraphy of the North Pacific region is well known (Schrader, 1973; Koizumi, 1985; Barron, 1985b, 1992; Akiba, 1986), studies of the Oligocene and the early part of the early Miocene have been largely confined to isolated samples and/or sections bounded either by unconformities or intervals barren of diatoms. Limited late Oligocene and early Miocene diatom assemblages have been documented from Deep Sea Drilling Project (DSDP) Sites 438 and 439 off the northeast coast of Japan (late early Miocene) by Barron (1980), Akiba (1986), Akiba and Yanagisawa (1986), and Yanagisawa and Akiba (1990); from a calcareous nodule from the Okuyama Formation on the Boso Peninsula of central Honshu, Japan (late early Miocene) by Akiba (1980); from the Okubosawa section of eastern Hokkaido, Japan (late Oligocene and early Miocene) by Akiba et al. (1993); from isolated dredge haul samples from the Navarin Basin of the Bering Sea (late Oligocene? and earliest Miocene) by Baldauf and Barron (1987); from the San Gregorio Formation of southern Baja California, Mexico (late Oligocene and earliest Miocene) by Kim and Barron (1986); and from the Morowan Formation of eastern Hokkaido (early late Oligocene) by Saito et al. (1988). Slightly older early Oligocene diatom assemblages are reported from the Shirasaka Formation in the Joban Coal Field of northeast Japan by Yanagisawa and Suzuki (1987) and from the Kamensky Formation of Bering Island in the Komandorsky Islands at the westernmost end of the Aleutians by Gladenkov (1988). Additional Oligocene assemblages are documented in Russian literature from the Viventekskaya and Gakhinskaya formations of western Kamchatka by Dolmatova et al. (1984), from Karaginsky Island off northeastern Kamchatka by Oreshkina (1982), from Sakhalin Island by Tuzov et al. (1991), as well as from dredge samples taken from the seafloor off the Kuril Islands (Pushkar, 1987) and off eastern Kamchatka (Gleser et al., 1986).

In spite of these numerous studies, the diatom biostratigraphy of the upper Oligocene and the greater part of the lower Miocene age sediments of the North Pacific is largely uncertain (Barron, 1985b; Fenner, 1985; Akiba et al., 1993) because of the absence of continuous sections and the lack of good correlations to the geological time scale. Consequently, when a seemingly complete section of upper Oligocene through lower Miocene diatom-bearing sediment was cored in Ocean Drilling Program (ODP) Hole 884B (Cores 145-884B-63X through -70X) (Shipboard Scientific Party, 1993b) (Fig. 1) in the northwest Pacific on the eastern flank of Detroit Seamount (51°27.026′N, 168°20.228′E, water depth 3827 m), a unique opportunity presented itself to clarify the upper Oligocene and lower Miocene diatom biostratigraphy in the North Pacific. A detailed study of this material was initiated by A. Gladenkov with this goal in mind.

MATERIALS AND METHODS

Samples were selected for study from the FO of *Denticulopsis hyalina* in Sample 145-884B-62X-4, 25–26 cm, through the base of the diatom-bearing sediments in Core 145-884B-74X. Generally, one sample per section was taken for study from near the 25 cm interval of each section. Diatoms are present throughout this interval but with varying abundance and preservation.

Aboard the *JOIDES Resolution,* strewn slides were prepared by placing a small amount of material in a snap-cap vial, adding distilled water, agitating the vial, and removing part of the upper suspension with a pipette. When required (because of a low concentration of diatoms or an induration of the sediment), selected samples were processed by boiling them in hydrogen peroxide and hydrochloric acid, then using the centrifuge (at 1200 rpm for 2–4 min) to remove these chemicals from the suspension. On land in the laboratory, beakers were used in the preparation of additional samples in the place of the snap-cap vials, and acid-treated material was made pH neutral by repeated washing with distilled water, allowing 4 hr or more for settling. Strewn slides were prepared by spreading the pipette suspension onto a cover glass (size 22 × 30 mm), drying on a hot plate, and mounting in Hyrax (index of diffraction = 1.71). A single slide per sample was examined under a Jeneval (Zeiss) light microscope by A. Gladenkov at ×400 with identifications checked at ×1000. J.A. Barron checked occurrences on a second set of slides. Whenever possible, all of the diatom taxa were tabulated until 200 specimens (other than *Chaetoceros* spores) were counted. Then, the rest of the slide was examined in its entirety for sparser occurrences. When fewer than 200 diatom valves were encountered on a slide, all of the taxa were tabulated.

Absolute ages are updated throughout this paper according to the Cande and Kent (1992) geomagnetic polarity time scale. The correla-

[1] Rea, D.K., Basov, I.A., Scholl, D.W., and Allan, J.F. (Eds.), 1995. *Proc. ODP, Sci. Results,* 145: College Station, TX (Ocean Drilling Program).

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Table 1. Relative abundance of common and stratigraphically important diatoms in the Oligocene to lower middle Miocene section of Hole 884B compared with occurence of diatom zones.

Core, section, interval (cm)	Depth (mbsf)	Zone	Abundance	Preservation	*Actinocyclus ingens*	*A. ingens* var. *nodus*	*A. octonarius*	*A. tsugaruensis*	*A. (ochotensis-ingens* form)	*Asteromphalus* cf. *darwinii*	*A.* aff. *oligocenicus*	*A.* aff. *robustus-symmetricus*	*Azpeitia biradiata*	*A. oligocenica*	*A. praenodulifera*	*A.* aff. *praenoduliera*	*A. salisburyana*	*A. tabularis*	*Cavitatus exiguus*	*C. jouseanus*	*C. lanceolatus*	*C. linearis*	*C. miocenicus*	*C. rectus*	*Cestodiscus kugleri*	*C. trochus*	*Coscinodiscus lewisianus*
145-884B-																											
62X-4, 25–26	570.05	*D. hyalina*	C–A	G–M	90	5	+												1	6	7	(+)	4				
62X-6, 25–26	573.05	*D. lauta*	A	G	118	5	+											+	+	3	1	1	2				
62X-CC	574.21		A	G	134	8													1	3	+	+	3				1
63X-2, 25–26	576.55		A	G	96	+												1	+	1			6				
63X-4, 25–26	579.55	*D. praelauta*	C	M	170							+							+	+			2				
63X-5, 25–26	581.05		A	G	30							1							+	+		+	6				
63X-6, 25–26	582.55		A	G–M	112													+		+		+	4				+
63X-CC	583.83		A	G	118					+	+	+						+		1		+	7				+
64X-1, 25–26	584.65	*Cr. kanayae*	C	G	34							1			(+)			+		1			12				
64X-2, 25–26	586.15		C–A	G	47							1			1			+		+		+	14				
64X-3, 25–26	587.65		A	G	14					+	+	+			1		+			+			7				
64X-4, 28–29	589.15		C–A	G	8			+	2			+		(+)	+		+	1		1		+	9				+
64X-5, 25–26	590.65	*Cr. sawamurae*	A	M–G	4		+	2	6	+	+	1			+	+		+		1		3	11				+
64X-6, 28–29	591.48		C	G	6			17	3			3								1		+	17				
64X-CC	594.1		A	M	3			+	2	+	+	2			+					+		+	13				
65X-2, 25–26	595.85		C	M	6			+	5			+								1		+	3				
65X-4, 25–26	598.85		C	M	7		+	+	18			+			+			+		6		2	11				
65X-6, 25–26	601.85		C	M	3		+	+	6						+	+				4		+	5				
65X-CC	603.8		C	M	3		+	3							+	2				2			3				+
66X-1, 25–26	604.05	*T. fraga*	A	M–G	+		+							(+)	+	1				2			4				
66X-2, 25–26	603.35		C	M			3							(+)	6	3				2		1	4				
66X-3, 25–26	605.55		A	G			3							(4)	7	3	1			10		6	15			+	
66X-4, 25–26	607.05		F	M	(+)		3					1		(3)						17		1	3			2	
66X-5, 25–26	608.55		C	M			5							(+)						12		4	4			2	
66X-6, 25–26	610.05	*T. praefraga*	C	M			6													12		1	12		1	6	
66X-CC	612.3		F	M	1		1							(+)						8		4	19	(+)	+	10	
67X-1, 24–25	613.54		C	M			1											1		4		1	10	+			
67X-2, 24–25	615.04		C	M			1						+	(1)	+			2		1		+	2	1	+	+	
67X-3, 24–25	616.54		C	G	(+)		1						10	5	+		+	5		11		5	14	+		+	
67X-4, 24–25	618.04		C	M–G			2							+				3		3		3	6	1		+	
67X-5, 24–25	619.54		C	M	(+)		2							+				2		19		30	11	2	+	+	
67X-6, 24–25	621.04		C	G			1					+		1				4		7		4	3	1	+	+	
67X-7, 24–25	621.68		C	G			3							+				1		5		+	6	2	1	+	
67X-CC	621.84		F	M			2							+				3		11		4	9	1	2	1	
68X-1, 25–26	623.05	*Rocella gelida*	F	P			3											2		11		2	8		1		
68X-2, 25–26	624.55		R–F	P–M																4		1	3				
68X-3, 25–26	626.05		F	M			1													20		11	5	10	1	1	
68X-4, 25–26	627.55		F	P–M			1											1		5		1	9	2			
68X-5, 25–26	629.05		R	P–M			1													3		1	3		1		
68X-6, 25–26	630.55		F	M														+		6		3	6	1	1		
68X-7, 25–26	632.05		F	M			+													5		+	5	1			
68X-CC	632.4		C	M			3							1						19		2	13	1		+	
69X-1, 25–26	632.65		C	G			1							+						13		6	5	1	+	+	
69X-2, 25–26	634.15		C	G			+				+									31		11	13	2	+	+	
69X-3, 25–26	635.65		C	M–G							+									45		9	31	5	1	+	
69X-4, 25–26	637.15		C	M			+													45		18	21	5	1	+	
69X-5, 25–26	638.65		R	P																3		1	2				
69X-6, 25–26	640.15		B																								
69X-CC	642.0		R	P																		(1)	(1)				
70X-1, 25–26	642.25		B																								
70X-2, 25–26	643.75		B																								
70X-3, 25–26	645.25		B																								
70X-4, 25–26	646.75		B																								
70X-5, 25–26	648.25		F	P			1							1						17		6	9	+	4	+	
70X-6, 25–26	649.75	*Cavitatus rectus*	C	M			+							1						9		17	33	4	+	+	
70X-7, 25–26	651.25		C	M			1					+		+						56		25	14	15	1	+	
70X-CC	651.7		C	M			3				+	+								57		38	14	20	4	4	
71X-1, 25–26	651.95		C	M			+							1						45		29	24	21	2	+	
71X-3, 25–26	654.95		C	M			1							1				+		57		30	17	2	3	+	
71X-4, 25–26	656.45		C	M			2							+						4			10	1	7	1	
71X-5, 25–26	657.95	*R. vigilans*	C	M			4							+						2			3		92	4	
71X-6, 25–26	659.45		F	M			2											2		5			6		3	1	
71X-7, 25–26	660.95		R	M			1							2						2			4				
71X-CC	661.3	Unzoned	R	M			3																4				
72X-CC	671.0		R	P										1													
73X-CC	678.02		R	P										1				2									
74X-CC	690.2		R	M														3		1							

Notes: Relative abundance (A = abundant, C = common, F = few, R = rare, B = barren) and preservation (G = good, M = moderate, P = poor) of each sample are also estimated. Plus sign (+) = specimens recorded after count. Parentheses are placed around occurrences of specimens with uncertain identification (e.g., fragments and related taxonomic forms). *N* = number.

tion of the geologic epochs and periods used follows that of Berggren et al. (1985a, 1985b).

RESULTS

The tabulated occurrences of stratigraphically important and relatively common diatom taxa are shown in Table 1. The North Pacific references on Oligocene and early Miocene diatom assemblages were consulted in choosing stratigraphically important taxa, along with Fenner (1985), Barron (1985a), and Harwood and Maruyama (1992). Numerous other taxa, including *Pyxidicula* spp., certain *Hemiaulus* spp., and various benthic taxa were also tabulated; however, they are not treated below the genus level because of time and space limitations. Illustrations of the stratigraphically important and common

Table 1 (continued).

C. lewisianus var. *levis*	*C. marginatus*	*C. rhombicus*	*Crucidenticula ikebei*	*C. kanayae*	*C. sawamurae*	*Cymatosira* aff. *lorenziana*	*Denticulopsis hyalina*	*D. lauta*	*D. praelauta*	*Goniothecium decoratum*	*G. odontella*	*Hemiaulus* cf. *incisus*	*Hemiaulus* sp. (*pyxiloides*)	*Ikebea tenuis*	*Kisseleviella carina*	*K. ezoensis*	*K. magnaareolata*	*Kozloviella minor*	*Lisitzinia ornata*	*L. ornata* f. *pentagona*	*Mediaria splendida*	*Melosira architecturalis*	*Nitzschia challengeri*	*N.* aff. *challengeri*	*N. maleinterpretaria*	*Pseudodimerogramma elegans*	*Pseudotriceratium radiosoreticulatum*	*Pyxilla* spp.	*Raphidodiscus marylandicus*	*Rhizosolenia hotaense*	*R. norwegica*	*Rocella gelida*	*R. gelida* v. *schraderi*	*R. praenitida*
	2						+	22						2	1						3		(+)											
	2		+					24						5	1						4		+	+				+						
	3							3						+	+						1		(+)	+										
	8		+	+				6	4						+						3		(+)	+										
	4								1					+	+						+		+											
	1								111					+	+						7		2	12										
	18								13					+	+						5		1	+			+							
	19			+					11					2	+						1		2					+						
	106		+	2										+	3						+													
	48		+	48	1									+	+						+							+						
	43		2	50	10									+	+						+							+						
	37		2	16	6									+	+																			
	16		1		34									1	1						+						+	+		+				
	28				8										1													2						
	29		+		54									+	+						+											+		
	69				5									1	2						+							+						
	16		+		15									+	1						2													
	12				8									1	1															+				
	27				4									+	+													+			+			
	61														1															+	+			
	32													2	1										26					2	1			
	2													5	3				+									+	2	2	4			
	34					+								3	7		+					1						1		2				
	71													2	15															3				
	12													8	40	+			+								+			1				
	32										1			2	17	+												+						
	1										8			4	62				+			+				+	+	1						
	2										+	1		2	61				+			+				1	1	2						
	3													6	45	+			2							+	+	+						
	2										2	1	3	2	57				2			1				1	1	5				+		
	10									+	+	+		5	36	+			3			+				1	+	3	+			+		
	43					+					+		+	3	56				4			+				2	+	2				1		
	3	+								+	+		+	7	51	+	1		2			+				3	+	2						
	5													6	50	+	+		6			1				4	4	7						
	2												1	2	22											3	1	4						
	5										1		4		14		1		1			1				2		6						
	2										+				25							1				+		1						
	2												1		35		1		2			2				2	1	4				1		
	3														8				1									4						
	2	1									2		2		27				1			3					1	3				2		
	1												1		13				2								+	5				3		
	2										1		4		39				6			2				+	1	6				11		
	49	1											+	+	5				+							+		1				69	1	
	32	+											+		6				30	+		+				+	1	+				10	1	
	18	+									+		3		8				46									+				+		
	11												1		8				46								+	3				+		
	3																		1?															
	4																																	
	+												3		9							1						6				1		
	2					+							+	1	11			2									+	+						
	2					+							1	1	6							1					1	2						
	2					+								1	2			3									+	1						
	3													1	12											+	+	2						
	2										+		+	2	14											+	+	1						
	3												+	2	21												1	2						
	1													2	10							2					+	1					2	1
+	2												3	1	11							1					2	14						
	2												+	1	3							1					2	6						
	2											1			9												2	2						
	4																											7						
	17											1			1							1					+	13						+
															1							2						14						

diatom taxa can be found on the plates, and the taxonomy used is summarized in the Appendix.

Preservation

Diatom preservation is generally moderate to good throughout the section studied (Table 1), with the exception of a barren to poorly preserved interval from the upper part of Core 145-884B-70X to the lower part of Core 145-884B-69X (~648–638 mbsf) and a poorly preserved interval below 660 mbsf (Core 145-884B-71X).

The ranges of the stratigraphically important diatom taxa in Cores 145-884B-74X through -63X are compiled in Figure 2. Additional warm-water, stratigraphically important taxa such as *Coscinodiscus lewisianus, C. lewisianus* var. *levis, C. rhombicus, Nitzschia maleinterpretaria,* and *Raphidodiscus marylandicus* have very restricted occurrences in Hole 884B (Table 1), most likely during intervals of

Table 1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Zone	*R. semigelida*	*R. vigilans*	*Rouxia* cf. *granda*	*R. isopolica*	*R. naviculoides*	*R. obesa*	*Sceptroneis tenue-peplonus* (group)	*Simonseniella interposita*	*S. praebarboi*	*Stellarima* spp.	*Thalassionema nitzschioides*	*T. nitzschioides* var. *parva*	*Thalassiosira dubiosa*	*T. fraga*	*T. irregulata*	*T. lusca*	*T. mediaconvexa*	*T. praefraga*	*Thalassiothrix longissima*	*Yoshidaia divergens*	*Chaetoceros* spores	Other resting spores	*Actinoptychus senarius*	*Paralia sulcata*	Benthic diatoms	Diatoms counted (*N*)
145-884B-																												
62X-4, 25–26	570.05	*D. hyalina*					1				5	1	3								23	+	15	4	3	+	+	215
62X-6, 25–26	573.05					+	+				6	+	3								18	+	22	1	2	+	+	222
62X-CC	574.21	*D. lauta*									3	+	15								16		6	+	+		+	206
63X-2, 25–26	576.55										21	+	6								26		5	+	18	+	+	205
63X-4, 25–26	579.55						+				7	+	1								13		3	1	2		+	203
63X-5, 25–26	581.05	*D. praelauta*					7				5	+	1								14		2	+	1		+	202
63X-6, 25–26	582.55										10	10	4								15		21	3	3		+	221
63X-CC	583.83						2				2	7	3			+					13		26	4	5	+	+	226
64X-1, 25–26	584.65										2	2	10								19		36	2	1	+	+	236
64X-2, 25–26	586.15	*Cr. kanayae*									4	3	5								16		15	+	5	1	+	215
64X-3, 25–26	587.65										3	21	4								40		14	2	+	+	+	214
64X-4, 28–29	589.15											29	4	68							16		10	5	1	+	+	210
64X-5, 25–26	590.65					1	+				4	31	9	11		1					53		40	5	+	+	+	240
64X-6, 28–29	591.48										6	37	2								62		21	2				221
64X-CC	594.1	*Cr. sawamurae*									4	29	3								57		21	1	+	+	2	221
65X-2, 25–26	595.85						(+)				4	69	3								25		14	1	+	2	+	214
65X-4, 25–26	598.85						(+)				3	55	7			+					42		13	3	1	2	+	216
65X-6, 25–26	601.85										2	110	3			1					30		9	8	+	1	+	209
65X-CC	603.8						(+)				1	109	5			+					27		18	5		2	+	218
66X-1, 25–26	604.05								+			91	3			1				1	23		12	6	+	+	+	212
66X-2, 25–26	603.35											63	9			4				4	15		16	9	+		1	216
66X-3, 25–26	605.55	*T. fraga*										71	4			37				14	8		22	3	+	+	+	222
66X-4, 25–26	607.05											66	2			17				10	1		34	18		2	+	234
66X-5, 25–26	608.55											43	2			4				8	2		69	16	+	+	3	269
66X-6, 25–26	610.05								(+)			7	2							+	4		89	54	+	5	4	289
66X-CC	612.3											24	7							7	4		68	28	1	3	1	268
67X-1, 24–25	613.54				+							10	1					+	(+)	+	5		122	30	8	2	2	322
67X-2, 24–25	615.04	*T. praefraga*							+			2	9							+	5		62	20	8	17	8	262
67X-3, 24–25	616.54						+	+	+			19	6				+	+	(+)	1	17		138	12	3	2	5	338
67X-4, 24–25	618.04				+			+	+			2	12						(+)	+	5		63	25	5	14	5	263
67X-5, 24–25	619.54			+	+			+	+			2	1				+	+	(+)	+	7		53	17	9	3	6	253
67X-6, 24–25	621.04				+			1	+	+		1	7							+	3		51	18	4	6	8	251
67X-7, 24–25	621.68			+	+		(1)	+	+	+		3	2				+	+		+	11		82	20	2	9	2	282
67X-CC	621.84						(1)	1	+			4	2				+	1		1	9		99	40	6	7	10	299
68X-1, 25–26	623.05							2	2			1	3								11		56	30	4	8	5	215
68X-2, 25–26	624.55			1									2								6		52	20	3	8	9	171
68X-3, 25–26	626.05			1			(1)	1				12	5				1	1			18		31	10	1	4	3	193
68X-4, 25–26	627.55			1								3	4					1			22		75	21	1	5	3	238
68X-5, 25–26	629.05											1	1								2		30	6	1	4	1	86
68X-6, 25–26	630.55											1	4					1			16		21	15	2	3	2	178
68X-7, 25–26	632.05							1	1			3	3					1			17		15	9	1	4	2	118
68X-CC	632.4	*Rocella gelida*						1	+			2	+								21		45	30	2	7	4	245
69X-1, 25–26	632.65			+								4	+								9		21	5	1	+	+	221
69X-2, 25–26	634.15			+				+				3	+								30		5	6	2		+	205
69X-3, 25–26	635.65			2					+			2	+				+		+		14		10	2	3	6	+	210
69X-4, 25–26	637.15			4				2					+								5		27	14	3	7		227
69X-5, 25–26	638.65																				1			1				16
69X-6, 25–26	640.15																											
69X-CC	642.0												1								1							10
70X-1, 25–26	642.25																											
70X-2, 25–26	643.75																											
70X-3, 25–26	645.25																											
70X-4, 25–26	646.75																											
70X-5, 25–26	648.25			1	2			4	2			3	2								4		4	9	6	13	4	165
70X-6, 25–26	649.75				+			1	+			+	+						+		2		34	12	4	3	+	234
70X-7, 25–26	651.25	*Cavitatus rectus*		1	+			3	+				+				(+)				2		37	9	+	20	1	237
70X-CC	651.7			+				1	+			5	+								3		29	5	4	2	+	229
71X-1, 25–26	651.95			+				2	1			1	+								3		34	3	3	8	+	234
71X-3, 25–26	654.95			+	1		1	1	+			2	+		+				1		5		31	9	7	10	1	231
71X-4, 25–26	656.45		1	1	2		1	5	(2)	+		6	+		+		(1)		1		8		36	9	6	10	2	236
71X-5, 25–26	657.95		39	1	1		1	3	(+)	+		4	+		+				1		+		37	11	4	1	1	237
71X-6, 25–26	659.45	*R. vigilans*	2	3				8	(10)	1		2	+		1						4		22	11	4	4	4	222
71X-7, 25–26	660.95			1				6	(4)			2	1								2		11	4	6	5	6	139
71X-CC	661.3							4				1	2								+		19	5	2	3	4	161
72X-CC	671.0	Unzoned							(3)														1			1	1	20
73X-CC	678.02						1		(2)			1												2	7		2	109
74X-CC	690.2								(2)															1	1	1	2	33

warmer sea-surface temperatures. As revealed by Figure 2 and Table 1, the FOs of a number of diatom taxa are rather distinct and spaced throughout the section, whereas LOs tend to be more sporadic and difficult to recognize. It is possible that some diatom taxa are reworked from outcrops higher on the flank of the Detroit Seamount, but without more knowledge of the true LOs of various taxa in the North Pacific, it is difficult to assess the extent of reworking. Indeed, an unconformity separating lower Oligocene sediments below from upper lower Miocene sediments above was recorded in the core catcher of Core 145-883B-68X, which lies on the top of Detroit Seamount (Shipboard Scientific Party, 1993a) (Fig.1).

Zonation

A late Oligocene and early early Miocene diatom zonation for the North Pacific is proposed in the following section based on the ranges

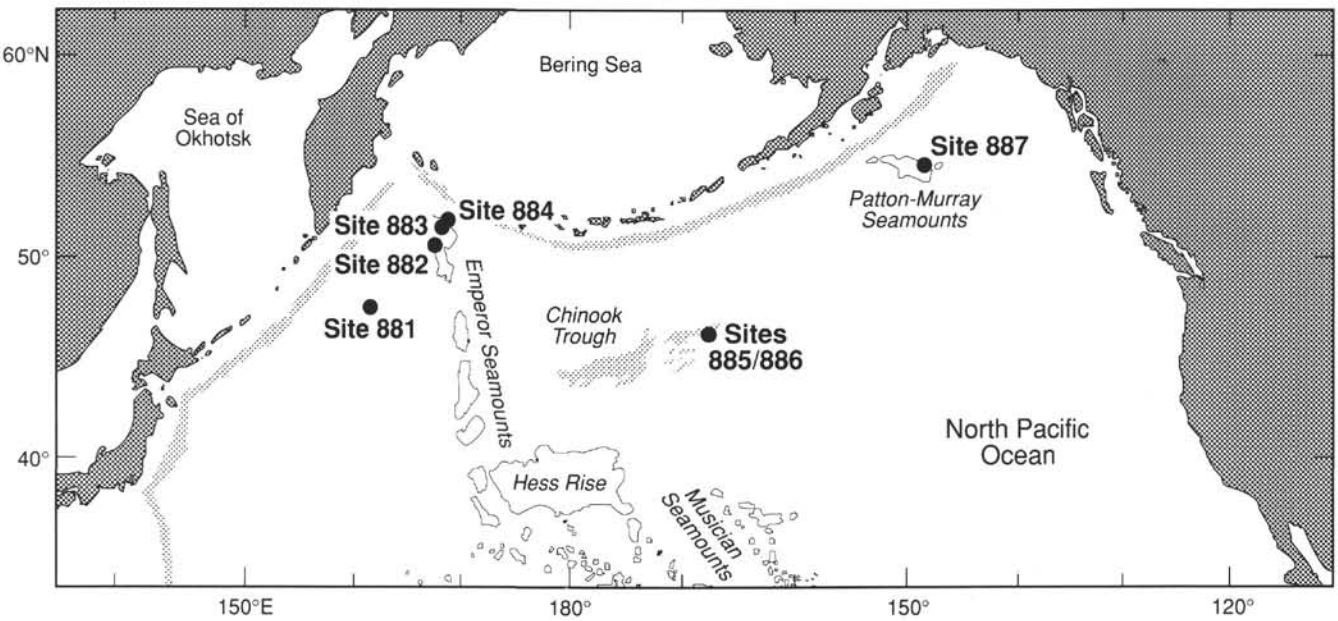

Figure 1. Location of Site 884 and other Leg 145 sites in the North Pacific.

of diatoms in Hole 884B (Fig. 2). The papers of Fenner (1985), Barron (1985a), Akiba et al.'s (1993), and Harwood and Maruyama (1992) have been consulted in an effort to give this zonation a widespread geographic application. The present zonation follows the example of Akiba's (1986) North Pacific diatom zonation for the late early Miocene through Pliocene in that it is based entirely on successive FOs of diatom taxa and it uses partial range zones.

An age vs. depth plot (sedimentation curve; Fig. 3) for the Oligocene and lower Miocene sediments of Hole 884B has been constructed using diatom, calcareous nannofossil, and radiolarian datum levels that have been tied to the paleomagnetic stratigraphy (Table 2) as well as to selected magnetostratigraphic events that are recognizable in Hole 884B. All of the pre-20 Ma calibrations of microfossil datum levels to magnetostratigraphy are from the tropical oceans or the Southern Ocean, so this age vs. depth plot should be considered tentative. Nevertheless, the datum levels line up on a relatively straight line, although the LOs of the calcareous nannofossil *Reticulofenestra bisecta* and the diatom *Lisitzinia ornata* fall some distance from this line, with the former occurring below (or older) and the latter occurring above (or younger) than expected (Fig. 3). The earlier LO of *R. bisecta* is probably caused by selective preservation, because carbonate is sparse in the upper Oligocene to lower Miocene sediments of Hole 884B (Shipboard Scientific Party, 1993b). Reworking of Oligocene diatoms upsection, on the other hand, may result in a younger LO for *L. ornata* (Table 1).

This age vs. depth plot suggests continuous sedimentation at Site 884 during the Oligocene and early Miocene, although it is possible that the interval between 31.7 and 30.2 Ma is removed at an unconformity at about 660 mbsf (alternative 2) (see Shipboard Scientific Party, 1993b). In the following section the proposed late Oligocene and early Miocene diatom zonation is discussed along with stratigraphically significant diatom occurrences.

DIATOM ZONES

Rocella vigilans Partial Range Zone

Definition: Interval from the FO of *Rocella vigilans* to the FO of *Cavitatus rectus*

Age: ~30.2 Ma (Subchron C11r.2r, Southern Ocean, Harwood and Maruyama, 1992) to ~29.6 Ma (estimated ages at Site 884, this report)

Authors: New zone, modified from the *R. vigilans* Zone of Fenner (1984) for use in the North Pacific. Fenner's (1984) *R. vigilans* Zone is defined as the range of *R. vigilans* below the FO of *Bogorovia veniamini*, which is a warm-water taxon that is extremely sparse in the North Pacific.

Remarks: *Cestodiscus kugleri, C. trochus, Thalassiosira dubiosa*, and *T. mediaconvexa* all have FOs in Hole 884B that closely approximate the base of the *R. vigilans* Zone; however, it is possible that these taxa may have older ranges than *R. vigilans* because an interval of relatively poor preservation lies immediately below the *R. vigilans* Zone in Hole 884B (Fig. 2). The robust, resistant nature of *R. vigilans*, along with the near coincidence of its FO in Hole 884B (estimated at 30.2 Ma) with the LO of the calcareous nannofossil *Reticulofenestra umbilica* (31.72 Ma) (Table 2), argue that the FO of *R. vigilans* in Sample 145-884B-70X-7, 25–26 cm, is not dissolution controlled. This is the first reported occurrences of *Thalassiosira dubiosa* in the North Pacific.

Rocella semigelida first occurs in the *R. vigilans* Zone, but it becomes common in the overlying *Cavitatus rectus* Zone (Fig. 2).

Cavitatus rectus Partial Range Zone

Definition: Interval from the FO of *Cavitatus rectus* to the FO of *Rocella gelida*

Age: ~29.6–28.2 Ma (estimated ages at Site 884, this report)

Authors: New zone, modified from the *C. rectus* Zone of Akiba et al. (1993). Akiba et al. (1993) propose a *C. rectus* Interval Zone as the interval between the LO of *Rocella gelida* and the FO of *Thalassiosira fraga*. It is difficult, however, to determine the LO of *R. gelida*, because it is a resistant species that is easily reworked.

Secondary marker: The LO of *Kozloviella minor* is a secondary marker for the top of the *C. rectus* Zone.

Remarks: The FO of *Cavitatus linearis* falls just above the base of the zone in Hole 884B (Fig. 2). *Thalassiosira dubiosa* and *Rocella semigelida* are restricted to the lower part of the *C. rectus* Zone, whereas *Kozloviella minor* is restricted to the upper part of the zone. This is the first reported occurrence of *K. minor* in the North Pacific.

Rocella gelida Partial Range Zone

Definition: Interval from the FO of *Rocella gelida* to the FO of *Thalassiosira praefraga*

Age: ~28.2 to ~24.0 Ma (estimated ages at Site 884, this report)

Authors: New zone, modified from the *R. gelida* Zone of Gombos and Ciesielski (1983), the *R. gelida* Zone of Barron (1983), and the *R. gelida* Zone of Baldauf and Barron (1991).

Secondary marker: The FO of *Kisseleviella ezoensis* closely approximates the top of the zone (Fig. 2).

Remarks: Gombos and Ciesielski (1983) proposed a *R. gelida* Concurrent-Range Zone for the Southern Ocean as the interval from the FO of *R.*

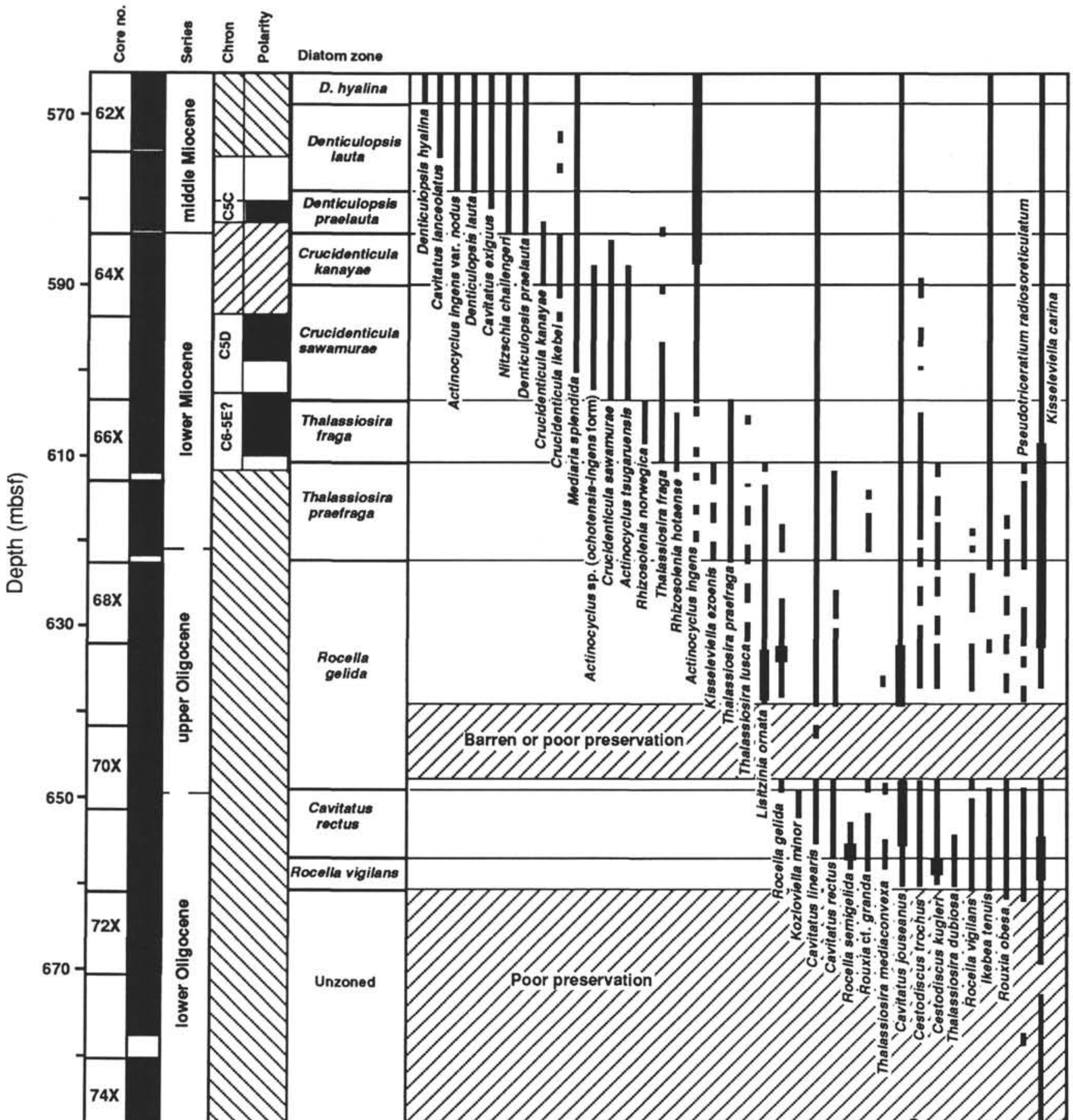

Figure 2. Ranges of stratigraphically important diatoms in the Oligocene to lower middle Miocene of Hole 884B referenced to diatom zones and depth in the core. Thicker parts of range bars indicate relatively common occurrences of the taxon; dashed range bar indicates discontinuous occurrences. Magnetostratigraphy is from Shipboard Scientific Party (1993b), with some modifications suggested by Barron and Gladenkov (this volume). Core recovery is indicated by black-filled intervals.

gelida to the LO of *Rossiella* sp. Barron (1983) recognized a *R. gelida* Partial Range Zone in the equatorial Pacific as the range of *R. gelida* below the FO of *Rossiella paleacea.* In the Southern Ocean, Baldauf and Barron (1991) modified the top of the *R. gelida* Zone of Gombos and Ciesielski (1983) to be the FO of *Thalassiosira spumellaroides.* Unfortunately, neither *R. paleacea* nor *T. spumellaroides* are present in the North Pacific, making them poor choices for marker species for a *R. gelida* Partial Range Zone. However, Barron (1983) and Baldauf and Barron (1991) report forms recorded as *Thalassiosira spinosa* Schrader, which are equivalent to *T. praefraga* sp. nov. of this report (Barron, unpublished data), in lowermost Miocene sediments in the equatorial Pacific and Southern Ocean, so there is some possibility that a *R. gelida* Partial Range Zone, defined as the range of *R. gelida* below the FO of *T. praefraga* can be recognized in all three regions.

The FO of *Rocella gelida* in Sample 145-884B-70X-5, 25-26 cm is immediately below an interval of poor preservation ranging up through Sample 145-884B-69X-5, 25–26 cm (Table 1; Fig. 2). The FO of *Lisitzinia ornata* is immediately above this interval of poor preservation (Table 1).

The LO of *Thalassiosira mediaconvexa* and the FO of *T. lusca* fall within the *R. gelida* Zone in Hole 884B (Fig. 2). This is the first reported occurrence of *T. lusca* in the North Pacific.

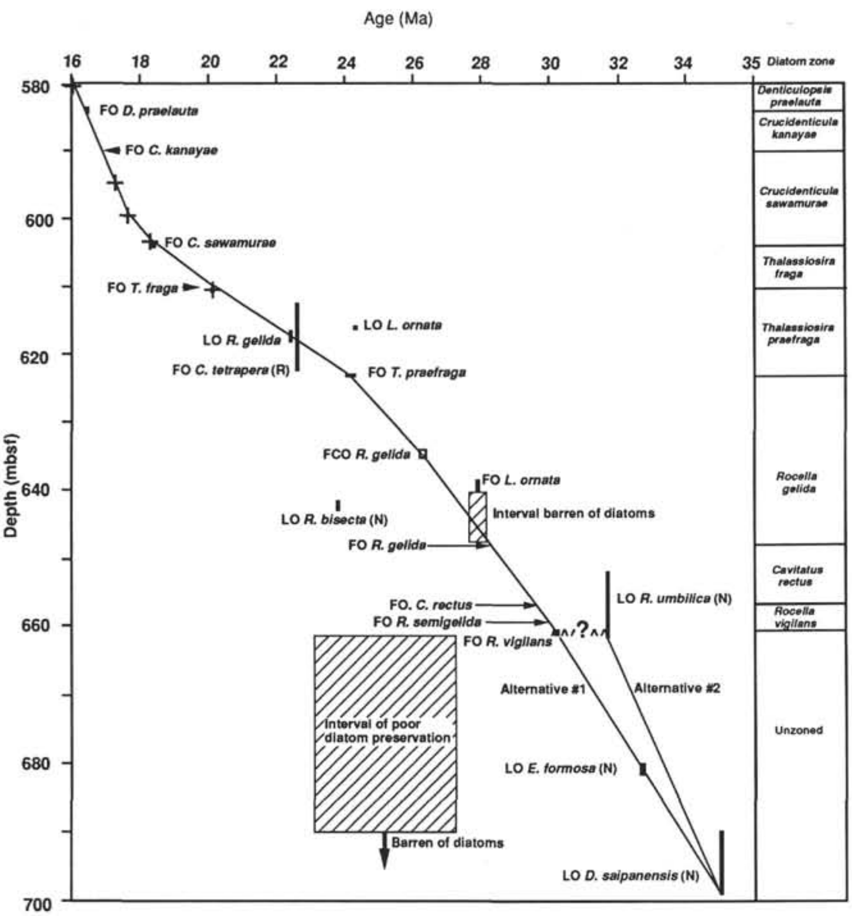

Figure 3. Age vs. depth plot of the Oligocene and lower Miocene portion of Hole 884B based on diatom, calcareous nannofossil (N), and radiolarian (R) events, and on paleomagnetic events (+) (Table 2). FCO = first common occurrence; ^^^ = possible unconformity. Bar shows depth constraint of the microfossil events. Two alternatives are shown for the lower Oligocene.

Thalassiosira praefraga Partial Range Zone

Definition: Interval from the FO of *Thalassiosira praefraga* to the FO of *T. fraga*

Age: ~24.0–20.3 Ma (Subchron C6r.1r?) (estimated ages at Site 884, this report)

Author: New name for *T. spinosa* Zone of Barron, 1985a

Remarks: In Hole 884B, the total range of *Kisseleviella ezoensis* closely approximates the entire *T. praefraga* Zone. Akiba (1986), however, indicates that *K. ezoensis* ranges up to the top of his *Thalassiosira fraga* Zone at DSDP Site 439 off Japan.

The LOs of *Rocella vigilans, R. gelida, Rouxia* sp. cf. *R. granda, R. obesa,* and *Cestodiscus kugleri* all fall within the *T. praefraga* Zone (Fig. 2); however, these taxa have fairly sporadic occurrences (Table 1), so caution should be used in applying these diatom events for long-range correlation. For example, Akiba et al. (1993) show more limited occurrences of *Rocella vigilans, R. gelida,* and *Rouxia obesa* in the Okubonosawa section of eastern Hokkaido.

The FO of *Rhizosolenia hotaense* and the LO of *Cavitatus rectus* fall just below the FO of *Thalassiosira fraga,* near the top of the *T. praefraga* Zone, in Hole 884B. A similar relationship between the LO of *C. rectus* and the FO of *T. fraga* is reported by Akiba et al. (1993) in the Okubonosawa section of eastern Hokkaido, further supporting the stratigraphic utility of these two diatom events.

The last consistent occurrence of *Lisitzinia ornata* in Sample 145-884B-67X-1, 24-25 cm (613.54 mbsf) lies in the upper part of the *T. praefraga* Zone in Hole 884B (Table 1; Fig. 2). This relatively young LO is somewhat surprising, because *L. ornata* has a LO below the FO of *Rocella gelida* in the Okubonosawa section of eastern Hokkaido (Akiba et al., 1993), whereas the LO of *L. ornata* lies well below the LO of *R. gelida* in the Southern Ocean, according to Harwood and Maruyama (1992).

Also coinciding with the top of the *T. praefraga* Zone in Hole 884B is the last sporadic occurrence of *Pseudotriceratium radiosoreticulatum.* Akiba (1986) records the LO of *P. radiosoreticulatum* (as *P. cheneiveri*) at the top of his *T. fraga* Zone at Site 439 off Japan, a somewhat younger range than in Hole 884B.

Thalassiosira fraga Partial Range Zone

Definition: Interval from the FO of *Thalassiosira fraga* to the FO of *Crucidenticula sawamurae*

Age: 20.3 Ma (Subchron C6r.1r?) to 18.4 Ma (Subchron C5En.1n) (magnetostratigraphic correlation in Hole 884B)

Author: Modified from the *T. fraga* Zone of Barron (1985b). Barron (1985b) proposed a *T. fraga* Zone based on the range of *T. fraga* below the FO of *Actinocyclus ingens.* As mentioned below, isolated specimens of *A. ingens* range well down into the early Miocene, making its FO difficult to recognize. This zone was referred to Akiba and Yanagisawa (unpublished data) by Akiba et al. (1993) but it has not been published.

Remarks: Barron (1992) has argued for the near coincidence of the FOs of *C. sawamurae* (previously recorded as *C. nicobarica* or *Denticulopsis nicobarica*) and *Actinocyclus ingens.* In Hole 884B, forms referable to *A. ingens,* however, were observed well below the FO of *C. sawamurae* and down into the *T. praefraga* Zone (Table 1).

The total range of *Rhizosolenia norwegica* is restricted to the *T. fraga* Zone in Hole 884B, and *R. hotaense* has its LO within the zone.

The FO of *Azpeitia praenodulifera* in Hole 884B can be found in Sample 145-884B-66X-3, 25–26 cm (Table 1), above the FO of *T. fraga* (Sample 145-884B-66X-5, 25–26 cm), a younger FO for this warm-water taxon than what was recorded by Barron (1983) in the equatorial Pacific.

A single common occurrence of *Nitzschia maleinterpretaria* is reported in Sample 145-884B-66X-2, 25–26 cm, just below the FO of *Crucidenticula sawamurae* in Sample 145-884B-65X-CC, which marks the top of the *T. fraga* Zone (Table 1). It is interesting to note that Yanagisawa and Akiba (1990) record an isolated abundance peak of *N. maleinterpretaria* immediately below the FO of *C. sawamurae* in equatorial Pacific Site 71, and it is tempting to think that the two occurrences may be time equivalent. This is the first recorded occurrence of *N. maleinterpretaria* in the North Pacific.

The restriction of the *Thalassiosira fraga* Zone to the interval from Samples 145-884B-66X-1, 25–26 cm, to -66X-5, 25–26 cm (603.8–610.05 mbsf or about 6.2 m total thickness) contrasts with its greater thickness (25 m) in Hole 883B (Barron and Gladenkov, this volume). Lithologic evidence for

Table 2. Stratigraphic occurrence and age of diatom, calcareous nannofossil, radiolarian, and magetostratigraphic events in the Oligocene and lower middle Miocene section of Hole 884B.

	Datum	Age (Ma)	Source	Region	Interval	Depth (mbsf)
T	C5ACn.1n	14.059				559.0
FO	*Denticulopsis hyalina*	14.9–15.1	1	Site 887	62X-4, 25–26 cm, to 62X-6, 25–26 cm	567.05–570.05
T	C5Cn.1n?	16.035				580.0
FO	*Denticulopsis lauta*	15.9	2	North Pacific	63X-3, 25–26 cm, to 63X-4, 25–26 cm	578.05–579.55
FO	*Denticulopsis praelauta*	16.2	2	North Pacific	63X-CC to 64X-1, 25–26 cm	583.83–584.65
T	C5Dn.1n?	17.31				594.2
B	C5Dn.1n?	17.65				599.0
T	C5En.1n?	18.317				602.8
FO	*Crucidenticula sawamurae*	18.3–18.5	1	Site 887	65X-CC to 66X-1, 25–26 cm	603.8–604.05
B	C6n.1n?	20.162				610.0
FO	*Thalassiosira fraga*	20.1	4	Southern Ocean	66X-5, 25–26 cm, to 66X-6, 25–26 cm	610.05–611.55
LO	*Lisitzinia ornata*	24.3	3	Southern Ocean	66X-CC to 67X-1, 25–26 cm	613.3–613.55
FO	*Cyrtocapsella tetrapera*	22.6	5	Mid latitudes	66X-CC to 67X-CC	613.3–632.4
LO	*Rocella gelida*	22.4	2	Equatorial Pacific	67X-3, 25–26 cm, to 67X-4, 25–26 cm	616.54–618.04
FO	*Thalassiosira praefraga*	24.0–24.3	4	Southern Ocean	67X-CC to 68X-1, 25–26 cm	622.8–623.05
FCO	*Rocella gelida*	26.2–26.4	3	Southern Ocean	69X-2, 25–26 cm, to 69X-3, 25–26 cm	634.15–635.55
FO	*Lisitzinia ornata**	27.9	3	Southern Ocean	69X-5, 25–26 cm, to 69X-6, 25–26 cm	638.65–640.15
LO	*Reticulofenestra bisecta*	23.8	5	Mid latitudes	69X-CC to 70X-1, 48 cm	642.0–642.48
FO	*Rocella vigilans*	30.2	3	Southern Ocean	71X-7, 25–26 cm, to 71X-CC	660.95–661.3
LO	*Reticulofenestra umbilica*	31.7	5	Mid latitudes	70X-CC to 71X-CC	651.7–661.3
LO	*Erisonia formosa*	32.7	5	Mid latitudes	73X-CC to 74X-1, 50 cm	680.6–681.1
LO	*Discoaster saipanenesis*	35.0	5	Mid latitudes	74X-CC to 75X-CC	690.2–699.8

Notes: *C. tetrapera* is a radiolarian; *R. bisecta*, *R. umbilica*, *E. formosa*, and *D. saipanensis* are calcareous nannofossils. Ages are according to the Cande and Kent (1992) geomagnetic polarity time scale. Asterisk (*) = above interval of dissolution. Sources for microfossil events are as follows: 1= Barron and Gladenkov (this volume), 2 = Barron (1992), 3 = Harwood and Maruyama (1992), 4 = Baldauf and Barron (1991), and 5 = Shipboard Scientific Party (1993a). T = top of initial occurrence, B = bottom of initial occurrence, FO = first occurrence, LO = last occurrence, and FCO = first common occurrence.

compression of the *T. fraga* Zone in Hole 884B includes the bioturbated nature of the sediments and the presence of sharp color contacts that may represent surfaces of erosion or nondeposition (see Core 145-884B-66X description in Shipboard Scientific Party, 1993b).

Crucidenticula sawamurae Partial Range Zone

Definition: Interval from the FO of *Crucidenticula sawamurae* to the FO of *C. kanayae*

Age: 18.4 Ma (Subchron C5En.1n) to 16.9 Ma (Subchron C5Cr.3r) (magnetostratigraphic correlation in Hole 884B)

Author: This zone is referred to Akiba and Yanagisawa (unpublished data) by Akiba et al. (1993), but it has not been published.

Remarks: The first consistent occurrence of *Actinocyclus ingens* coincides with the base of the *C. sawamurae* Zone (Table 1); however, sporadic occurrences of *A. ingens* can be found down into the *T. praefraga* Zone. Apparently, Barron (1980, 1985b) and Koizumi (1985) recognized this first consistent occurrence of *A. ingens* as the base of their *A. ingens* Zones.

The FO of *Actinocyclus tsugaruensis* and *A.* sp. (*ochotensis-ingens* form) also lie in the lowermost part of the *C. sawamurae* Zone in Hole 884B (Fig. 2).

The FO of *Mediaria splendida* can be found in the lower part of the *C. sawamurae* Zone, whereas the FO of *Crucidenticula ikebei* is near the top of the zone. At Site 439 off Japan, Akiba (1986) reports the FO of *M. splendida* in his *Crucidenticula kanayae* Zone, which is equivalent to the *C. sawamurae* and *C. kanayae* zones of this paper. Yanagisawa and Akiba (1990), however, suggest that the FOs of *C. sawamurae* and *C. ikebei* are equivalent.

The last consistent occurrence of *Thalassiosira fraga* lies in the *C. sawamurae* Zone in Hole 884B, but an isolated occurrence in Sample 145-884B-63X-CC can be found in the lower part of the *Denticulopsis praelauta* Zone (Fig. 2; Table 1).

Crucidenticula kanayae Partial Range Zone

Definition: Interval from the FO of *Crucidenticula kanayae* to the FO of *Denticulopsis praelauta*

Age: 16.9 Ma (Subchron C5Cr.3r) to 16.3 Ma (Subchron C5Cn.1n) (magnetostratigraphic correlation in Hole 884B)

Author: This zone is referred to Akiba and Yanagisawa (in press) by Akiba et al. (1993), but it has not been published.

Remarks: The LO of *Crucidenticula sawamurae* lies near the top of the *C. kanayae* Zone, a younger range than what is suggested by Yanagisawa and Akiba (1990) off Japan. Also falling in the upper *C. kanayae* Zone are the LO of *Azpeitia praenodulifera* in Sample 145-884B-64X-1, 25-26 cm (Table 1), and the LOs of *Actinocyclus tsugaruensis* and *A.* sp. (*ochotensis-ingens* form) (Fig. 2). At Site 439 off Japan, Akiba (1986) records a similar LO for *Azpeitia praenodulifera* in his *C. kanayae* Zone.

Denticulopsis praelauta Partial Range Zone

Definition: Interval from the FO of *Denticulopsis praelauta* to the FO of *D. lauta*

Age: 16.3 Ma (Subchron C5Cn.1n) to 15.9 Ma (Subchron C5Br.2r) (magnetostratigraphic correlation in Hole 884B)

Author: Akiba (1986)

Remarks: In Hole 884B, the FO of *Nitzschia challengeri* coincides with the FO of *D. praelauta* at the base of the *D. praelauta* Zone. In Holes 438B and 439 off Japan, however, the FO of *N. challengeri* is slightly above this horizon (Akiba, 1986; Yanagisawa and Akiba, 1990).

In the upper part of the *D. praelauta* Zone, *Cavitatus exiguus* first occurs, a stratigraphic occurrence supported by Akiba et al. (1993).

Denticulopsis lauta Partial Range Zone

Definition: Interval from the FO of *Denticulopsis lauta* to the FO of *D. hyalina*

Age: 15.9 Ma (Subchron C5Br.2r) to ~14.9 Ma (Chron C5B) (magnetostratigraphic correlation from Holes 884B and 887A; Barron and Gladenkov, this volume)

Author: Maruyama (1984b)

Remarks: The FO of *Cavitatus lanceolatus* and the LO of *Crucidenticula ikebei* appear to fall in the *D. lauta* Zone in Hole 884B (Fig. 2). Akiba et al. (1993) report a similar FO for *C. lanceolatus*.

TRANSPORTED DIATOMS

Site 884 was positioned on the Meiji Drift, a sediment drift deposit occurring along the eastern flank of Emperor Seamount Chain that is more than 800 km long and 350 km wide (Scholl et al., 1977) (see Shipboard Scientific Party, 1993b). Lithologic Subunit IIA (604.8–694.7 mbsf), which encompasses the lower half of the section studied for diatom biostratigraphy, displays modest evidence for reworking in the form of sharp contacts, parallel laminae, and thin turbidites (Shipboard Scientific Party, 1993b). Within this interval, increased numbers of benthic diatoms, diatoms transported from shelf regions (*Actinoptychus senarius* and *Paralia sulcata*), and resting spores that are also normally associated with neritic environments are evidence of downslope transport (Table 1). However, backtracking of Site 884 along the Hawaiian Seamount trend for the past 35 million years places it in the central North Pacific at about 40°N and 165°W (Shipboard Scientific Party, 1993b), far to the south of possible neritic source areas along the Aleutian Islands or in the Bering Sea. Together, these observations suggest extensive reworking of seafloor sediments in the North Pacific east of the Emperor Seamount Chain by bottom currents during the Oligocene and early Miocene.

CONCLUSIONS

The Oligocene through early middle Miocene diatom biostratigraphy of Hole 884B is documented, and 7 new partial range zones are proposed for the North Pacific based on the successive FO's of *Rocella vigilans* (30.2 Ma), *Cavitatus rectus* (29.6 Ma), *Rocella gelida* (28.3 Ma), *Thalassiosira praefraga* sp. nov. (~24.0 Ma), *Thalassiosira fraga* (20.3 Ma), *Crucidenticula sawamurae* (18.4 Ma), and *Crucidenticula kanayae* (16.9 Ma). In the upper part of the interval studied in Hole 884B, the successive FOs of *Denticulopsis praelauta, D. lauta,* and *D. hyalina* are used to recognize the respective bases of the *Denticulopsis praelauta, D. lauta,* and *D. hyalina* Partial Range zones of Akiba (1986). Diatoms are generally common and are moderately-well to good preservation throughout the interval investigated, making Hole 884B a unique reference section in the North Pacific for Oligocene and early Miocene.

Absolute age estimates for the interval from 20 to 14 Ma are derived from magnetostratigraphy, whereas those in the interval from 30 to 20 Ma are suggested by an age vs. depth curve constructed from published age estimates of diatoms, calcareous nannofossils, and radiolarians from low-latitudes and the Southern Ocean. All ages are according to the geomagnetic polarity time scale of Cande and Kent (1992).

In addition to the ranges of the 10 marker species for the diatom zonation, the ranges of 27 other stratigraphically important diatom taxa are documented. Based of calcareous nannofossil biostratigraphy, *Rocella vigilans* has a FO in the early Oligocene which approximates its FO in the Southern Ocean (~30.2 Ma). *Rocella semigelida* is documented for the first time in the North Pacific and found to range from the upper part of the *R. vigilans* Zone through the lower half of the overlying *Cavitatus rectus* Zone. Other taxa recorded for the first time in the North Pacific include *Kozloviella minor,* which is restricted to the upper part of the *C. rectus* Zone, and *Nitzschia maleinterpretaria*, which has a single common occurrence in the *Thalassiosira fraga* Zone. *Rocella gelida* appears to have originated in the North Pacific based on its apparent older FO (~28.3 Ma) than what is reported by Harwood and Maruyama (1992) in the Southern Ocean (26.4–26.2 Ma). The FO of *R. gelida* in the Southern Ocean appears to coincide with the first common occurrence of *R. gelida* at Site 884.

A new species, *Thalassiosira praefraga* is proposed for specimens previously identified as *T. spinosa* Schrader by Barron (1983, 1985a), Baldauf and Barron (1991), and us (in Rea, Basov, et al., 1993). *Thalassiosira praefraga* is sparse but consistent throughout the *T. praefraga* Zone, whereas *Kisseleviella ezoensis* is restricted (in very rare, sporadic occurrences) to the *T. praefraga* Zone.

Rocella vigilans, R. gelida, and *Lisitzinia ornata* lack sharp last occurrences in the lower Miocene (*T. praefraga* Zone) of Site 884. This may reflect reworking of Oligocene sediments at the site, which is consistent with sedimentologic and seismic evidence that these lower Miocene sediments have been redeposited by bottom currents.

The documentation of sparse specimens of *Actinocyclus ingens* through the *Thalassiosira fraga* and *T. praefraga* zones argues against previous practice of using the FO of *A. ingens* as a late early Miocene marker species. Nevertheless, *A. ingens* does become more consistent and more common in the late early Miocene at the base of the *Crucidenticula sawamurae* Zone (18.4 Ma).

The relatively common occurrence of benthic diatoms, *Paralia sucata, Actinoptychus senarius,* and *Chaetoceros* resting spores, especially in the Oligocene and lower Miocene sediments of Hole 884B, is evidence of transport of bottom sediments over at least 1200 km based on a probable source of these coastal and shallow water taxa near the Aleutian Islands and/or Bering Sea and on backtracking of Site 884 at 35 Ma to a position of about 40°N and 165°W in the central North Pacific. These observations support sedimentologic and seismic evidence that Site 884 is located on an extensive sediment drift, the Meiji Drift, (Shipboard Scientific Party, 1993b).

ACKNOWLEDGMENTS

We thank Fumio Akiba, David Harwood, Elisabeth Fourtanier, Rainer Gersonde, Scott Starratt, and David Bukry for their helpful reviews and suggestions for improving the manuscript. Iwona Rek of the California Academy of Sciences aided with some Russian translations. The research of Andrey Gladenkov was supported by Grant #93-05-9558 of the Russian Foundation for Fundamental Research and in part by a JOI travel grant to Russian scientists. Kevin Purcell of the U.S. Geological Survey aided in the assembly of the manuscript. We are grateful to David Rea, Ivan Basov, and the scientists and crew members of Leg 145 of the *JOIDES Resolution* for their support and encouragement. Samples were provided by the Ocean Drilling Program.

REFERENCES*

Akiba, F., 1980. A lower Miocene diatom flora from the Boso Peninsula, Japan, and the resting spore formation of an extinct diatom, *Kisseleviella carina* Sheshukova-Poretzkaya. *Bull. Tech. Lab., JAPEX,* 23:81–100.

————, 1986. Middle Miocene to Quaternary diatom biostratigraphy in the Nankai trough and Japan trench, and modified lower Miocene through Quaternary diatom zones for middle-to-high latitudes of the North Pacific. *In* Kagami, H., Karig, D.E., Coulbourn, W.T., et al., *Init. Repts. DSDP,* 87: Washington (U.S. Govt. Printing Office), 393–481.

Akiba, F., Hiramatsu, C., and Yanagisawa, Y., 1993. A Cenozoic diatom genus *Cavitatus* Williams; an emended description and two new biostratigraphically useful species, *C. lanceolatus* and *C. rectus* from Japan. *Bull. Nat. Sci. Mus. Ser. C.: Geol. Paleontol. (Tokyo),* 19:11–39.

Akiba, F., and Yanagisawa, Y., 1986. Taxonomy, morphology and phylogeny of the Neogene diatom zonal marker species in the middle-to-high latitudes of the North Pacific. *In* Kagami, H., Karig, D.E., Coulboum, W.T., et al., *Init. Repts. DSDP,* 87: Washington (U.S. Govt. Printing Office), 483–554.

Baldauf, J.G., and Barron, J.A., 1980. *Actinocyclus ingens* var. *nodus:* a new stratigraphically useful diatom of the circum-North Pacific. *Micropaleontology,* 26:103–110.

————, 1987. Oligocene marine diatoms recovered in dredge samples from the Navarin Basin province, Bering Sea. *U.S. Geol. Surv. Bull.,* 1765.

————, 1991. Diatom biostratigraphy: Kerguelen Plateau and Prydz Bay regions of the Southern Ocean. *In* Barron, J., Larsen, B., et al., *Proc. ODP, Sci. Results,* 119: College Station, TX (Ocean Drilling Program), 547–598.

Barron, J.A., 1980. Lower Miocene to Quaternary diatom biostratigraphy of Leg 57, off Northeastern Japan, Deep Sea Drilling Project. *In* von Huene, R., Nasu, N., et al., *Init. Repts. DSDP,* 56, 57 (Pt. 2): Washington (U.S. Govt. Printing Office), 641–686.

————, 1983. Latest Oligocene through early middle Miocene diatom biostratigraphy of the eastern tropical Pacific. *Mar. Micropaleontol.,* 7:487–515.

————, 1985a. Miocene to Holocene planktic diatoms. *In* Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 763–809.

————, 1985b. Late Eocene to Holocene diatom biostratigraphy of the equatorial Pacific Ocean, Deep Sea Drilling Project Leg 85. *In* Mayer, L., Theyer, F., Thomas, E., et al., *Init. Repts. DSDP,* 85: Washington (U.S. Govt. Printing Office), 413–456.

————, 1992. Neogene diatom datum levels in the equatorial and North Pacific. *In* Ishizaki, K., and Saito, T. (Eds.), *The Centenary of Japanese Micropaleontology:* Tokyo (Tokyo Univ. Press), 413–425.

Berggren, W.A., Kent, D.V., and Flynn, J.J., 1985a. Jurassic to Paleogene: Part 2. Paleogene geochronology and chronostratigraphy. *In* Snelling, N.J.

* Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

(Ed.), *The Chronology of the Geological Record.* Geol. Soc. London Mem., 10:141–195.

Berggren, W.A., Kent, D.V., Flynn, J.J., and van Couvering, J., 1985b. Neogene geochronology and chronostratigraphy. *In* Snelling, N.J. (Ed.), *The Chronology of the Geological Record.* Geol. Soc. London Mem., 10:211–250.

Cande, S.C., and Kent, D.V., 1992. A new geomagnetic polarity time scale for the Late Cretaceous and Cenozoic. *J. Geophys. Res.,* 97:13917–13951.

Castracane, C.A.F., 1886. *Report of the Scientific Results of the Voyage of* H.M.S. Challenger *during the Years 1873–1876. Botany,* 2: London (H.M.S.O.).

Dolmatova, L.M., Lupikina, E.G., and Oreshkina, T.V., 1984. Diatom flora. *In* Menner, V.V. (Ed.), *Atlas of Flora and Fauna of Neogene Sediments of the Far East*: Moscow (Nauka), 67–70. (in Russian)

Fenner, J., 1984. Middle Eocene to Oligocene planktonic diatom stratigraphy from Deep Sea Drilling sites in the South Atlantic, equatorial Pacific, and Indian Oceans. *In* Hay, W.W., Sibuet, J.-C., et al., *Init. Repts. DSDP,* 75 (Pt. 2): Washington (U.S. Govt. Printing Office), 1245–1271.

————, 1985. Late Cretaceous to Oligocene planktic diatoms. *In* Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 713–762.

————, 1991. Late Pliocene-Quaternary quantitative diatom stratigraphy in the Atlantic sector of the Southern Ocean. *In* Ciesielski, P.F., Kristoffersen, Y., et al., *Proc. ODP, Sci. Results,* 114: College Station, TX (Ocean Drilling Program), 97–121.

Fryxell, G.A., Sims, P.A., and Watkins, T.P., 1986. *Azpeitia* (Bacillariophyceae): related genera and promorphology. *Syst. Bot. Monogr.,* 13:1–74.

Gladenkov, A.Y., 1988. The Paleogene diatom flora of the Komandorsky Islands (The Bering Sea). *In* Simola, H. (Ed.), *Proc. 10th Int. Diatom Symp., Joensuu, Finland:* Koenigstein (Koeltz Sci. Books), 243–247.

Gleser, Z.I., Dolmatova, L.M., and Lupikina, E.G., 1986. Marine Paleogene diatom algae of eastern Kamchatka. *Bot. Zh. (Leningrad),* 71:851–859. (in Russian)

Gombos, A.M., Jr., 1983. Survey of diatoms in the upper Oligocene and lower Miocene in Holes 515B and 516F. *In* Barker, P.F., Carlson, R.L., Johnson, D.A., et al., *Init. Repts. DSDP,* 72: Washington (U.S. Govt. Printing Office), 793–804.

Hajós, M., 1976. Upper Eocene and lower Oligocene Diatomaceae, Archaeomonadaceae, and Silicoflagellatae in southwestern Pacific sediments, DSDP Leg 29. *In* Hollister, C.D., Craddock, C., et al., *Init. Repts. DSDP,* 35: Washington (U.S. Govt. Printing Office), 817–883.

Harwood, D.M., 1986. Diatoms. *In* Barrett, P.J. (Ed.), *Antarctic Cenozoic History from the MSSTS-1 Drillhole, McMurdo Sound.* DSIR Bull. N.Z., 237:69–107.

Harwood, D.M., and Maruyama, T., 1992. Middle Eocene to Pleistocene diatom biostratigraphy of Southern Ocean sediments from the Kerguelen Plateau, Leg 120. *In* Wise, S.W., Jr., Schlich, R., et al., *Proc. ODP, Sci. Results,* 120: College Station, TX (Ocean Drilling Program), 683–733.

Heiden, H., and Kolbe, R.W., 1928. Die marinen Diatomeen der Deutschen Südpolar-Expedition 1901–1903. *In* von Drygalski, E. (Ed.), *Deutsche Südpolar-Expedition, 1901–1903* (Vol. 8): *Botanik:* Berlin (Walter de Gruyter), 447–715.

Jousé, A.P., 1973. Diatoms in the Oligocene-Miocene biostratigraphic zones of the tropical areas of the Pacific Ocean. *Nova Hedwigia Beih.,* 45:333–357.

Kanaya, T., 1959. Miocene diatom assemblages from the Onnagawa Formation and their distribution in correlative formations in northeast Japan. *Sci. Rep. Tohoku Univ., Ser. 2,* 30:1–130.

Kim, W.H., and Barron, J.A., 1986. Diatom biostratigraphy of the upper Oligocene to lowermost Miocene San Gregorio Formation, Baja California Sur, Mexico. *Diatom Res.,* 1:169–187.

Koizumi, I., 1968. Tertiary diatoms from the Oga Peninsula, Akita Prefecture, northeast Japan. *Sci. Rep. Tohoku Univ., Ser. 2,* 40:171–240.

————, 1985. Diatom biochronology for the Late Cenozoic northwest Pacific. *J. Geol. Soc. Japan,* 91:195–211.

Lohman, K.E., 1974. Lower Miocene marine diatoms from Trinidad. *Verhandl. Naturforsch. Ges. Basel,* 84:326–360.

Maruyama, T., 1984a. Miocene diatom biostratigraphy of onshore sequences on the Pacific side of Northeast Japan, with reference to DSDP Hole 438A (Part 1). *Sci. Rep. Tohoku Univ., Ser. 2,* 54:141–164.

————, 1984b. Miocene diatom biostratigraphy of onshore sequences on the Pacific side of Northeast Japan, with reference to DSDP Hole 438A (Part 2). *Sci. Rep. Tohoku Univ., Ser. 2,* 55:77–140.

Oreshkina, T.V., 1982. Marine diatoms from the Paleogene sediments of Karaginsky Island, eastern Kamchatka. *In* Jousé, A.P., and Krasheninnikov, V.A. (Eds.), *Marine Micropaleontology:* Moscow (Nauka), 159–162. (in Russian)

Pushkar, V.A., 1987. Diatoms of Paleogene sediments of the northwest Pacific. *In* Markevich, V.A. (Ed.), *Palynology of the Eastern USSR.* Trans. USSR Acad. Sci., 60–70. (in Russian)

Rea, D.K., Basov, I.A., Janecek, T.R., Palmer-Julson, A., et al., 1993. *Proc. ODP, Init. Repts.,* 145: College Station, TX (Ocean Drilling Program).

Saito, T., Barron, J.A., and Sakamoto, M., 1988. An early late Oligocene age indicated by diatoms for a primitive Desmostylian mammal *Behemotops* from eastern Hokkaido, Japan. *Proc. Jpn. Acad., Ser. B,* 64:269–273.

Scholl, D.V., Hein, J.R., Marlow, M., and Buffington, E.C., 1977. Meiji sediment tongue: North Pacific evidence for limited movement between the Pacific and North American plates. *Geol. Soc. Am. Bull.,* 88:1567–1576.

Schrader, H.-J., 1973. Cenozoic diatoms from the Northeast Pacific, Leg 18. *In* Kulm, L.D., von Huene, R., et al., *Init. Repts. DSDP,* 18: Washington (U.S. Govt. Printing Office), 673–797.

————, 1976. Cenozoic planktonic diatom biostratigraphy of the Southern Pacific Ocean. *In* Hollister, C.D., Craddock, C., et al., *Init. Repts. DSDP,* 35: Washington (U.S. Govt. Printing Office), 605–671.

Schrader, H.-J., and Fenner, J., 1976. Norwegian Sea Cenozoic diatom biostratigraphy and taxonomy. *In* Talwani, M., Udintsev, G., et al., *Init. Repts. DSDP,* 38: Washington (U.S. Govt. Printing Office), 921–1099.

Shipboard Scientific Party, 1993a. Site 883. *In* Rea, D.K., Basov, I.A., Janecek, T.R., Palmer-Julson, A., et al., *Proc. ODP, Init. Repts.,* 145: College Station, TX (Ocean Drilling Program), 121–208.

————, 1993b. Site 884. *In* Rea, D.K., Basov, I.A., Janecek, T.R., Palmer-Julson, A., et al., *Proc. ODP, Init. Repts.,* 145: College Station, TX (Ocean Drilling Program), 209–302.

Simonsen, R., 1974. The diatom plankton of the Indian Ocean expedition of R/V *Meteor,* 1964–1965. In *"Meteor" Forschunsergebnisse, Reihe D* (No. 19): *Biologie:* Berlin-Stuttgart (Gebrüder Borntraeger).

Sims, P.A., Fryxell, G.A., and Baldauf, J.G., 1989. Critical examination of the diatom genus *Azpeitia.* Species useful as stratigraphic markers for the Oligocene and Miocene Epochs. *Micropaleontology,* 35:293–307.

Sundström, B.G., 1986. The marine diatom genus *Rhizosolenia:* a new approach to the taxonomy [Ph.D. dissert.]. Lund Univ., Sweden.

Tuzov, V.P., Boldyreva, V.P., and Gladenkov, A.Y., 1991. About the age of Pilengskaya and Daekhuriinskaya formations of Sakhalin. *Tr. Akad. Nauk SSSR, Ser. Geol.,* 4:127–131. (in Russian)

Williams, D.M., 1988. An illustrated catalogue of the type specimens in the Greville diatom herbarium. *Bull. Br. Mus. (Nat. Hist.) Bot.,* 18:1–148.

Yanagisawa, Y., and Akiba, F., 1990. Taxonomy and phylogeny of three marine diatom genera, *Crucidenticula, Denticulopsis,* and *Neodenticula. Bull. Geol. Surv. Jpn.,* 41:197–301.

Yanagisawa, Y., and Suzuki, Y., 1987. Diatoms and silicoflagellates from the Oligocene Shirasaka Formation of the Joban Coalfield, northeast Japan. *Bull. Geol. Surv. Jpn.,* 38:81–98. (in Japanese)

Date of initial receipt: 5 April 1994
Date of acceptance: 5 August 1994
Ms 145SR-105

APPENDIX

TAXONOMY

Thalassiosira praefraga A. Gladenkov et Barron, sp. nov.
(Pl. 2, Figs. 3–6, 9)

Synonym. *Thalassiosira spinosa* Schrader sensu Barron, 1983, p. 512, pl. IV, fig. 8; sensu Barron, 1985a, p. 793, pl. 11, fig. 15; sensu Baldauf and Barron, 1991, p. 591; ?sensu Harwood and Maruyama, 1992, p. 708

Not *Thalassiosira spinosa* Schrader 1976, p. 636, pl. 6, figs. 5-7, or *Thalassiosira spinosa* var. *aspinosa* Schrader 1976, p. 636, pl. 6, fig. 3

Description. Valves convex, circular 12–24 µm in diameter. Hexagonal-rounded areolae cover the entire valve surface. Areolae in convex lines and curved tangential rows, sometimes appearing fasciculated. Areolae 10–12 in 10 µm in the valve's center, decreasing in size toward the margin (to 14–15 in 10 µm). Margin 1–1.5 µm wide with radial striae and small, indistinct, irregularly situated strutted spines (processes), approximately 1.5–2 µm apart with a length of 0.5–1 µm.

Remarks. Previously (Rea, Basov, et al., 1993), these specimens were tabulated as *Thalassiosira spinosa* Schrader and were used as the basis of the *Thalassiosira spinosa* Zone. However, Fumio Akiba (written comm., 1994) correctly pointed out that *Thalassiosira spinosa* Schrader 1976 is a junior homonym of *Thalassiosira spinosa* Simonsen, 1974, pp. 10–11, pls. 4–5.

Compared with Schrader's (1976, p. 636) description of *T. spinosa* and *T. spinosa* var. *aspinosa,* the specimens illustrated and described here have less strongly convex valves, finer areolation, and their areolae display a greater decrease in the size from the center of the valve to the valve's margin. Consequently, it seems inappropriate to rename Schrader's taxa.

Thalassiosira praefraga sp. nov. differs from *Thalassiosira fraga* Schrader emend Akiba and Yanagisawa, 1986 (p. 498, pl. 51, figs. 5–10, pl. 53, figs. 1–8) by the nonlinear pattern of its areolae and its lack of a prominent strutted processes (4–5 in 10 µm with a 1.5-µm-long tube) around its margin.

Holotype. Pl. 2, Fig. 9, Sample 145-884B-66X-5, 25–26 cm (specimen deposited in the Institute of the Lithosphere, Russian Academy of Sciences, Moscow)

Isotypes. Pl. 2, Fig. 4, Sample 145-884B-66X-4, 25–26 cm; Pl. 2, Fig. 6, Sample 145-884B-67X-CC (specimens deposited in the Institute of the Lithosphere, Russian Academy of Sciences, Moscow)

Derivation of name: A combination of "*prae*" (Latin, = before) plus "*fraga*" (from *Thalassiosira fraga* Schrader). *Thalassiosira praefraga* sp. nov. occurs stratigraphically below *T. fraga* and may be its ancestor.

Taxonomic Notes and References to Good Figures

Taxonomic references to diatom taxa tabulated in Hole 884B and illustrated on Plates 1–9 are listed below. In general, only references to good figures are listed following a semicolon. The reader should refer to these references for the original reference of the taxon. Important synonyms and limited remarks are included.

Actinocyclus ingens Rattray; Akiba, 1986, pl. 16, figs. 6, 9 (Pl. 7, Figs. 1, 2)

Actinocyclus ingens var. *nodus* Baldauf *in* Baldauf and Barron, 1980, pl. 1, figs. 5-9 (Pl. 7, Fig. 7)

Actinocyclus octonarius Ehrenberg; Akiba, 1986, pl. 29, fig. 4 = *A. ehrenbergii* Ralfs *in* Pritchard (Pl. 6, Fig. 15)

Actinocyclus tsugaruensis Kanaya, 1959, p. 99, pl. 8, figs. 5-8 (Pl. 7, Figs. 3, 6)

Remarks. Unlike many previous authors, we have chosen not to include this form with *A. ingens*, because we feel it has a distinct morphology.

Actinocyclus sp. (*ochotensis-ingens* form) (Pl. 7, Figs. 4, 5)

Remarks. Forms resembling *A. ochotensis* Jousé, but probably related to *A. ingens* Rattray, are tabulated here.

Actinoptychus senarius (Ehrenberg) Ehrenberg; Akiba, 1986, p. 447, pl. 29, fig. 2 = *A. undulatus* (Bailey) Ralfs.

Asteromphalus sp. cf. *A. darwinii* Ehrenberg; Koizumi, 1968, pl. 32, fig. 7 (Pl. 9, Fig. 2)

Asteromphalus sp. aff. *A. oligocenicus* Schraderet Fenner, 1976, p. 965, pl. 21, figs. 8, 1, 14; pl. 28, fig. 1 (Pl. 9, Figs. 1, 6)

Asteromphalus sp. aff. *A. robustus -symmetricus* (Pl. 9, Figs. 3, 7)

Remarks. Forms intermediate between *A. robustus* Castracane sensu Schrader (1973, pl. 21, figs. 4, 5, 7) and *A. symmetricus* Schrader and Fenner (1976, p. 966, pl. 21, figs. 7, 10–12)

Azpeitia biradiata (Greville) Sims *in* Fryxell et al. 1986, p. 7, figs. 4, 5, 27 (1–3) = *Coscinodiscus biradiatus* Greville; Williams, 1988, p. 25, pl. 31, fig. 1 (Pl. 6, Fig. 23a–b)

Azpeitia oligocenica (Jousé) Sims *in* Sims et al., 1989, p. 302, pl. 2, figs. 1–3; pl. 3, figs. 8, 9 = *Coscinodiscus oligocenicus* Jousé; Barron, 1983, p. 512, pl. 3, figs. 8, 11 (Pl. 5, Figs. 24, 26)

Azpeitia praenodulifera (Barron) Sims and Fryxell *in* Sims et al., 1989, p. 298, pl. 1, figs. 8–13; pl. 3, fig. 11 = *Coscinodiscus praenodulifer* Barron, 1983, p. 511, pl. 3, figs. 9, 10; pl. VI, fig. 8 (Pl. 2, Fig. 21)

Azpeitia sp. aff. *A. praenodulifera* (Barron) Sims et Fryxell (Pl. 3, Fig. 1)

Remarks. Differs from *A. praenodulifera* by smaller size and coarser nature of areolae, less prominent marginal processes, and wider central hyaline area.

Synonym. *Coscinodiscus* cf. *nodulifer* of Akiba, 1980, pl. 4, fig. 49

Azpeitia salisburyana (Lohman) Sims *in* Sims et al., 1989, p. 302, pl. 2, figs. 4–6; pl. 3, fig. 5 = *Coscinodiscus salisburyanus* Lohman (Pl. 2, Fig. 20)

Azpeitia tabularis (Grunow) Fryxell et Sims *in* Fryxell et al., 1986, p. 16, figs. 14, 15, 30(1) (Pl. 3, Figs. 9, 11)

Remarks. *A. endoi* (Kanaya) Sims and Fryxell is regarded as a variant of *A. tabularis* and is tabulated here as such.

Cavitatus exiguus Yanagisawa et Akiba *in* Akiba et al., 1993, p. 18, figs. 5, 1–11 (Pl. 5, Fig. 4)

Cavitatus jouseanus (Sheshukova-Poretzkaya) Williams; Akiba et al., 1993, p. 20, figs. 6, 19–20 = *Synedra jouseana* Sheshukova-Poretzkaya, 1967; Akiba, 1986, pl. 21, fig. 9 (Pl. 5, Figs. 3, 15, 18–19, 22–23)

Cavitatus lanceolatus Akiba et Hiramatsu *in* Akiba et al., 1993, p. 22, figs. 6 (1a–6b), 7 (1–7) (Pl. 5, Figs. 5, 6)

Cavitatus linearis (Sheshukova-Poretzkaya) Akiba et Yanagisawa *in* Akiba et al., 1993, p. 26, figs. 6 (17–18), 8 (1–10) = *Synedra jouseana* f. *linearis* Sheshukova-Poretzkaya, 1967; Akiba, 1986, pl. 21, fig. 8 (Pl. 5, Figs. 16–17, 25)

Cavitatus miocenicus (Schrader) Akiba et Yanagisawa *in* Akiba et al. 1993, p. 29, fig. 9 (1–11) = *Synedra miocenica* Schrader; Akiba, 1986, pl. 21, fig. 7 (Pl. 5, Figs. 1–2, 27)

Cavitatus rectus Akiba et Hiramatsu *in* Akiba et al., 1993, p. 28, fig. 6 (7–15) (Pl. 5, Figs. 7–10)

Cestodiscus kugleri Lohman, 1974, p. 340, pl. 4, figs. 4, 5, 8 = *Cestodiscus* aff. *trochus* Castracane sensu Fenner, 1984, p. 1270, pl. 1, fig. 4 (Pl. 3, Figs. 2–6, 7?)

Remarks. A range of forms have been tabulated together under this taxon, because they seemed to intergrade with one another. Fumio Akiba (written comm., 1994) thinks that specimens with a hyaline center and nonfasciculated areolar pattern (i.e., pl. 3, fig. 7) represent a distinct species. A detailed taxonomic study of *Cestodiscus* spp. is needed.

Cestodiscus trochus Castracane, 1886, p. 123, pl. 7, figs. 1, 3 (Pl. 3, Figs. 8, 10)

Chaetoceros spores (Pl. 2, Fig. 17; Pl. 9, Fig. 8)

Coscinodiscus lewisianus Greville; Schrader, 1973, pl. 8, figs. 1–6, 10, 15 (Pl. 3, Fig. 13)

Coscinodiscus lewisianus var. *levis* (Jousé) Harwood et Maruyama, 1992, p. 702, pl. 3, figs. 12–15 = *Actinocyclus levis* Jousé, 1973, p. 353, pl. 5, fig. 2 (Pl. 1, Figs. 14a–b)

Coscinodiscus marginatus Ehrenberg; Akiba, 1986, pl. 1, figs. 1–4 (Pl. 9, Figs. 4, 5)

Coscinodiscus rhombicus Castracane; Fenner, 1985, p. 729, pl. 7, figs. 1–4 (Pl. 3, Fig. 12)

Crucidenticula ikebei Akiba et Yanagisawa, 1986, p. 485, pl. 1, figs. 1–2 (Pl. 8, Figs. 34, 35)

Crucidenticula kanayae Akiba et Yanagisawa, 1986, p. 486, pl. 1, figs. 3–8; pl. 3, figs. 1–6, 9–11 (Pl. 8, Figs. 37–40, 44–47)

Crucidenticula sawamurae Yanagisawa et Akiba, 1990, p. 227, pl. 1, figs. 5–9 = *Denticulopsis nicobarica* (Grunow) Simosen; Barron, 1983, pl. 5, figs. 1, 2 (Pl. 8, Figs. 31-33, 36, 41-42)

Cymatosira sp. aff. *C. lorenziana* Grunow (Pl. 5, Figs. 14, 20–21)

Remarks. This form has a hyaline central area like the form of Akiba, 1980, pl. 4, fig. 47.

Denticulopsis hyalina (Schrader) Simonsen; Akiba, 1986, pl. 26, figs. 20–25 (Pl. 8, Fig. 43)

Denticulopsis lauta (Bailey) Simonsen; Akiba, 1986, pl. 26, Figs. 15–19 (Pl. 8, Figs. 20–26)

Denticulopsis praelauta Akiba et Koizumi; Akiba, 1986, pl. 26, figs. 10–14 (Pl. 8, Figs. 9–19)

Goniothecium decoratum Brun; Schrader and Fenner, 1976, pl. 6, figs. 3, 5; pl. 37, figs. 1–4, 33, 5, 11–14 (Pl. 6, Fig. 22)

Goniothecium odontella Ehrenberg; Schrader and Fenner, 1976, pl. 6, figs. 1, 2 and 4 (Pl. 2, Fig. 19)

Hemiaulus sp. cf. *H. incisus* Hajós, 1976, p. 829, pl. 23, figs. 4–9

Hemiaulus sp. (*pyxiloides* form), Schrader and Fenner, 1976, p. 984, pl. 10, figs. 1–3 (Pl. 4, Figs. 7, 13–14)

Ikebea tenuis (Brun) Akiba, 1986, p. 439, pl. 19, figs. 1–5 = *Goniothecium tenue* Brun (Pl. 6, Figs. 9, 19–20)

Kisseleviella carina Sheshukova-Poretzkaya; Akiba, 1986, pl. 19, figs. 17–18; Akiba and Yanagisawa, 1986, p. 494, pl. 36, figs. 1–13; pl. 37, figs. 1–9 (Pl. 6, Figs. 16, 17)

Kisseleviella ezoensis Akiba, 1986, p. 440, pl. 19, figs. 13–16 (Pl. 6, Figs. 10–12)

Kisselviella magnaareolata Akiba et Yanagisawa, 1986, p. 495, pl. 38, figs. 10–18 (Pl. 6, Figs. 18, 21)

Kozloviella minor Jousé, 1973, p. 352, pl. 4, fig. 18 (Pl. 1, Figs. 13, 20)

Lisitzinia ornata Jousé; Fenner, 1985, p. 734, pl. 10, fig. 11 (Pl. 1, Figs. 15–18)

Lisitzinia ornata f. *pentagona* Harwood, 1986, p. 86, pl. 2, figs. 5, 9 = *L. quinquelobata* Pushkar, 1987, p. 67, pl. 2, fig. 8 (Pl. 1, Fig. 19)

Mediaria splendida Sheshukova-Poretzkaya; Schrader, 1973, pl. 3, figs. 14, 15 (Pl. 6, Figs. 13, 14)

Melosira architecturalis Brun; Schrader and Fenner, 1976, p. 989, pl. 14, fig. 13; pl. 29, figs. 7–8; pl. 35, figs. 1-4 = *Cyclotella hannae* Kanaya (Pl. 2, Fig. 2)

Nitzschia challengeri Schrader; Akiba, 1986, pl. 24, fig. 12(?) (Pl. 8, Figs. 1, 2)

Nitzschia sp. aff. *N. challengeri* Schrader (Pl. 8, Figs. 3–8)

Remarks. Distinguished by asymmetrical apices and more convex (transpically) margins. It is also similar to *N. januaria* Schrader 1976, although it differs in its asymmetrical apices and much older age distribution.

Nitzschia maleinterpretaria Schrader; Barron, 1983, pl. 5, figs. 7, 8; Yanagisawa and Akiba, 1990, p. 226, pl. 1, figs. 1–4; pl. 9, figs. 1–7 (Pl. 8, Figs. 2–8)

Paralia sulcata (Ehrenberg) Cleve = *Melosira sulcata* (Ehrenberg) Kützing; Schrader, 1973, pl. 20, fig. 9 (Pl. 2, Fig. 1)

Pseudodimerogramma elegans Schrader *in* Schrader and Fenner, 1976, p. 993, pl. 3, fig. 14 (Pl. 6, Fig. 8)

Pseudotriceratium radiosoreticulatum Grunow; Fenner, 1985, pl. 12, fig. 11 = *P.* aff. *chenevieri* sensu Schrader and Fenner, 1976, pl. 26, figs. 6, 8–9; pl. 27, figs. 4, 13 (Pl. 4, Figs. 11, 12)

Pyxilla spp. (Pl. 4, Figs. 6, 15, 17)

Remarks. Probably includes *P. reticulata* Grove et Sturt and *P. gracilis* Tempère et Forti.

Raphidodiscus marylandicus Christian; Schrader and Fenner, 1976, pl. 7, fig. 16; Barron, 1983, p. 512, pl. 5, fig. 14 (Pl. 1, Fig. 11)

Rhizosolenia hotaense Akiba, 1980, p. 10, pl. 4, figs. 56, 57 (Pl. 4, Figs. 5, 16)

Remarks. Akiba (1980) notes that *R. hotaense* possesses a larger and more slender valve than *R. norwegica*, and that the valve's maximum diameter is more toward the apex than it is in *R. norwegica*.

Rhizosolenia norwegica Schrader *in* Schrader and Fenner, 1976, p. 996, pl. 9, figs. 4, 10 (Pl. 4, Figs. 3–4)

Rocella gelida (Mann) Bukry; Gombos, 1983, pl. 1, figs. 1–6; Barron, 1985a, pl. 12, fig. 16 (Pl. 1, Figs. 3, 7)

Rocella gelida var. *schraderi* (Bukry) Barron; Barron, 1985a, pl. 12, fig. 15 = *R. schraderi* Bukry; Gombos, 1983, pl. 1, figs. 13–16 (Pl. 1, Figs. 4, 8)

Remarks. The scarcity of this variety in Hole 884B, compared with its more common abundance in tropical sediment, suggests that it preferred warmer waters.

Rocella praenitida (Fenner) Fenner *in* Kim and Barron, 1986, p. 177, pl. 4, fig. 3 = *Coscinodiscus praenitidus* Fenner *in* Schrader and Fenner, 1976, p. 972, pl. 14, figs. 7, 8, 9, 12; pl. 27, fig. 8; pl. 35, fig. 5

Rocella semigelida Gombos, 1983, p. 796, pl. 2, figs. 1–12 (Pl. 1, Figs. 5–6, 9–10, 12)

Remarks. The occurrence of *R. semigelida* in Hole 884B is the first reported occurrence of this taxon in the Pacific Ocean; previous reports are from the South Atlantic (Gombos, 1983) and the southern Indian Ocean (Harwood and Maruyama, 1992).

Rocella vigilans Fenner; Gombos, 1983, pl. 1, figs. 7–12; Fenner, 1985, pl. 7, figs. 14, 15 (Pl. 1, Figs. 1, 2)

Rouxia sp. cf. *R. granda* Schrader *in* Schrader and Fenner, 1976, p. 997, pl. 7, fig. 17 (Pl. 6, Figs. 3, 4)

Remarks. Only observed as fragments.

Rouxia isopolica Schrader, 1976, p. 635, pl. 5, figs. 9, 14–15, 20 (Pl. 6, Figs. 1, 2)

Rouxia naviculoides Schrader, 1973, p. 710, pl. 3, figs. 27–32 (Pl. 6, Fig. 5)

Rouxia obesa Schrader *in* Schrader and Fenner, 1976, p. 997, pl. 24, figs. 5, 6 (Pl. 6, Figs. 6, 7)

Sceptroneis spp. (*tenue-pesplanus* group) (Pl. 4, Figs. 8, 9)

Remarks. Fragments of *S. pesplanus* Fenner et Schrader *in* Schrader and Fenner, 1976, p. 998, pls. 22 (figs. 30–31) and 25 (figs. 10–11); and *S. tenue* Schrader and Fenner, 1976, p. 999, pls. 3 (figs. 1–4), 24 (figs. 14–16), and 25 (figs. 12, 22, 24) are tabulated together.

Simonseniella interposita (Hajós) A. Gladenkov et Barron, comb. nov.

Basionym. *Rhizosolenia interposita* Hajós, 1976, p. 827, pl. 21, fig. 8

Remarks. If Sundström's (1986) publication of *Proboscia* in a Ph.D. dissertation is considered a valid publication, then this taxon might be cited as *Proboscia praebarboi* (Hajós) Jordan and Priddle.

Simonseniella praebarboi (Schrader) Fenner = *Rhizosolenia praebarboi* Schrader, 1973, p. 709, pl. 24, figs. 1–3 (Pl. 4, Figs. 1, 2)

Remarks. If Sundström's (1986) publication of *Proboscia* in a Ph.D. dissertation is considered a valid publication, then this taxon might be cited as *Proboscia praebarboi* (Hajós) Jordan and Priddle.

Stellarima spp. (group) = *Coscinodiscus symbolophorus* Grunow; Akiba, 1986, pl. 2, fig. 1 (Pl. 9, Figs. 9, 10)

Remarks. *S. microtrias* Hasle et Sims, 1976, and *S. stellaris* Hasle and Sims, 1976, are not separated here.

Thalassionema nitzschioides Grunow; Schrader, 1973, pl. 23, figs. 2, 6, 8, 9, 10, 26, 29, 34 (Pl. 5, Figs. 11, 12)

Thalassionema nitzschioides var. *parva* Heiden *in* Heiden and Kolbe, 1928, p. 564, pl. 35, fig. 118 (Pl. 5, Fig. 13)

Thalassiosira dubiosa Schrader *in* Schrader and Fenner, 1976, p. 1001, pl. 35, figs. 4-6 (Pl. 2, Fig. 7a–b)

Thalassiosira fraga Schrader; Akiba, 1986, pl. 8, figs. 12–13 (Pl. 1, Figs. 14–15, 18)

Thalassiosira irregulata Schrader *in* Schrader and Fenner, 1976, p. 1001, pl. 20, figs. 10–12 (Pl. 2, Figs. 12, 13a–b)

Thalassiosira lusca Schrader *in* Schrader and Fenner, 1976, p. 1002, pl. 35, figs. 1–3 (Pl. 1, Figs. 10, 11)

Thalassiosira mediaconvexa Schrader *in* Schrader and Fenner, 1976, p. 1002, pl. 36, fig. 1 (Pl. 2, Figs. 8, 16 [aff.])

Thalassiothrix longissima Cleve et Grunow; Akiba, 1986, p. 447, pl. 21, fig. 18 (Pl. 5, Fig. 28)

Yoshidaia divergensis Komura; Yanagisawa and Akiba, 1990, pl. 9, figs. 10–11 (Pl. 8, Fig. 27)

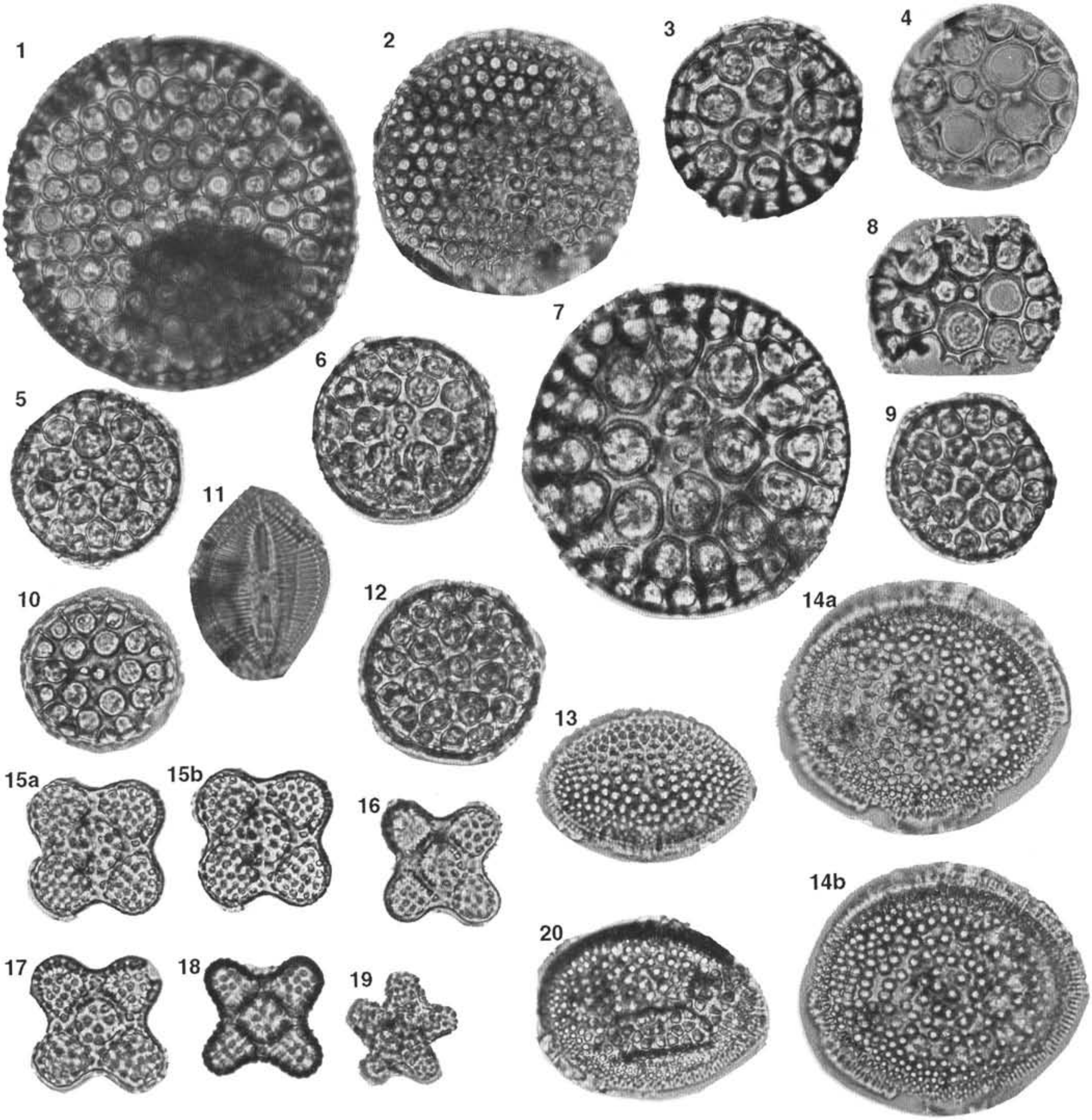

Plate 1. Magnification for all figures is 1000×. **1, 2.** *Rocella vigilans;* (1) Sample 145-884B-69X-4, 25–26 cm; (2) Sample 145-884B-70X-CC. **3, 7.** *Rocella gelida;* (3) Sample 145-884B-69X-2, 26–26 cm; (7) Sample 145-884B-69X-1, 25–26 cm. **4, 8.** *Rocella gelida* var. *schraderi,* Sample 145-884B-71X-4, 25–26 cm. **5, 6, 9, 10, 12.** *Rocella semigelida,* Sample 145-884B-71X-4, 25–26 cm. **11.** *Raphidodiscus marylandicus,* Sample 145-884B-66X-3, 25–26 cm. **13, 20.** *Kozloviella minor;* (13) Sample 145-884B-70X-6, 25–26 cm; (20) Sample 145-884B-70X-CC. **14.** *Coscinodiscus lewisianus* var. *levis,* Sample 145-884B-70X-6, 25–26 cm (a, b = different focuses of the same specimen). **15–18.** *Lisitzinia ornata;* (15–17) Sample 145-884B-69X-3, 25–26 cm (15a–b = different focuses); (18) Sample 145-884B-69X-2, 25–26 cm. **19.** *Lisitzinia ornata* f. *pentagona,* Sample 145-884B-69X-2, 25–26 cm.

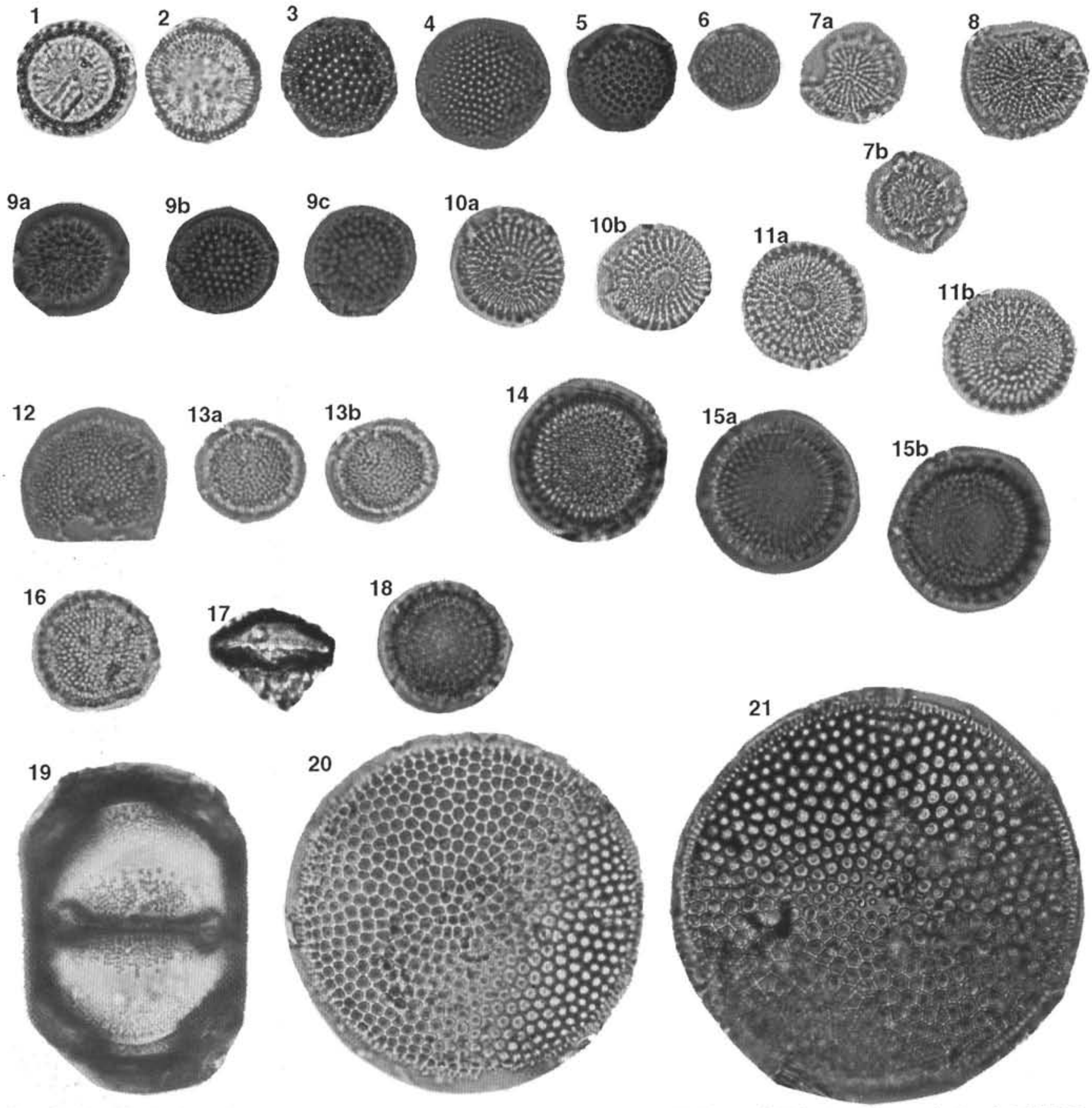

Plate 2. Magnification for all figures is 1000×. **1.** *Paralia sulcata,* Sample 145-884B-69X-3, 25–26 cm. **2.** *Melosira architecturalis,* Sample 145-884B-68X-CC. **3–6, 9.** *Thalassiosira praefraga* sp. nov.; (3, 4) Sample 145-884B-66X-4, 25–26 cm; (5) Sample 145-884B-66X-5, 25–26 cm (a–c = different focuses); (6) Sample 145-884B-67X-CC; (9) holotype Sample 145-884B-66X-5, 25–26 cm (a–c = different focuses). **7.** *Thalassiosira dubiosa,* Sample 145-884B-71X-6, 25–26 cm (a, b = different focuses). **8.** *Thalassiosira mediaconvexa,* Sample 145-884B-69X-3, 25–26 cm. **10, 11.** *Thalassiosira lusca,* Sample 145-884B-67X-7, 24–25 cm (a, b = different focuses). **12, 13.** *Thalassiosira irregulata;* (12) Sample 145-884B-68X-3, 25–26 cm; (13) Sample 145-884B-67X-3, 24–25 cm (a, b = different focuses). **14, 15, 18.** *Thalassiosira fraga,* Sample 145-884B-66X-3, 25–26 cm (15a, b = different focuses). **16.** *Thalassiosira* aff. *mediaconvexa,* Sample 145-884B-67X-3, 24–25 cm. **17.** *Chaetoceros* spore, Sample 145-884B-69X-1, 25–26 cm. **19.** *Goniothecium odontella,* Sample 145-884B-68X-6, 25–26 cm. **20.** *Azpeitia salisburyana,* Sample 145-884B-67X-3, 24–25 cm. **21.** *Azpeitia praenodulifera,* Sample 145-884B-66X-3, 25–26 cm.

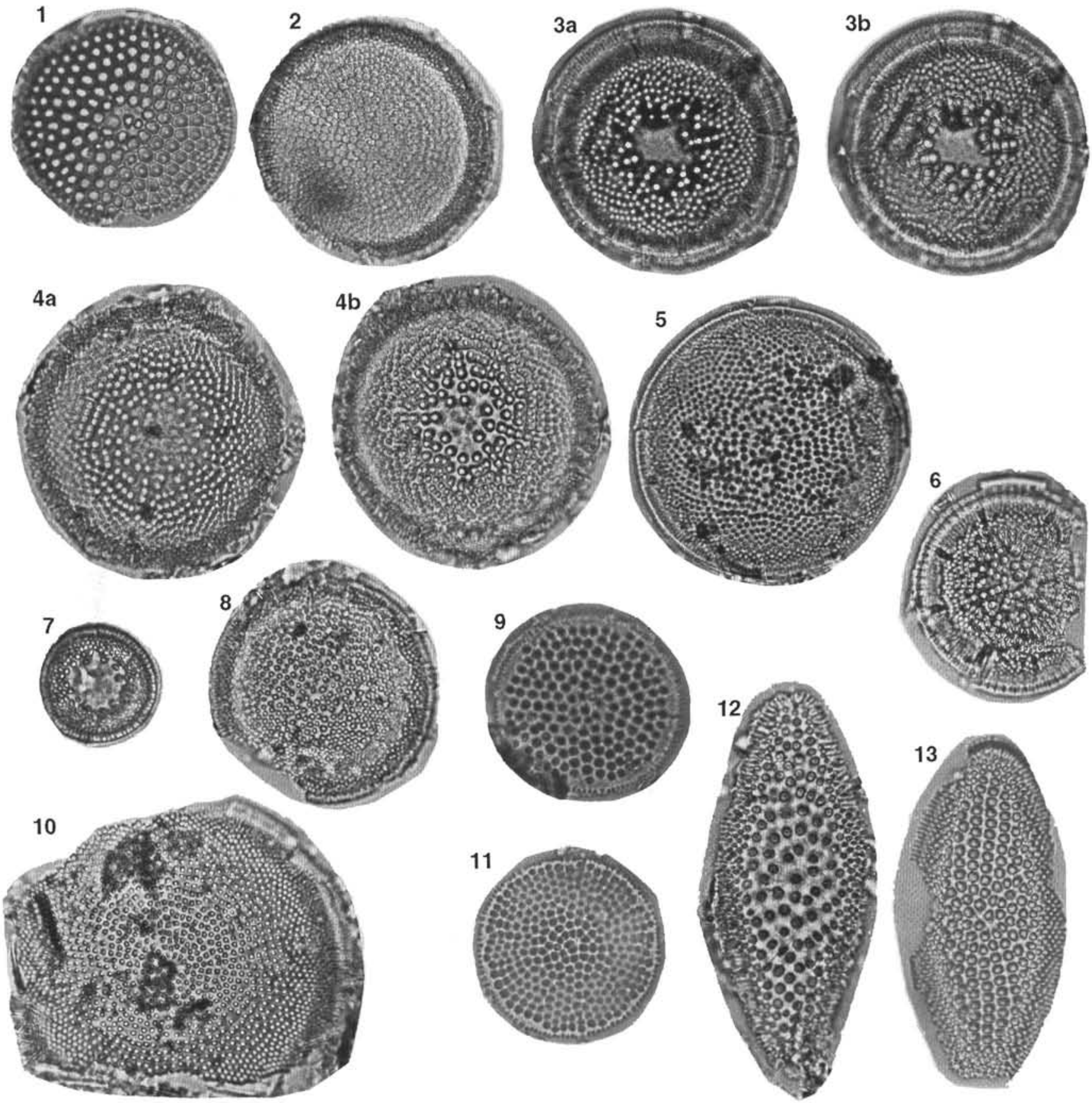

Plate 3. Magnification for all figures is 1000×. **1.** *Azpeitia* sp. aff. *A. praenodulifera,* Sample 145-884B-66X-3, 25–26 cm. **2–6.** *Cestodiscus kugleri;* (2) Sample 145-884B-70X-CC; (3, 4) Sample 145-884B-71X-5, 25–26 cm (a, b = different focuses); (5) Sample 145-884B-69X-1, 25–26 cm; (6) Sample 145-884B-71X-4, 25–26 cm. **7.** *Cestodiscus kugleri*?, Sample 145-884B-71X-4, 25–26 cm. **8, 10.** *Cestodiscus trochus;* (8) Sample 145-884B-69X-1, 25–26 cm; (10) Sample 145-884B-70X-CC. **9, 11.** *Azpeitia tabularis,* (9) Sample 145-884B-64X-4, 28–29 cm; (11) Sample 145-884B-67X-7, 24–25 cm. **12.** *Coscinodiscus rhombicus,* Sample 145-884B-69X-1, 25–26. **13.** *Coscinodiscus lewisianus,* Sample 145-884B-62X-CC.

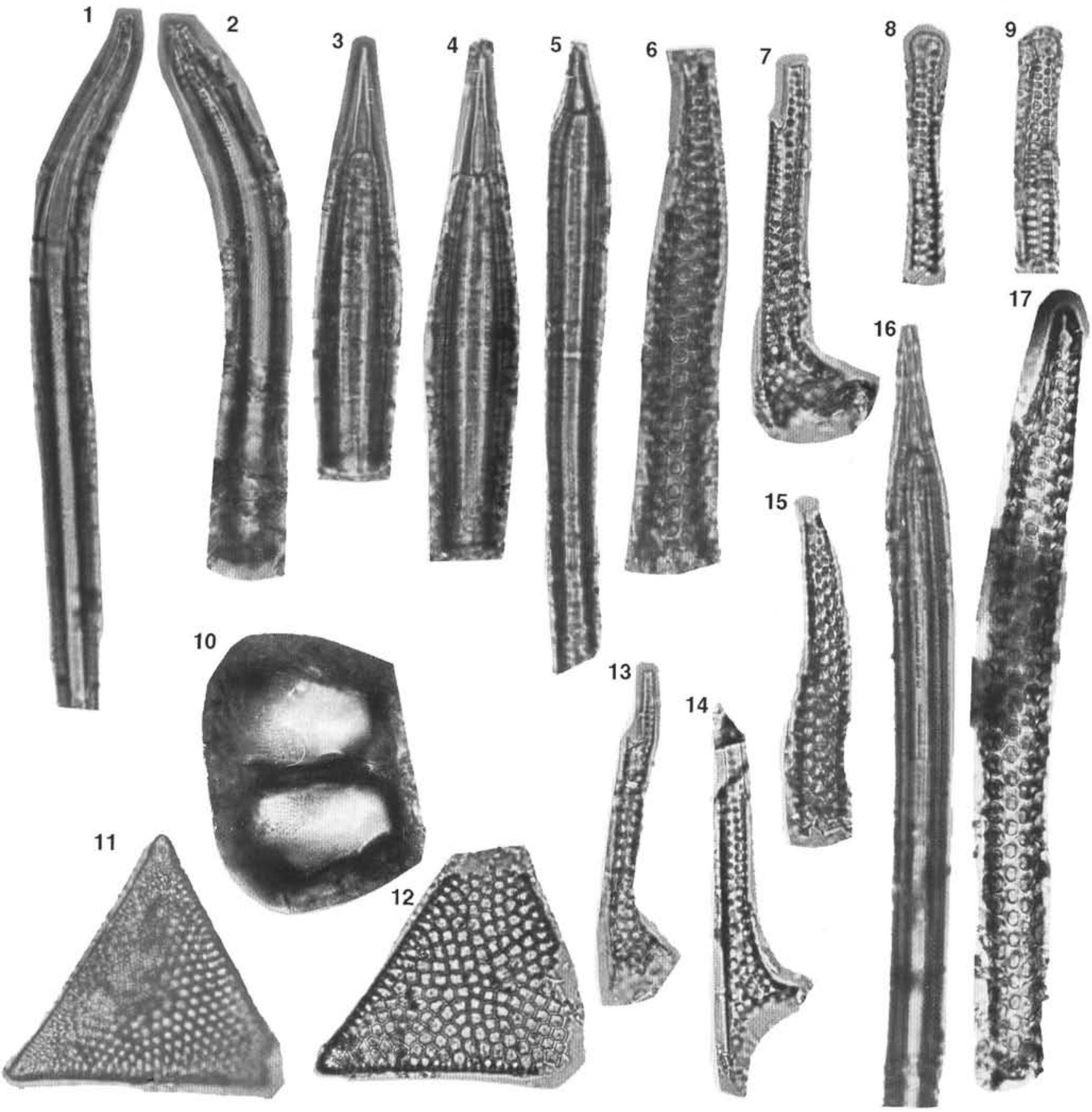

Plate 4. Magnification for all figures is 1000×. **1, 2.** *Simonseniella praebarboi;* (1) Sample 145-884B-64X-1, 25–26 cm; (2) Sample 145-884B-64X-3, 25–26 cm. **3, 4.** *Rhizosolenia norwegica,* Sample 145-884B-66X-3, 25–26 cm. **5, 16.** *Rhizosolenia hotaense;* (5) Sample 145-884B-66X-3, 25–26 cm; (16) Sample 145-884B-66X-1, 25–26 cm. **6, 15, 17.** *Pyxilla* spp.; (6) Sample 145-884B-68X-CC; (15) Sample 145-884B-71X-4, 25–26 cm; (17) Sample 145-884B-69X-1, 25–26 cm. **7, 13, 14.** *Hemiaulus* sp. (*pyxiloides*); (7) Sample 145-884B-70X-6, 25–26 cm; (13) Sample 145-884B-70X-7, 25–26 cm; (14) Sample 145-884B-69X-2, 25–26 cm. **8, 9.** *Sceptroneis tenue-pesplanus* group; (8) Sample 145-884B-69X-3, 25–26 cm; (9) Sample 145-884B-70X-CC. **10.** *Goniothecium odontella,* Sample 145-884B-69X-1, 25–26 cm. **11, 12.** *Pseudotriceratium radiosoreticulatum;* (11) Sample 145-884B-67X-7, 24–25 cm; (12) Sample 145-884B-70X-7, 25–26 cm.

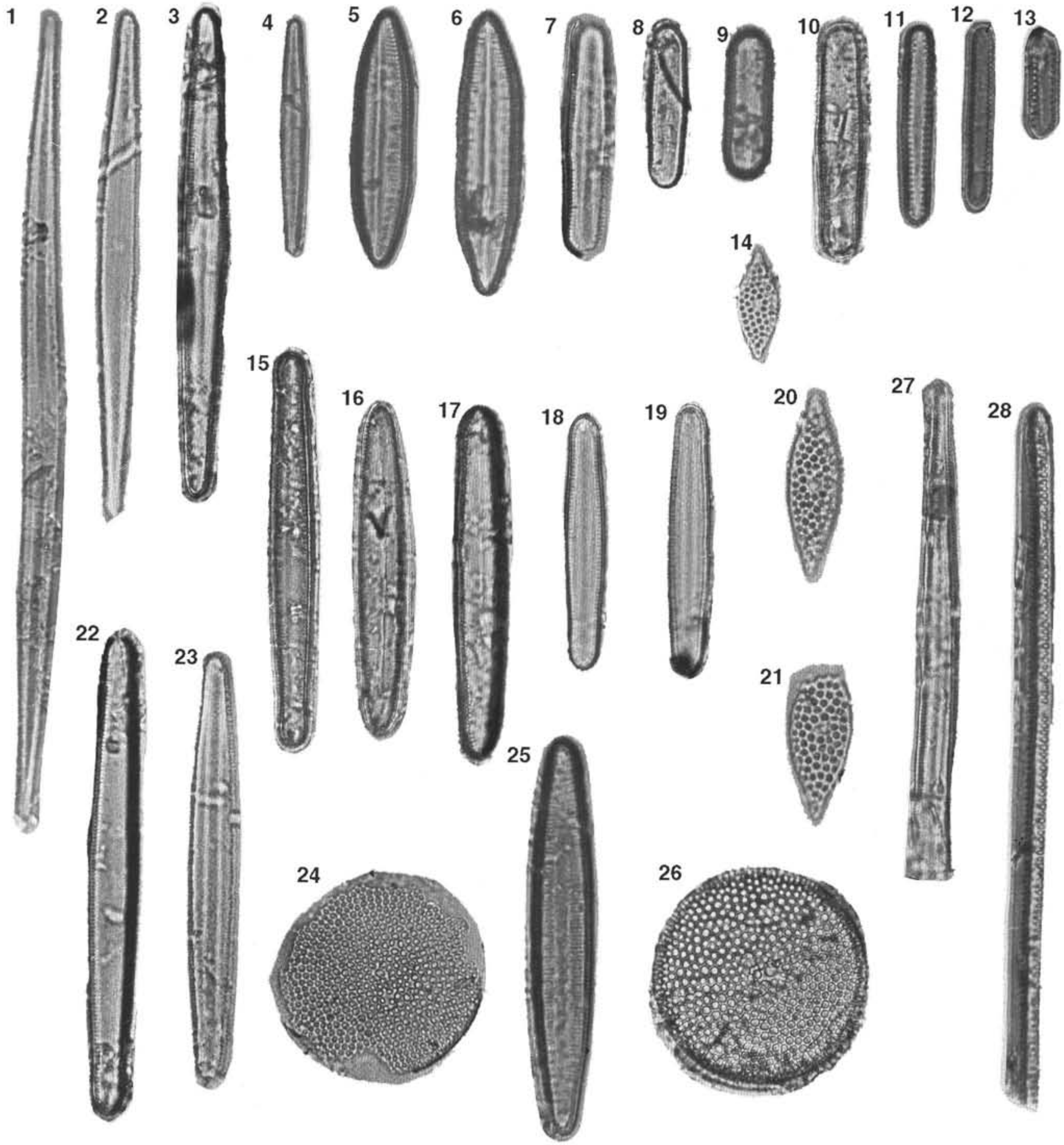

Plate 5. Magnification for all figures is 1000×. **1, 2, 27.** *Cavitatus miocenicus,* Sample 145-884B-70X-6, 25–26 cm. **3, 15, 18, 19, 22, 23.** *Cavitatus jouseanus;* (3, 18, 19) Sample 145-884B-70X-CC; (15) Sample 145-884B-69X-4, 25–26 cm; (22) Sample 145-884B-69X-3, 25–26 cm; (23) Sample 145-884B-70X-7, 25–26 cm. **4.** *Cavitatus exiguus,* Sample 145-884B-62X-4, 25–26 cm. **5, 6.** *Cavitatus lanceolatus,* Sample 145-884B-62X-4, 25–26 cm. **7–10.** *Cavitatus rectus;* (7) Sample 145-884B-70X-7, 25–26 cm; (8) Sample 145-884B-70X-CC; (9) Sample 145-884B-67X-7, 24–25 cm; (10) Sample 145-884B-69X-3, 25–26 cm. **11, 12.** *Thalassionema nitzschioides;* (11) Sample 145-884B-64X-4, 28–29 cm; (12) Sample 145-884B-64X-5, 25–26 cm. **13.** *Thalassionema nitzschioides* var. *parva,* Sample 145-884B-64X-4, 28–29 cm. **14, 20, 21.** *Cymatosira* sp. aff. *C. lorenziana;* (14) Sample 145-884B-70X-6, 25–26 cm; (20, 21) Sample 145-884B-70X-7, 25–26 cm. **16, 17, 25.** *Cavitatus linearis;* (16, 17) Sample 145-884B-70X-6, 25–26 cm; (25) Sample 145-884B-66X-3, 25–26 cm. **24, 26.** *Azpeitia oligocenica;* (24) Sample 145-884B-70X-7, 25–26 cm; (26) Sample 145-884B-70X-6, 25–26 cm. **28.** *Thalassiothrix longissima,* Sample 145-884B-64X-3, 25–26 cm.

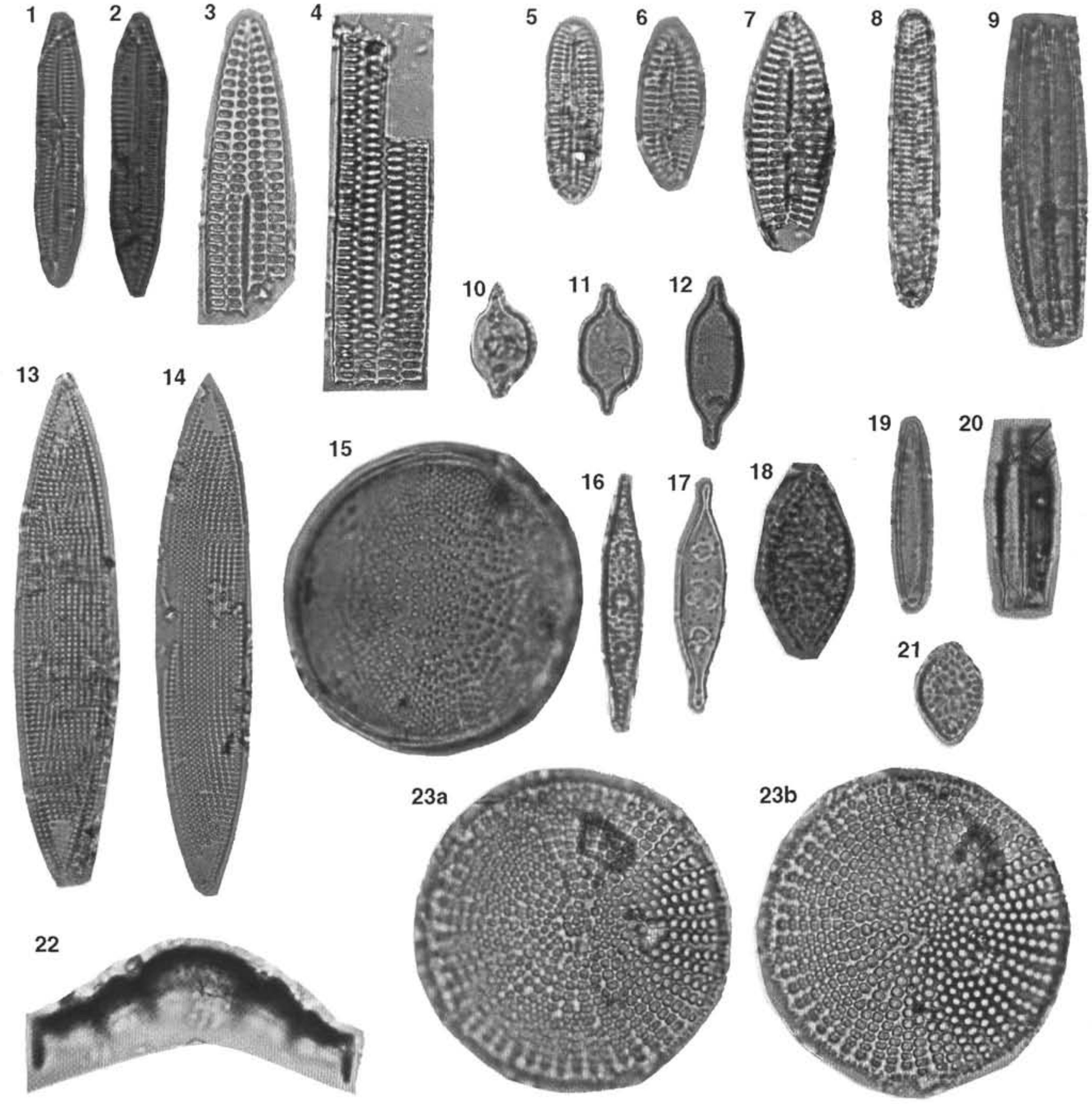

Plate 6. Magnification for all figures is 1000×. **1, 2.** *Rouxia isopolica,* Sample 145-884B-64X-5, 25–26 cm. **3, 4.** *Rouxia* sp. cf. *R. granda;* (3) Sample 145-884B-67X-7, 24–25 cm; (4) Sample 145-884B-70X-6, 25–25 cm. **5.** *Rouxia naviculoides,* Sample 145-884B-73X-CC. **6, 7.** *Rouxia obesa,* (6) Sample 145-884B-67X-6, 24–25 cm; (7) Sample 145-884B-70X-CC. **8.** *Pseudodimerogramma elegans,* Sample 145-884B-67X-4, 24–25 cm. **9, 19, 20.** *Ikebea tenuis;* (9) Sample 145-884B-66X-6, 25–26 cm; (19) Sample 145-884B-67X-7, 24–25 cm; (20) Sample 145-884B-63X-CC. **10–12.** *Kisseleviella ezoensis;* (10) Sample 145-884B-67X-3, 24–25 cm; (11) Sample 145-884B-66X-6, 25–26 cm; (12) Sample 145-884B-67X-5, 24–25 cm. **13, 14.** *Mediaria splendida,* Sample 145-884B-63X-5, 25–26 cm. **15.** *Actinocyclus octonarius,* Sample 145-884B-66X-3, 25–26 cm. **16, 17.** *Kisseleviella carina;* (16) Sample 145-884B-67X-7, 24–25 cm; (17) Sample 145-884B-67X-6, 24–25 cm. **18, 21.** *Kisseleviella magnaareolata,* (18) Sample 145-884B-66X-4, 25–26 cm; (21) Sample 145-884B-67X-7, 24–25 cm. **22.** *Goniothecium decoratum,* Sample 145-884B-67X-7, 24–25 cm. **23.** *Azpeitia biradiata,* Sample 145-884B-67X-3, 24–25 cm (a, b = different focuses).

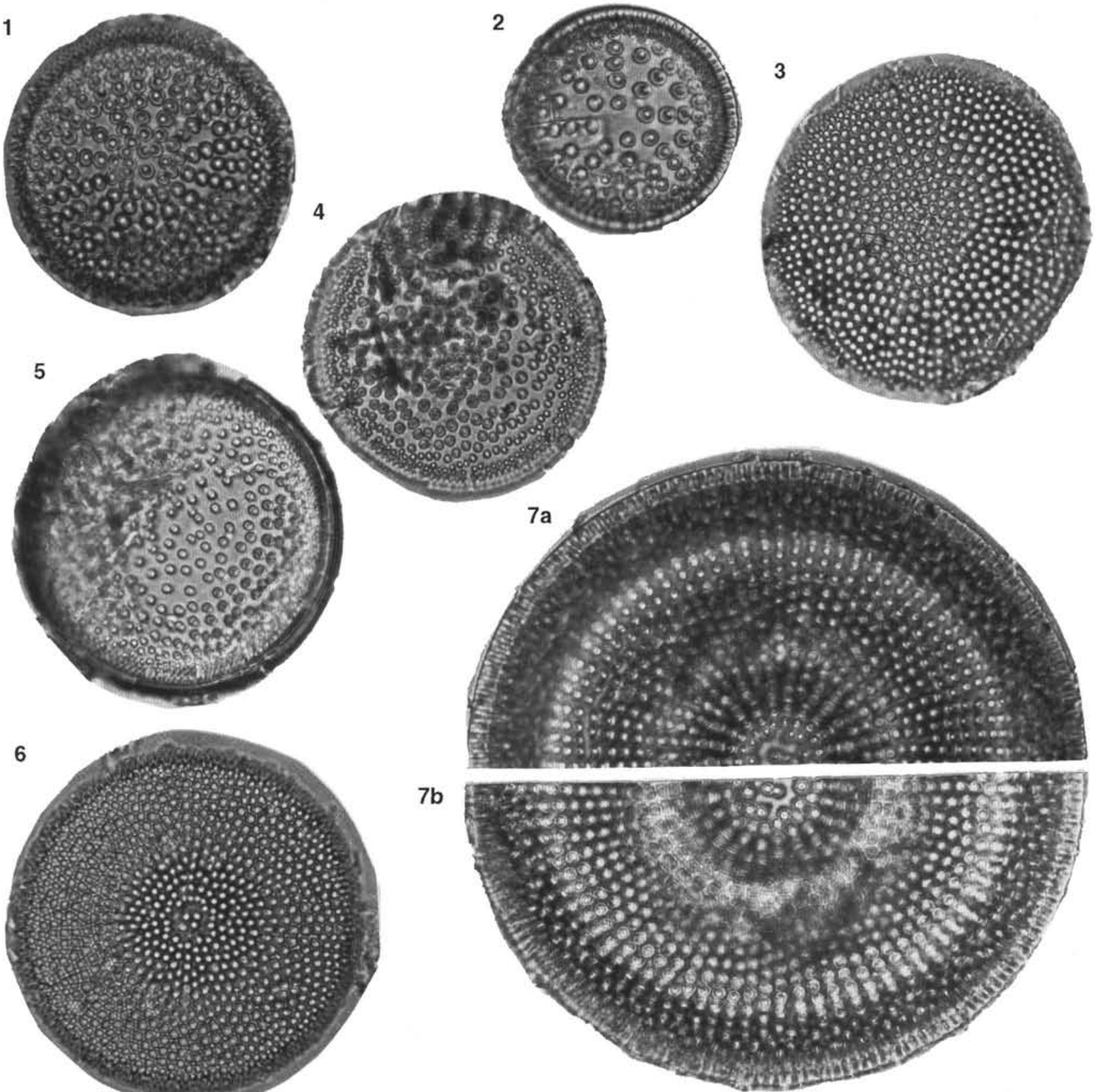

Plate 7. Magnification for all figures is 1000×. **1, 2.** *Actinocyclus ingens;* (1) Sample 145-884B-63X-2, 25–26 cm; (2) Sample 145-884B-63X-4, 25–26 cm. **3, 6.** *Actinocyclus tsugaruensis,* Sample 145-884B-64X-6, 25–26 cm. **4, 5.** *Actinocyclus* sp. (*ohotensis-ingens* form), Sample 145-884B-64X-6, 25–26 cm. **7.** *Actinocyclus ingens* var. *nodus,* Sample 145-884B-62X-CC (a, b = different focuses).

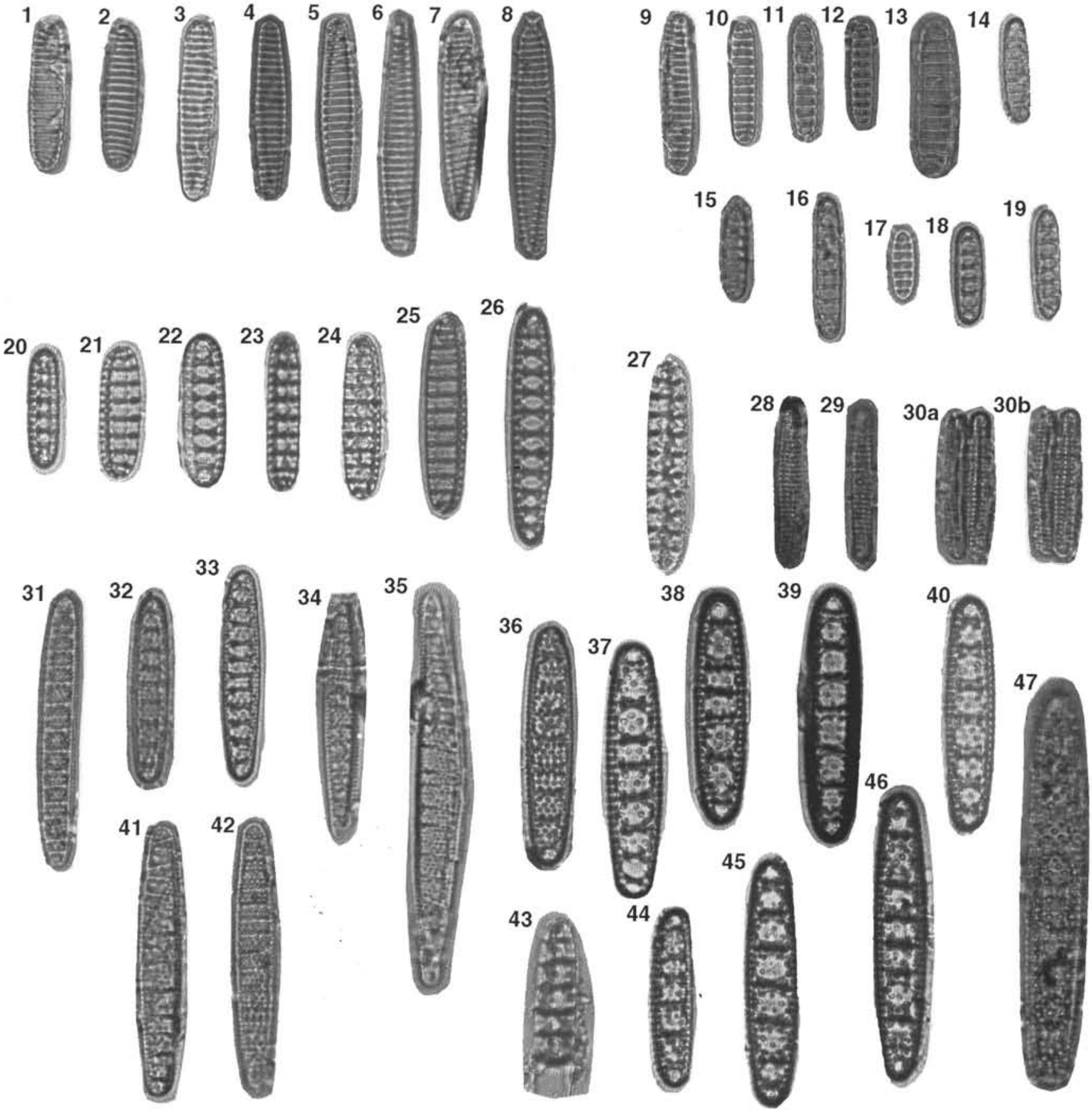

Plate 8. Magnification for all figures is 1000×. **1, 2.** *Nitzschia challengeri,* Sample 145-884B-63X-5, 25–26 cm. **3–8.** *Nitzschia* sp. aff. *N. challengeri,* Sample 145-884B-63X-5, 25–26 cm. **9–19.** *Denticulopsis praelauta;* (9–13, 16, 18, 19) Sample 145-884B-63X-5, 25–26 cm; (14, 15, 17) Sample 145-884B-63X-CC. **20–26.** *Denticulopsis lauta,* Sample 145-884B-62X-6, 25–26 cm. **27.** *Yoshidaia divergens,* Sample 145-884B-62X-6, 25–26 cm. **28–30.** *Nitzschia maleinterpretaria,* Sample 145-884B-66X-2, 25–26 cm (30a–b = different focuses). **31–33, 36, 41, 42.** *Crucidenticula sawamurae;* (31) Sample 145-884B-64X-6, 25–26 cm; (32, 33) Sample 145-884B-64X-CC; (36, 42) Sample 145-884B-64X-5, 25–26 cm; (41) Sample 145-884B-64X-3, 25–26 cm. **34, 35.** *Crucidenticula ikebei,* Sample 145-884B-64X-3, 25–26 cm. **37–40, 44–47.** *Crucidenticula kanayae;* (37–40, 44) Sample 145-884B-64X-3, 25–26 cm; (45, 46) Sample 145-884B-64X-4, 28–29 cm; (47) Sample 145-884B-64X-2, 25–26 cm. **43.** *Denticulopsis hyalina,* Sample 145-884B-62X-4, 25–26 cm.

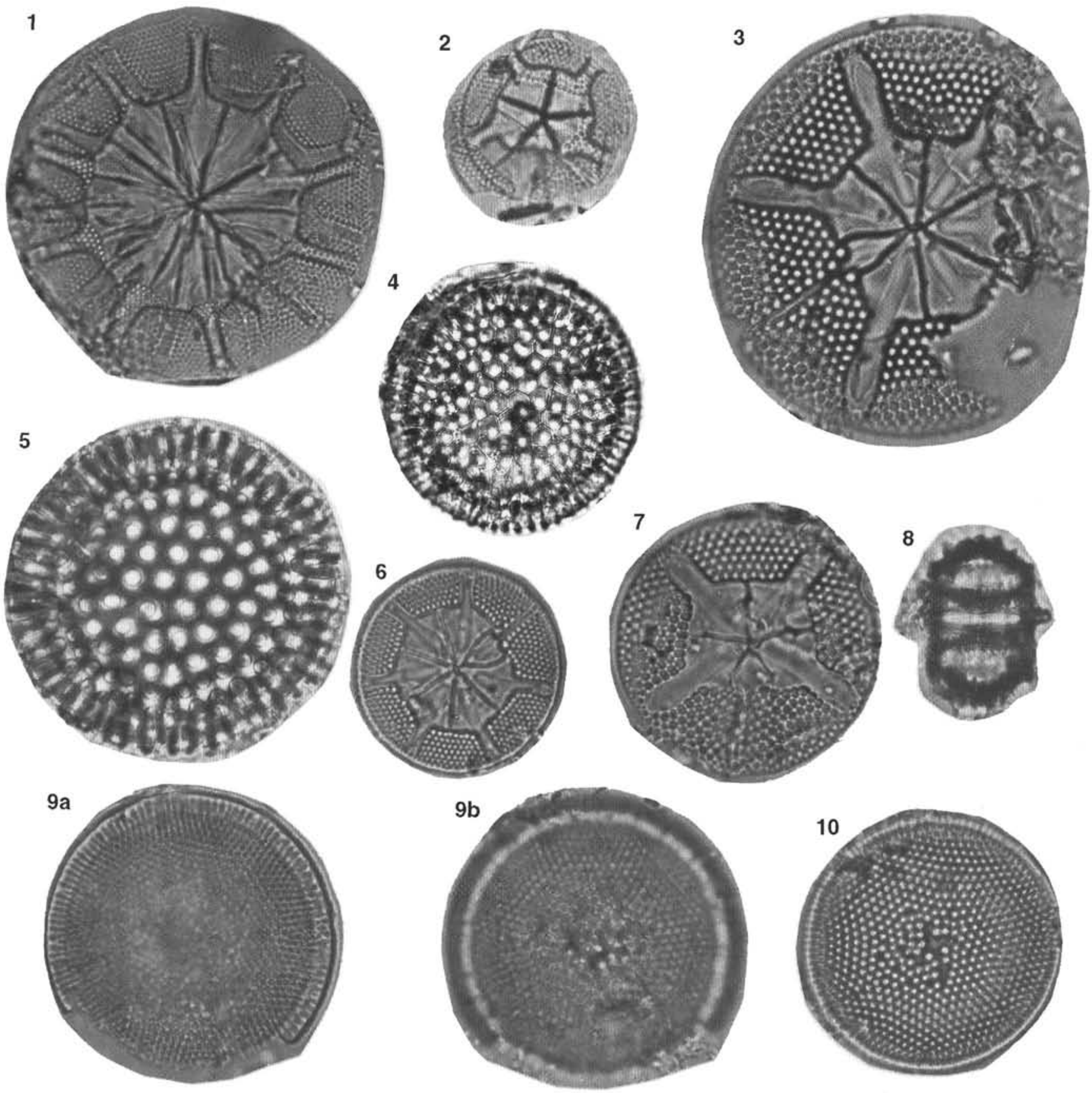

Plate 9. Magnification for all figures is 1000×. **1, 6.** *Asteromphalus* sp. aff. *A. oligocenicus,* Sample 145-884B-64X-5, 25–26 cm. **2.** *Asteromphalus* sp. cf. *A. darwinii,* Sample 145-884B-63X-CC. **3, 7.** *Asteromphalus* sp. aff. *A. robustus-symmetricus,* Sample 145-884B-64X-5, 25–26 cm. **4, 5.** *Coscinodiscus marginatus;* (4) Sample 145-884B-69X-2, 25–26 cm; (5) Sample 145-884B-66X-2, 25–26 cm. **8.** *Chaetoceros* spore, Sample 145-884B-66X-6, 25–26 cm. **9, 10.** *Stellarima* group; (9) Sample 145-884B-66X-6, 25–26 cm (a, b = different focuses); (10) Sample 145-884B-66X-5, 25–26 cm.