

8. LATE EOCENE TO HOLOCENE DIATOM BIOSTRATIGRAPHY OF THE EQUATORIAL PACIFIC OCEAN, DEEP SEA DRILLING PROJECT LEG 85¹

John A. Barron, U.S. Geological Survey, Menlo Park²

ABSTRACT

Excellent reference sections for lower Oligocene through Holocene diatoms were recovered at DSDP Sites 572 to 575 in the central equatorial Pacific. Diatoms are generally common and well preserved at all sites, except in the upper Oligocene. These sections are zoned and correlated on the basis of diatoms, including the identification and correlation of 89 additional secondary datum levels in the Miocene and Pliocene. Paleomagnetic stratigraphy was obtained for the entire *Denticulopsis nicobarica* Zone (17.8 to 16.4 Ma) at Site 575, and upper lower Miocene diatom datum levels are correlated directly to paleomagnetic stratigraphy for the first time.

Quantitative diatom studies of upper lower Miocene to uppermost Miocene (18.0 to 6.2 Ma) of Sites 572, 574, and 575 are supplemented by quantitative diatom studies at Sites 77 and 158 to form transects across the central and eastern equatorial Pacific. Where the sampling interval is 100,000 yr. or less, quantitative trends in *Cestodiscus pulchellus*, *Coscinodiscus radiatus*, *Denticulopsis hustedtii*, *D. nicobarica*, and *Thalassiothrix longissima* are readily correlatable, thereby greatly enhancing biostratigraphic resolution. Comparison of species abundance reveals minor differences between the eastern and central equatorial Pacific. *Thalassionema nitzschiooides*, *D. hustedtii*, and *D. nicobarica* show preferences for the eastern equatorial Pacific, whereas *C. pulchellus*, *Actinocyclus ellipticus*, *Coscinodiscus tuberculatus*, and *Nitzschia* spp. seem to prefer the central equatorial Pacific.

Five new diatom taxa are proposed: *Actinocyclus ellipticus* var. *spiralis* Barron, n. var., *Coscinodiscus lewisanus* var. *rhomboides* Barron, n. var., *C. loeblichii* Barron, n. sp., *C. yabei* var. *ellipticus* Barron, n. var., and *Thalassiosira tappanae* Barron, n. sp.

INTRODUCTION

The central equatorial Pacific has been a key area for biostratigraphic and paleoceanographic studies since the inception of the Deep Sea Drilling Project. Drilling has been carried out on four previous DSDP legs in the region (Legs 5, 8, 9, and 16), and nearly all major studies of Oligocene to Quaternary tropical microfossils and isotopes in the Pacific have utilized cores collected from the area. The section at DSDP Site 77 alone has figured in more such studies than any other Pacific DSDP section. The main purpose of Leg 85 was to revisit the central equatorial Pacific with the hydraulic piston corer (HPC) to recover a series of upper Eocene through Quaternary reference sections that are relatively free of the drilling disturbance associated with rotary coring. The HPC allows coring in the upper 100 to 300 m of sediment, making possible the collection of relatively undisturbed material having high sediment accumulation rates (15 m/m.y.), which is crucial to high-resolution stratigraphic and paleoceanographic studies. The five Leg 85 sites selected by the JOIDES Ocean Paleoenvironment Panel form transects from the eastern equatorial Pacific (Sites 571 and 572) to the central equatorial Pacific (Sites 573 to 575) and from south to north across equatorial high-productivity zones of the Oligocene to Holocene (Sites 573 to 575) (Fig. 1).

Diatoms are present throughout all five sections cored on Leg 85 (Sites 571 to 575). Only one core of the uppermost Quaternary *Pseudoeunotia doliolus* Zone was re-

covered at Site 571, but drilling at Sites 572 to 575 produced numerous cores with uppermost Eocene to Quaternary diatoms. Coring at Sites 572 and 575 terminated in the lower middle Miocene (about 15 Ma) and lower Miocene (about 22 Ma), respectively. Uppermost Eocene to Quaternary sections were cored at both Site 573 and Site 574. Diatom preservation was poor in the upper Oligocene, and most of the lower Miocene of Site 573 is barren of diatoms; otherwise, diatom preservation was typically good to excellent.

Previous studies of Oligocene to Quaternary diatom biostratigraphy in the area have been numerous. R. Kolbe (1954) pioneered diatom biostratigraphic work in the tropics with his study of piston cores collected by the Swedish Deep Sea Expedition. V. V. Mukhina and A. P. Jousé have led Russian diatomists in a major effort to document late Cenozoic equatorial diatom assemblages (Mukhina, 1963, 1965, 1966, 1969; Jousé, 1968, 1973, 1977). L. H. Burckle calibrated numerous late early Miocene to Quaternary diatom datum levels directly to paleomagnetic stratigraphy in piston cores collected from the area (Burckle, 1972, 1977, 1978; Burckle and Opdyke, 1977; Burckle and Trainer, 1979; Burckle et al., 1982; Opdyke et al., 1974). Deep Sea Drilling Project studies have included those of Milow (in Hays et al., 1972, Leg 9), Bukry (1973, Leg 17), Gombos (1975, DSDP Site 66), Barron (1981a, 1983), Barron and Burckle (in Keller et al., 1982, DSDP Site 77), and Harwood (1982, Oligocene to lower Miocene of DSDP Sites 65 and 77). Other studies within the easternmost equatorial Pacific have also been helpful in refining late Cenozoic diatom biostratigraphy in the area: Bukry and Foster (1973, Leg 16), Barron (1980a, Leg 54), Harper et al. (1982, Leg 67), and Sancetta (1982, 1983, Legs 68 and 69).

¹ Mayer, L., Theyer, F., et al., *Init. Repts. DSDP*, 85: Washington (U.S. Govt. Printing Office).

² Address: U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025.

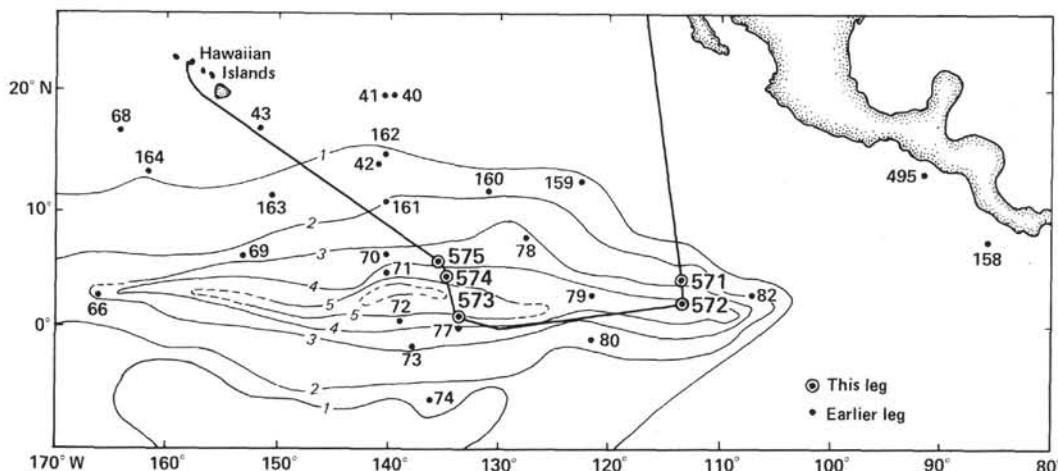


Figure 1. Locations of Leg 85 sites and other DSDP sites studied in the central and eastern equatorial Pacific. Contours represent two-way traveltimes in tenths of seconds.

Leg 85 offers the opportunity to apply the knowledge gained from these and other studies of the low-latitude Atlantic Ocean (Fenner, in press) and Indian Ocean (Schrader, 1974) to develop an updated and refined late Cenozoic diatom biostratigraphy for the central equatorial Pacific. In addition, graphic correlation techniques and quantitative diatom biostratigraphy (Barron and Keller, 1983) might also be applied to refine late Cenozoic time to 100,000 yrs. or less, so that the gap between conventional biostratigraphy and high-resolution isotope and CaCO_3 stratigraphy could be bridged. Such high-resolution biostratigraphy is necessary for integrated paleoceanographic and paleoclimatic studies, and for understanding the nature and mechanisms of oceanic and climatic change.

METHODS

Typically, two to three samples per 9.5-m core were selected for study; in selected intervals, one sample per 1.5-m section was examined. Samples (3 to 5 cm^3) were treated with 10% hydrochloric acid to remove the calcium carbonate. Core-catcher samples, which were processed on ship, were then cleansed of acid by centrifuging at 2000 rpm for 2 min., decanting off the liquid, washing in distilled water, and repeating that cycle four or more times. Care was taken in selecting core-catcher samples from a single lithology in order to minimize possible contamination. Samples processed on shore were cleansed by washing in distilled water in a 250-ml beaker, settling for 2 hrs., and decanting the liquid away. Generally, four such cycles were necessary to remove the acid. Strown slides were prepared by sampling the suspended sample with a pipette, spreading it on a 22 mm \times 30 mm cover glass, drying on a hot plate, and mounting in Hyrax.

The entire microscope slide was scanned at 500 \times to check for the presence of biostratigraphic marker species. These marker species were selected from Burckle (1978), Fenner (in press), and the author's own studies (Barron, 1980a, b; 1981a, b; 1983; in press). Identifications of species were checked routinely at 1250 \times .

Quantitative studies were done at 1250 \times , using random traverses across the slide and counting the first 300 diatoms encountered. The counting techniques of Schrader and Gersonde (1978) were used, and resting spores were not counted.

The paleomagnetic time scale of Berggren et al. (in press) has been adopted for Leg 85 studies, and absolute ages obtained by first- and second-order calibrations to paleomagnetics reflect that time scale. The time scale adopted for Leg 85 utilizes Berggren et al.'s (in press) age estimates for the paleomagnetic anomalies, but it is based on the traditional Anomaly 5-Chron 9 correlation (Barron et al., this volume).

ZONATION

The diatom zonation used here (Table 1) is that proposed by Barron (in press) for the Miocene through Quaternary of the equatorial Pacific, and a modification of that of Fenner (in press) for the Oligocene. Barron's (in press) zonation consists of Burckle's (1972) upper Miocene through Quaternary zonation, Barron's (1983) lower

Table 1. Diatom zonation with defining marker taxa used for Leg 85 studies.

Zone	Subzone	Marker ^a
<i>P. doliolus</i>		
<i>Nitzschia reinholdii</i>	B	T. <i>Nitzschia reinholdii</i>
	A	T. <i>Rhizosolenia paebergonii</i> var. <i>robusta</i>
	C	B. <i>Pseudoeunota doliolus</i>
<i>Rhizosolenia paebergonii</i>	B	T. <i>Thalassiosira convexa</i>
	A	T. <i>Nitzschia jouseae</i>
<i>Nitzschia jouseae</i>	C	B. <i>Rhizosolenia paebergonii</i>
	B	B. <i>Nitzschia jouseae</i>
<i>Thalassiosira convexa</i>	A	T. <i>Thalassiosira miocenica</i>
	B	T. <i>Thalassiosira praecanvexa</i>
<i>Nitzschia miocenica</i>	B	B. <i>Thalassiosira convexa</i>
	A	B. <i>Thalassiosira praecanvexa</i>
<i>Nitzschia porteri</i>	B	B. <i>Nitzschia miocenica</i>
	A	T. <i>Thalassiosira burckliana</i>
<i>Coscinodiscus yabei</i>	B	T. <i>Coscinodiscus yabei</i> (<i>plicatus</i>)
	A	B. <i>Thalassiosira burckliana</i>
<i>Actinocyclus moronensis</i>		T. <i>Actinocyclus moronensis</i>
<i>Craspedodiscus coscinodiscus</i>		T. <i>Craspedodiscus coscinodiscus</i>
<i>Coscinodiscus gigas</i> var. <i>diorama</i>		B. <i>Coscinodiscus temporei</i> var. <i>delicata</i>
<i>Coscinodiscus lewisi</i>		T. <i>Coscinodiscus lewisi</i>
<i>Cestodiscus peplum</i>	B	T. <i>Cestodiscus peplum</i>
	A	T. <i>Annellus californicus</i>
<i>Denticulopsis nicobarica</i>	B	B. <i>Cestodiscus peplum</i>
	A	T. <i>Thalassiosira bukryi</i>
<i>Triceratium pileus</i>		B. <i>Denticulopsis nicobarica</i>
<i>Craspedodiscus elegans</i>	C	T. <i>Craspedodiscus elegans</i>
	B	T. <i>Bogorovia veniamini</i>
<i>Rossiella paleacea</i>	A	T. <i>Coscinodiscus oligocenicus</i>
	B	T. <i>Thalassiosira primalabiata</i>
<i>Roccella gelida</i>		B. <i>Rossiella paleacea</i>
<i>Bogorovia veniamini</i>		B. <i>Roccella gelida</i>
<i>Roccella vigilans</i>	B	B. <i>Bogorovia veniamini</i>
	A	T. <i>Cestodiscus mukhiae</i>
<i>Coscinodiscus excavatus</i>		T. <i>Coscinodiscus excavatus</i>
		B. <i>Coscinodiscus excavatus</i>

^a B. = first occurrence (bottom); T. = last occurrence (top).

Miocene zonation, and new middle Miocene zones to bridge the gap between the two zonations.

Assignment of Leg 85 samples to this zonation is summarized on Table 2. All zonal and subzonal assignments were made using primary marker taxa. The zones themselves, their subzones and contained datum levels, and their correlation with other planktonic microfossil zones and with diatom zones are discussed thoroughly in the following section. Correlation of the various diatom zonations is shown on Figures 2 and 3. Table 3 shows the stratigraphic positions of 89 secondary upper Cenozoic diatom datum levels that occur in two or more of the Leg 85 sections. Absolute ages have been obtained for these datum levels both by direct correlation with paleomagnetic stratigraphy and by extrapolation between the paleomagnetically calibrated datum levels in age-versus-depth plots for the four main Leg 85 sections. These methods will be discussed more thoroughly in a later section of this chapter.

Upper Eocene?

Sections 1 and 2 of Core 574C-34 contain *Cestodiscus robustus* Jousé, *C. mukhinae* Jousé, *C. pulchellus* sensu Jousé (1973), *Coscinodiscus decrescens* Grunow, *C. oligocenicus* Jousé, *Melosira architecturalis* Brun, and *Hemiaulus polycystinorum* Ehrenberg; but the sections lack *Coscinodiscus excavatus* Greville. According to the argument that follows, these sections are tentatively assigned to the upper Eocene, an assignment supported by data on calcareous nannofossils and benthic foraminifers. Study of planktonic foraminifers indicates assignment of these sections to the lower Oligocene (P18) (see site chapter).

Coscinodiscus excavatus Zone

Category: Taxon-range zone

Author: Fenner (1984), modified here.

Definition: Interval of the total range of *Coscinodiscus excavatus*.

Age: Early Oligocene, about 36.5 to 33 Ma (extrapolated, Barron et al., this volume).

Remarks: Jousé (1973) and Fenner (1977) recognized the stratigraphic utility of *C. excavatus* in the tropical Pacific and subtropical South Atlantic respectively. This zonal definition is in contrast to that of Fenner (1984), who proposed the *C. excavatus* Zone as the interval between the first occurrence of *C. excavatus* and the first occurrence of *Cestodiscus reticulatus* Fenner, at DSDP Site 366 in the tropical Atlantic. She proposed the *Cestodiscus reticulatus* Zone for the overlying interval containing the total range of *C. reticulatus*, noting that the last occurrence of *Coscinodiscus excavatus* was near the top of that zone at DSDP Site 369. *C. excavatus* is a large, easily recognizable diatom, whereas *Cestodiscus reticulatus* can be easily confused with *Cestodiscus robustus* Jousé. For purposes of this preliminary report, these two *Cestodiscus* species were not separated, so the *Coscinodiscus excavatus* Range Zone has been utilized here without recognition of Fenner's (1984) *C. reticulatus* Zone.

Characteristic flora: *Cestodiscus robustus* (including *C. reticulatus*) is the most common constituent of the *C. excavatus* Zone floras; *Coscinodiscus excavatus*, *C. oligocenicus*, and *C. sp. cf. C. marginatus* Ehrenberg are the next most common species. Other characteristic species include *Cestodiscus mukhinae* and *C. pulchellus* sensu Jousé (1973). *Melosira architecturalis* Brun, *Coscinodiscus spiralis* Hajos, and *Hemiaulus polycystinorum* var. *mesolepta* Grunow are sporadic, being more characteristic of the lower part of the zone.

Correlation: Fenner (1984) places the first occurrence of *Coscinodiscus excavatus* within the upper part of the Eocene DSDP Core 366-10. This placement lies just above the CP16/CP15 calcareous nannofossil zonal boundary of Bukry (1978a) and just below the P17/P18 boundary of G. Keller (pers. comm., 1983) at Site 366. As such, this diatom datum very nearly coincides with the Eocene/Oligocene boundary of Berggren et al. (in press), which is the boundary used in the Leg 85 time scale. At Sites 573 and 574, the base of the *C. excavatus* Zone lies at or just above the CP16/CP15 zonal boundary, so it appears that the first occurrence of *C. excavatus* is isochronous between the tropical Atlantic and tropical Pacific.

At Site 369, Fenner (in press) places the last occurrence of *C. excavatus*, which defines the top of the *C. excavatus* Zone, near the base of CP17, within the *Globigerina ampliaperta* Zone (= P19-P20), and near the top of the *Thrysocyrtis tuberosa* Zone of radiolarians. In Leg 85 material, the last *C. excavatus* in Samples 573B-34,CC and 574C-27,CC is correlative with the top of the *T. tuberosa* Zone but is slightly above the top of CP17. *C. excavatus* is sparse near its last occurrence, and its last occurrence in Leg 85 material was determined with sieved slides. Admittedly, such a procedure is not preferable for diatom biostratigraphy, and other biostratigraphic criteria, such as Fenner's (in press) last occurrence of *Cestodiscus reticulatus*, may, with further study, be a better zonal marker to use within this interval of the Oligocene.

Correlation with other diatom zones: As stated in the foregoing, the *C. excavatus* Zone is equivalent to the *C. excavatus* and the *Cestodiscus reticulatus* zones of Fenner (1984). It is also correlative with Jousé's (1973) *Cestodiscus pulchellus* Zone and at least part of her *C. mukhinae* Zone, and with the uppermost *Rylandsia inequiradiata* to lower *Rhizosolenia gravida* Zone of Gombos and Ciesielski (1983) (Fig. 2).

Rouxia hannaee Jousé is restricted to Subzone b of the *Cestodiscus reticulatus* Zone of Fenner (in press) and to the lower *R. gravida* Zone of Gombos and Ciesielski (1983). Although *R. hannaee* was not observed in Leg 85 sediments, Fenner's (in press) correlation of its range with upper planktonic foraminiferal Zone P20 has been used to suggest correlation with the upper *C. excavatus* Zone of this chapter.

Rocella vigilans Zone

Category: Interval zone.

Author: Fenner (1984), modified here.

Table 2. Assignment of Leg 85 samples to the diatom zonation.

Diatom zone and subzone	Age of boundary (Ma) ^a	Holes 572A, 572B	Holes 572C, 572D	Hole 573	Holes 573A, 573B
<i>P. doliolus</i>		0/572A-2-3 (0/13.2)	0/572C-1,CC (0-9.5)	0/573-2,CC (0/11.5)	
<i>N. reinholdii</i>	0.65*	572A-2-4/572A-3-5 (14.7/25.7)	572C-2,CC (19.7)	573-3-1/573-3,CC (12.8/20.8)	573A-1CC/573A-2,CC (14.0/22.0)
	1.55*	572A-3-6/572A-4-3 (27.2/32.3)	572C-3,CC (29.3)	573-4-3 (25.3)	
	1.8*	572A-4-4 (33.8)		573-4,CC/573-5-2 (30.5/33.1)	573A-3,CC (31.3)
<i>R. praebengonii</i>	2.1*	572A-4-5/572A-5-3 (35.3/40.0)	572C-4,CC (38.8)	573-5-4 (36.1)	
	2.6*	572A-5-4/572A-6-2 (41.5/(48.1))	572C-5,CC (48.4)	573-5-6/573-6-3 (38.9/43.4)	573A-4,CC (39.7)
	3.0*	572A-6-3/572A-11-3 (49.6/95.1)	572C-6,CC/572C-9,CC (58.1/86.6)	573-6-5/573-9-5 (46.4/73.4)	573A-5,CC/573A-6,CC (49.2/57.6)
<i>N. jouseae</i>	4.5*	572A-11,CC/572A-14-3 (100.6/122.8)	572C-10,CC/572C-13,CC (96.5/111.5)	573-9,CC (76.2)	
	5.1*	572A-14,CC/572A-16,CC (128.2/145.2)	572C-14,CC/572C-16,CC (119.3/140.0)	573-10-1/573-12-1 (76.9/95.9)	
	5.8*	572A-17,CC/572B-3,CC (154.1/168.7)	572C-17,CC/572D-3-4 (146.0/175.2)	573-12-3/573-13-5 (98.9/110.7)	
<i>N. miocenica</i>	6.1*	572B-4,CC (172.1)	572D-3,CC/572D-5-2 (179.7/191.2)	573-13,CC (112.6)	
	6.3*		572D-5,CC/572D-6,CC (198.7/208.1)	573-14-2/573-15-5 (114.6/128.5)	
	7.3*		572D-7-1/572D-7,CC (208.5/217.6)	573-15,CC/573-16-2 (131.3/133.4)	
<i>N. porteri</i>	8.0*		572D-8-2/572D-8,CC (219.5/227.2)	573-16-5/573-16,CC (137.9/140.1)	
	8.6*		572D-9-1/572D-11,CC (227.5/255.7)	573-17-2/573-18,CC (142.2/152.9)	573B-1,CC/573B-3-1 (147.0/158.2)
	10.5		572D-12-2/572D-14-2 (257.5/276.5)	573-19-1/573-19,CC (153.5/159.1)	573B-3-1/573B-3,CC (158.3/167.2)
<i>C. yabei</i>	11.3*		572D-14-4/572D-18-3 (279.5/316.0)	573-15-2/573-18,CC (142.2/152.9)	573B-4-3/573B-5,CC (170.7/185.9)
	12.2*		572D-18,CC/572D-21,CC (321.1/348.5)		573B-6-1/573B-6,CC (186.7/195.6)
	12.8*		572D-22-1/572D-25-3 (350.5/382.5)		573B-7-3/573B-7,CC (199.2/203.4)
<i>C. gigas</i> var. <i>diorama</i>	13.5		572D-25,CC/572D-29-2 (388.7/419.0)		573B-8-4/573B-9-6 (210.2/222.7)
	14.2*		572D-29,CC/572D-33,CC (424.0/464.7)		573B-9,CC/573B-10,CC (224.1/232.8)
	15.0*				573B-11,CC/573B-12,CC (242.9/250.2)
<i>C. peplum</i>	16.3*				573B-13-2/573B-14-3 (254.7/265.7)
	17.0*				573B-14-4 (267.2)
	17.8*				573B-14-5 (268.7)
<i>T. pileus</i>	18.7*				
	19.9				
	20.6				
<i>R. paleacea</i>	21.7				
	22.7				
<i>R. gelida</i>	24.5			573B-19,CC (312.7)	
<i>B. veniamini</i>	26.5			573B-20,CC/573B-24,CC (328.2/362.2)	
<i>R. vigilans</i>	28.5			573B-26,CC (383.7)	
	34			573B-27,CC/573B-33,CC (392.5/450.7)	
<i>C. excavatus</i>	36.5			573B-34,CC/573B-42-1 (454.4/520.5)	

Note: Uppermost and lowermost section numbers assigned to each zone/subzone are separated by a slash. Numbers in parentheses are sub-bottom depths of these sections in meters. All zonal/subzonal assignments are based on primary markers.

^a Asterisk indicates direct paleomagnetic calibration (see text).

Table 2. (Continued).

Hole 574	Holes 574A, 574B, 574C	Holes 575, 575A	Holes 575B, 575C
0/574-1,CC (0/4.5)		575-1-1 (0.5)	
574-2-2 (7.3)		575-1-3 (3.5)	
574-2-3/574-2-4 (8.3/9.4)			
		575-1-4 (5.0)	
574-2,CC (14.1)	574A-2,CC (15.4)	575-1-5 (6.5)	575C-1,CC (6.3)
574-3-2/574-4-4 (16.8/29.3)	574A-3,CC (23.9)	575-1,CC (7.3)	575B-1,CC (12.8)
574-4,CC (33.1)	574-4,CC (33.1)		
574-5-2/574-5,CC (34.9/42.5)	574A-5,CC (42.3)	575-2-1/575-2-3 (7.8/10.8)	
574-6-2 (44.4)		575-2-4 (12.3)	
574-6-4/574-6-6 (47.4/50.4)		575-2-5 (13.8)	
574-6,CC/574-7-2 (52.0/53.9)	574A-6,CC (51.9)	575-2-6/575-3-2 (15.3/18.8)	575B-2,CC (21.5)
574-7-4/574-7,CC (56.9/60.9)		575-3-3/575-3-5 (20.3/23.3)	575B-3-4/575B-3,CC (24.2/29.7)
574-8-1 (61.4)	574A-7,CC (61.3)		
574-8-3/574-8-7 (64.4/70.1)	574A-8,CC (70.4)	575-3-6/575-3,CC (24.8/26.3)	
574-8,CC/574-9-6 (70.5/78.4)		575-4-1 (26.8)	
574-9,CC/574-11-4 (80.0/94.4)	574A-9,CC/574A-10,CC (79.9/87.2)	575-4-2/575-4-5 (28.3/32.8)	575B-4,CC (39.1)
574-11,CC/574-13-2 (98.6/110.0)	574A-11,CC/574A-12,CC (98.8/108.2)	575-4-6/575-5-4 (34.3/39.9)	575B-5,CC (48.3)
574-13-4/574-16-2 (113.0/129.5)	574A-13,CC/574A-16,CC (113.1/127.1)	575-5,CC/575-6-4 (44.6/49.4)	575B-6,CC (55.9)
574-16,CC/574-20,CC (132.6/152.5)	574A-17,CC/574A-19,CC (132.7/150.9)	575-6,CC/575-8-2 (54.0/65.4)	
574-21-2/574-24,CC (154.4/172.5)	574A-20,CC/574A-21,CC (160.2/167.4)	575-8,CC/575-9-2 (73.0/74.9)	575B-11-1/575B-11-3 (79.4/82.4)
574-25-2/574-29-2 (174.4/194.2)	574A-22,CC/574B-1,CC (178.0/194.4)	575-9,CC/575A-1-1 (74.9/94.3)	575B-11-4/575B-13-1 (83.9/96.4)
574-29,CC/574-31,CC (197.2/206.5)	574C-1,CC/574C-2,CC (202.2/213.4)	575A-1-2/575A-4-1 (95.8/105.6)	575B-13-2/575B-14-3 (97.9/98.4)
	574C-3,CC/574C-4-2 (218.8/224.9)	575A-4-2/575A-7,CC (107.1/123.3)	
	574C-4,CC/574C-5-3 (226.7/235.9)	575A-8-1/575A-12-2 (123.5/137.0)	
	574C-5,CC/574C-8-1 (238.8/261.4)	575A-12,CC/575A-20-2 (139.6/162.7)	
	574C-8-3/574C-9,CC (264.4/275.3)	575A-20,CC/575A-24-2 (164.7/176.1)	
	574C-10-2/574C-12,CC (281.9/308.4)	575A-24,CC/575A-30-2 (179.2/196.0)	
	574C-13-2/574C-15,CC (310.4/336.8)	575A-30,CC/575A-33,CC (197.9/208.3)	
	574C-16-1/574C-17,CC (337.4/354.0)		
	574C-18-1/574C-19,CC (356.4/368.2)		
	574C-20,CC/574C-21,CC (384.2/390.6)		
	574C-22,CC/574C-26,CC (398.9/435.9)		
	574C-27,CC/574C-33,CC (446.9/506.0)		
	574C-34-1/574C-34-2		

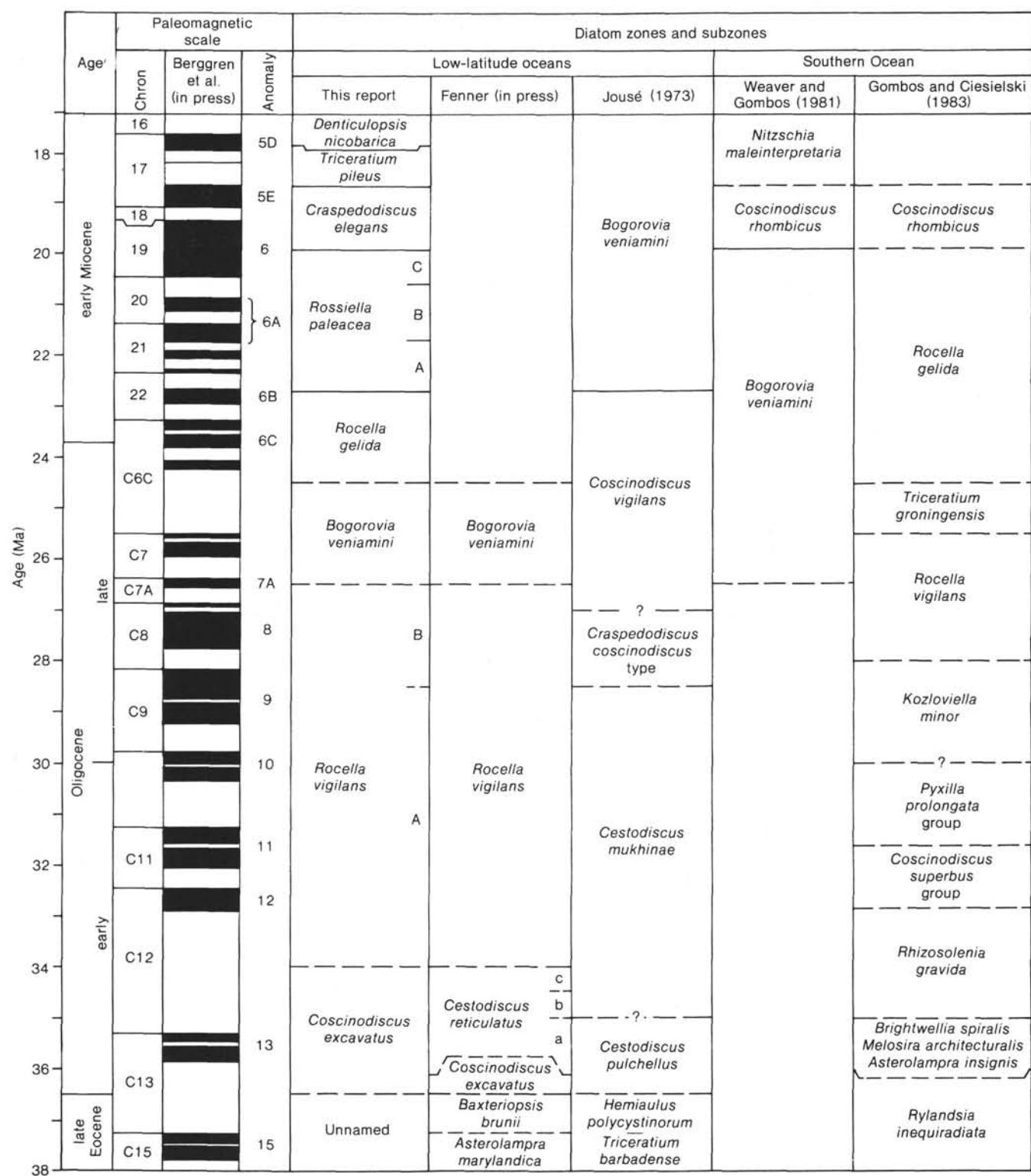


Figure 2. Correlation of the low-latitude diatom zonation of this report (Barron, 1983 and this report; Fenner, 1984) with the low-latitude diatom zonations of Fenner (in press) and Jousé (1973) and the Southern Ocean diatom zonations of Weaver and Gombos (1981) and Gombos and Ciesielski (1983) for the latest Eocene to middle early Miocene. Correlations are after Barron (1983) and this report.

Definition: Interval between the last occurrence of *Coscinodiscus excavatus* and the first occurrence of *Bogorovia veniamini*.

Subzones: Two subzones are proposed: Subzone A, from the base of the zone to the last occurrence of *Cestodiscus*

mukhinae, and Subzone B, from the top of Subzone A to the top of the zone.

Age: Early to late Oligocene, about 33 to about 26.5 Ma.
Subzone A/Subzone B boundary: about 28.5 Ma.
 (Ages extrapolated, Barron et al., this volume.)

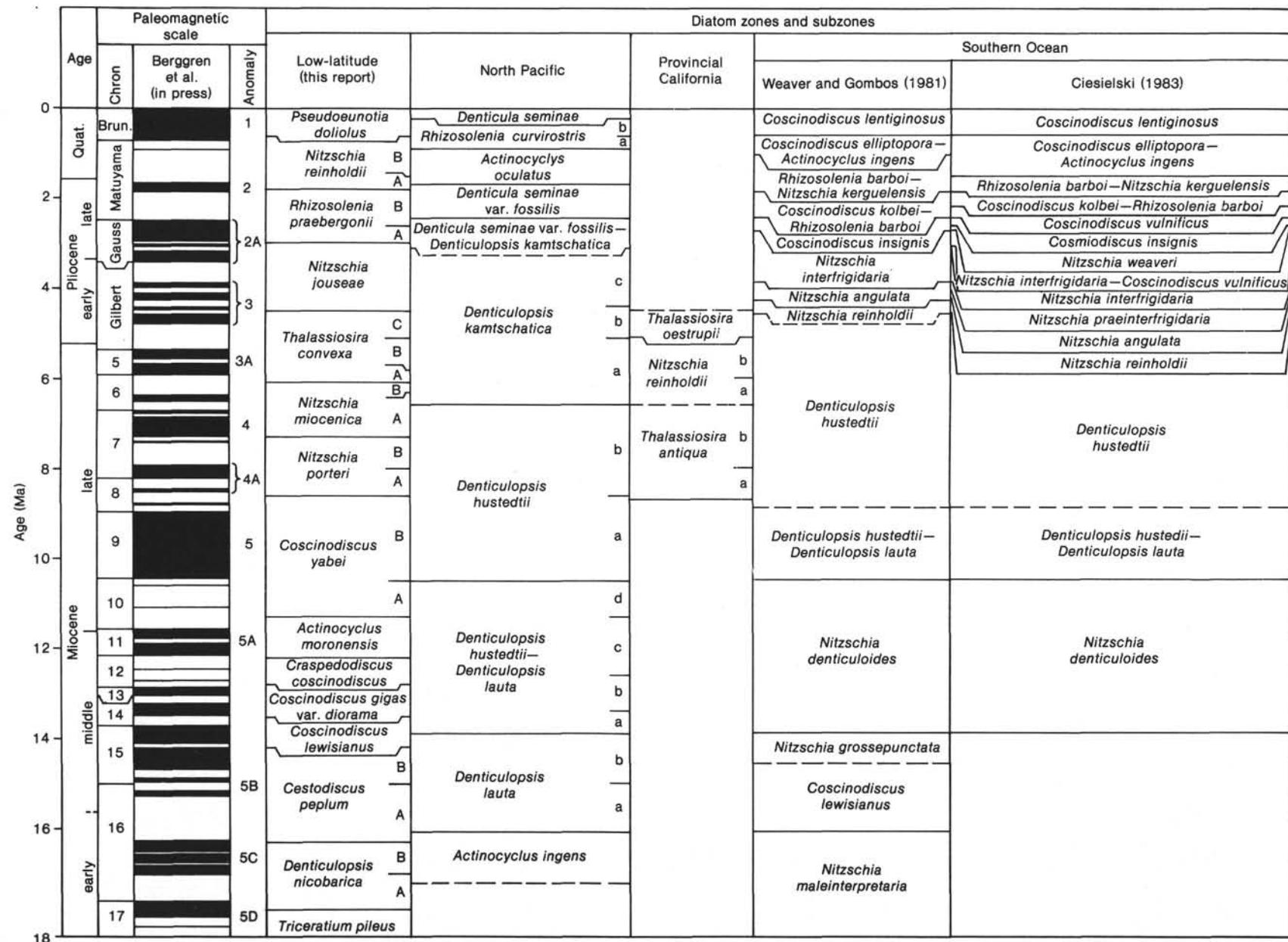


Figure 3. Correlation of the low-latitude diatom zonation of this report (Burckle, 1972; Barron, in press and 1983) with the North Pacific diatom zonation (Koizumi, 1973; Barron, 1980a; Barron and Keller, 1983), the provincial California diatom zonation for the latest Miocene to earliest Pliocene (Barron, 1981a), and the Southern Ocean diatom zonations of Weaver and Gombos (1981) and Ciesielski (1983) for the latest early Miocene through the Quaternary. Correlations are after Barron (in press), Ciesielski (1983), and this report.

Table 3. Correlation of secondary late Cenozoic diatom datum levels between Sites 572, 573, 574, and 575. Samples (Hole-Core-Section, level in cm) that constrain each datum level are separated by a slash.

Datum	Age (Ma) ^a	Site 572	Site 573	Site 574	Site 575
T. <i>Rhizosolenia matuyamai</i>	0.93 (1)	572A-2-5/572A-2-6			
B. <i>Rhizosolenia matuyamai</i>	1.0 (1)	572A-2-6/572A-2,CC			
T. <i>Rhizosolenia praebergonii</i>	1.82 (2)	572A-4-3/572A-4,CC	573-4-3/573-4,CC	574-1,CC/574-2,CC	575-1-3/575-1-4
T. <i>Actinocyclus ellipticus</i> f. <i>lanceolata</i>	3.5-3-2	572A-7-1/572A-7-2	573-6-5/573-6,CC	574-3-2/574-3-4	575-1,CC/575-2-1
B. <i>Thalassiosira convexa</i> var. <i>convexa</i>	3.6 (2)	572A-7-2/572A-7-3	573-7-1/573-7-3	574-3-4/574-3,CC	575-1,CC/575-2-1
A. <i>Asteromphalus elegans</i>	3.9 (3)	572A-7-5/572A-7-6	573-8-1/573-8-5	574-3,CC/574-4-4	575-1,CC/575-2-1
T. <i>Nitzschia cylindrica</i>	4.3 (3)	572A-9,CC/572A-10-3	573-8-5/573-8,CC	574-4-4/574-4,CC	575-1,CC/575-2-1
B. <i>Thalassiosira oestrupii</i>	5.1 (3)	572A-13,CC/572A-14,CC	573-9,CC/573-10-1	574-4,CC/574-5-2	575-1,CC/575-2-1
T. <i>Asterolampra acutiloba</i>	5.35 (3)	572A-14,CC/572A-15-3	573-10-1/573-10,CC	574-5-5/574-5,CC	575-2-3/575-2-4
T. <i>Nitzschia miocenica</i>	5.55 (3)	572A-15,CC/572A-16-3	573-11-5/573-11,CC	574-5-5/574-5,CC	575-2-3/575-2-4
T. <i>Nitzschia miocenica</i> var. <i>elongata</i>	5.65 (4)	572A-16-3/572A-16,CC	573-11,CC/573-12-1	574-5,CC/574-6-2	575-2-3/575-2-4
T. <i>Rossiella praepaleacea</i>	6.0 (4)	572D-2,CC/572D-3,CC	573-12,CC/573-13-2	574-6-2/574-6-4	575-2-5/575-2-6
B. <i>Thalassiosira miocenica</i>	6.1 (3)	572D-3-4/572D-3,CC	573-13-5/573-13,CC	574-6-2/574-6-4	575-2-4/575-2-5
T. <i>Nitzschia porteri</i>	6.8	572D-5,CC/572D-6-1	573-14,CC/573-15-4	574-6,CC/574-7-2	575-3-2/575-3-3
T. <i>Rossiella paleacea</i>	7.4 (3)	572D-6,CC/572D-7-1	573-15-5/573-15,CC	574-7-2/574-7-4	575-3-2/575-3-3
B. <i>Coscinodiscus nodulifer</i> var. <i>cyclopus</i>	7.9	572D-7-5/572D-7,CC	573-16-2/573-16-5	574-7-2/574-7-4	575-3-3/575-3-4
B. <i>Nitzschia reinholdii</i> s. ampl.	8.0	572D-7,CC/572D-8-2	573-16-2/573-16-5	574-7-4/574-7-6	575-3-4/575-3-5
T. <i>Actinocyclus ellipticus</i> var. <i>javanicus</i>	8.0	572D-7,CC/572D-8-2	573-16-2/573-16-5	574-7-4/574-7-6	575-3-4/575-3-5
B. <i>Nitzschia marina</i>	8.2-8.1	572D-8-2/572D-8-4	573-16-5/573-16,CC	574-7,CC/574-8-1	575-3-5/575-3-6
B. <i>Nitzschia cylindrica</i> s. ampl.	8.7-8.8	572D-9-1/572D-9-3	573-17-2/573-17-5	574-7,CC/574-8-1	575-3,CC/575-4-1
B. <i>Coscinodiscus nodulifer</i> var. <i>cyclopus</i>	8.9-8.8	572D-9-3/572D-9,CC	573-17-2/573-17-5	574-8-3/574-8-5	575-3-6/575-3,CC
T. <i>Coscinodiscus yabei</i> var. <i>ellipticus</i>	9.5-9.4	572D-10-2/572D-10-4	573-17,CC/573-18-3	574-8-3/574-8-5	
T. <i>Coscinodiscus loeblichii</i>	9.5-9.4	572D-10-2/572D-10-4	573-17,CC/573-18-3	574-8-3/574-8-5	575-3,CC/575-4-1
T. <i>Coscinodiscus temperei</i> var. <i>delicata</i>	9.7	572D-10-6/572D-10,CC	573-18-3/573-18,CC	574-8-3/574-8-5	575-3-6/575-3,CC
B. <i>Nitzschia fossilis</i>	9.8	572D-10,CC/572D-11-1 and 573B-3-1, 71/573B-3-1, 81	573-18-3/573-18,CC and 573B-3-1, 71/573B-3-1, 81	574-8-7/574-8,CC	575-3,CC/575-4-1
B. <i>Coscinodiscus yabei</i> var. <i>ellipticus</i>	9.8	572D-10,CC/572D-11-1 and 573B-3-1, 71/573B-3-1, 81	573-18-3/573-18,CC and 573B-3-1, 71/573B-3-1, 81	574-8-7/574-8,CC	575-3,CC/575-4-1
B. <i>Coscinodiscus loeblichii</i>	10.5-10.4	572D-11,CC/572D-12-2	573B-3-1, 71/573B-3-1, 81	574-8-7/574-8,CC	575-3,CC/575-4-1
T. <i>Denticulopsis hustedtii</i>	11.2-10.5	572D-11,CC/572D-12-2	573B-3-3,CC/573B-4-3	574-8-5/574-8-7	575-3,CC/575-4-1
T. <i>Coscinodiscus vetustissimum</i> v. <i>javanica</i>	10.7 (3)	572D-12-2/572D-12-4	573B-3-2/573B-3-4	574-8,CC/574-9-1	575-3,CC/575-4-1
B. <i>Coscinodiscus vetustissimum</i> v. <i>javanica</i>	11.2 (3)	572D-13-2/572D-13-4	573B-3,CC/573B-4-3	574-9-4/574-9,CC	575-4-1/575-4-2
B. <i>Actinocyclus ellipticus</i> f. <i>lanceolata</i>	11.4	572D-14-2/572D-14-4	573B-3,CC/573B-4-3	574-10-1/574-10-2	575-4-2/575-4-4
T. <i>Coscinodiscus tuberculatus</i>	12.0 (5)	572D-17,CC/572D-18-1	573B-4,CC/573B-5-1	574-10,CC/574-11-1	575-4-2/575-4-4
T. <i>Denticulopsis punctata</i> f. <i>hustedtii</i>	12.1 (5)	572D-17,CC/572D-18-1	573B-4,CC/573B-5-1	574-11-1/574-11-2	575-4-2/575-4-4
T. <i>Synedra jouseana</i>	12.3-12.1	572D-17,CC/572D-18-1	573B-5,CC/573B-6-1	574-11-1/574-11-2	575-4-6/575-4,CC
B. <i>Rossiella paleacea</i> var. <i>elongata</i>	12.3-12.2	572D-18-3/572D-18,CC	573B-5,CC/573B-6-1	574-11-2/574-11-4	575-4-4/575-4-5
B. <i>Thalassionema robusta</i>	12.3-12.3	572D-18-3/572D-18,CC	573B-5,CC/573B-6-1	574-11-4/574-11,CC	575-4-4/575-4-5
T. <i>Coscinodiscus gigas</i> var. <i>diorama</i>	12.3	572D-19-1/572D-19-3	573B-5,CC/573B-6-1	574-11-4/574-11,CC	575-4-2/575-4-4
T. <i>Actinocyclus ellipticus</i> var. <i>spiralis</i>	12.4-12.3	572D-19,CC/572D-20-1	573B-5,CC/573B-6-1	574-11-4/574-11,CC	575-4,CC/575-5-2
B. <i>Hemidiscus cuneiformis</i>	12.5 (3)	572D-20-2/572D-20,CC	573B-5,CC/573B-6-1	574-12-2/574-12-4	575-5-2/575-5-4
B. <i>Rossiella praepaleacea</i>	12.7	572D-21-4/572D-21,CC	573B-6-5/573B-6,CC	574-12-4/574-12,CC	575-5-4/575-5,CC
T. <i>Actinocyclus ingens</i>	12.8-12.5	572D-21,CC/572D-22-1	573B-6-5/573B-6,CC	574-12-2/574-12-4	575-5-4/575-5,CC
B. <i>Nitzschia porteri</i>	13.1-12.9	572D-22-1/572D-22,CC	573B-6-5/573B-6,CC	574-14,CC/574-15-2	575-5,CC/575-6-2
T. <i>Denticulopsis nicobarica</i>	13.2	572D-23-3/572D-23,CC	573B-7,CC/573B-8-4	574-15-2/574-15,CC	575-6-2/575-6-4
T. <i>Annelus californicus</i>	13.5-13.4	572D-24-2/572D-24,CC	573B-8-4/573B-8,CC	574-15,CC/574-16-2	575-6-4/575-6,CC
T. <i>Coscinodiscus salisburyanus</i>	13.5-13.4	572D-24,CC/572D-25-3	573B-7,CC/573B-8-4	574-16-2/574-16,CC	575-6,CC/575-7-2
B. <i>Coscinodiscus gigas</i> var. <i>diorama</i>	13.6-13.5	572D-25-3/572D-25,CC	573B-7,CC/573B-8-4	574-17-2/574-17,CC	575-6,CC/575-7-2
B. <i>Cestodiscus pulchellus</i>	13.6-13.5	572D-25,CC/572D-26-3	573B-7,CC/573B-8-4	574-16-2/574-16,CC	575-6,CC/575-7-2
B. <i>Denticulopsis punctata</i> f. <i>hustedtii</i>	13.7	572D-25,CC/572D-26,CC	573B-8,CC/573B-9-4	574-16,CC/574-17-2	575-6,CC/575-7-2
B. <i>Coscinodiscus nodulifer</i>	13.8	572D-26,CC/572D-27-3	573B-8-4/573B-8,CC	574-17,CC/574-18-2	575-6,CC/575-7-2
T. <i>Thalassiosira tappanae</i>	13.8	572D-26,CC/572D-27-3	573B-8-4/573B-8,CC	574-17,CC/574-18-2	575-6,CC/575-7-2
B. <i>Coscinodiscus plicatus</i>	13.9-13.8	572D-26,CC/572D-27-3	573B-8-4/573B-8,CC	574-18,CC/574-19-2	575-7-2/575-7,CC
B. <i>Triceratium cinnamomeum</i>	13.9-13.8	572D-26,CC/572D-27-3	573B-8-4/573B-8,CC	574-19-2/574-19,CC	575-7-2/575-7,CC
T. <i>Cestodiscus pulchellus</i> var. <i>maculatus</i>	13.9	?	573B-8,CC/573B-9-4	574-19-3/574-19,CC	575-7-2/575-7,CC
B. <i>Denticulopsis hustedtii</i> (main)	13.9	572D-27,CC/572D-28-2	573B-8,CC/573B-9-4	574-19,CC/574-19-2	575-7-2/575-7,CC
B. <i>Coscinodiscus tuberculatus</i>	14.0	572D-28-2/572D-28,CC	573B-8,CC/573B-9-4	574-19,CC/574-20-2	575-7-2/575-7,CC
B. <i>Actinocyclus ellipticus</i> var. <i>spiralis</i>	14.2-14.1	572D-29-2/572D-29,CC	573B-9-4/573B-9-6	574-20-2/574-20,CC	575-8-4/575-8,CC
B. <i>Denticulopsis hustedtii</i> (isolated)	14.2	572D-29,CC/572D-30-1	?	574-20,CC/574-21-2	?
B. <i>Actinocyclus ellipticus</i>	14.4-14.3	572D-30-1/572D-30,CC	573B-9,CC/573B-10-2	574-21,CC/574-22-2	575-8,CC/575-9-2
B. <i>Coscinodiscus blysmos</i>	14.4	572D-30,CC/572D-31-2	573B-9,CC/573B-10-2	574-22-2/574-22,CC	575-8,CC/575-9-2
T. <i>Coscinodiscus praenodulifer</i>	15.5-15.4	572D-31,CC/572D-31-2	573B-11,CC/573B-12-2	574-26-2/574-26,CC	575-9,CC/575-10-2
B. <i>Actinocyclus ingens</i>	15.5	572D-31,CC/572D-31-2	573B-10,CC/573B-11,CC	574-26,CC/574-27-2	575-10-2/575-10,CC
T. <i>Nitzschia maleinterpretaria</i>	15.6	572D-31,CC/572D-12-2	573B-11,CC/573B-12-2	574-27,CC/574-28-1	575-10,CC/575-11-2
T. <i>Coscinodiscus lewisanus</i> var. <i>similis</i>	15.7	572D-31-2/573B-12-4	573B-12-2/573B-12-4	574-27,CC/574-28-1 and 573B-12-4/573B-12-5	575-10-2/575-10,CC
Occurrence <i>Denticulopsis lauta</i>	15.9-15.8		573B-12-4	574-28,CC	575-10,CC
T. <i>Denticulopsis cf. kanayae</i>	16.0		573B-12-4/573B-12,CC	574-28,CC/574-29-2	575A-1-2/575A-1-3
T. <i>Thalassiosira fraga</i>	16.3-16.1		573B-13-2/573B-13-4	574-28,CC/574-29-2	575A-1-1,CC/575A-1-1
T. <i>Synedra miocenica</i>	16.5 (6)		573B-13-2/573B-13-4	574-29-2/574-29,CC	575A-1-3/575A-1,CC
T. <i>Raphidodiscus marylandicus</i>	16.7 (6)		573B-13-4/573B-13-13,CC	574-30,CC/574-31-2	575A-2-3/575A-2-4
B. <i>Denticulopsis cf. kanayae</i>	16.9 (6)		583B-13-4/573B-13,CC	574C-2,CC/574C-3,CC	575A-2,CC/575A-3-2
B. <i>Coscinodiscus blysmos</i>	17.1 (6)		573B-14-1, 7	574C-2,CC	575A-3-2
B. <i>Annelus californicus</i>	17.3 (6)		573B-14-1, 7/573B-14-1, 68	574C-2,CC/574C-3,CC	575A-4-2/575A-4-3
B. <i>Coscinodiscus coscinodiscus</i> s.str.	17.3 (6)		573B-14-1, 7/573B-14-1, 68	574C-2,CC/574C-3,CC	575A-5-2/575A-5-3
T. <i>Coscinodiscus lewisanus</i> var. <i>robustus</i>	17.4 (6)		?	?	575A-5-3/575A-5-5,CC
B. <i>Coscinodiscus lewisanus</i> var. <i>similis</i>	17.4 (6)		573B-14-1, 68/573B-14-3	574C-2,CC/574C-3,CC	575A-5,C/575A-6-1
B. <i>Cestodiscus pulchellus</i> var. <i>maculatus</i>	17.4 (6)		573B-14-1, 68/573B-14-3	574C-2,CC/574C-3,CC	575A-5,C/575A-6-1
T. <i>Thalassiosira spumellaroides</i>	17.5 (6)		573B-14-1, 68/573B-14-3	574C-2,CC/574C-3,CC	575A-6-2/575A-6-3
T. <i>Triceratium pilae</i>	17.6 (6)		574C-2,CC/574C-3,CC	575A-6-3/575A-6,CC	
T. <i>Thalassiosira spinosa</i>	17.9 (6)		574C-4,CC/574C-5-1	575A-9-2/575A-9,CC	
T. <i>Actinocyclus radionovae</i>	18.0 (6)		574C-5-1/574C-5-3	575A-9-2/575A-9,CC	
B. <i>Nitzschia maleinterpretaria</i>	18.8		574C-5,CC/574C-6-2	575A-12,CC/575A-13-2	
B. <i>Triceratium pilae</i>	18.8		574C-5,CC/574C-6-2	575A-12,CC/575A-13-2	
T. <i>Actinocyclus hajosiae</i>	19.6		?	575A-18-2/575A-18,CC	
B. <i>Thalassiosira fraga</i>	19.9		574C-8-1/574C-8-3	575A-20-2/575A-20,CC	
B. <i>Coscinodiscus lewisanus</i> var. <i>robustus</i>	20.0		574C-8-3/574C-8,CC	575A-20-2/575A-20,CC	
T. <i>Melosira architecturalis</i>	20.9-20.6		574C-10-4/574C-10,CC	575A-24-2/575A-24,CC	
B. <i>Actinocyclus radionovae</i>	21.2		574C-10,CC/574C-11,CC	575A-26,CC/575A-27,CC	
B. <i>Actinocyclus hajosiae</i>	22.0-21.6		574C-11,CC/574C-12,CC	575A-31,CC/575A-32,CC	

^a References indicate direct paleomagnetic calibration. (1) Burckle et al. (1978); (2) Burckle and Trainer (1979); (3) Burckle (1978); (4) Burckle (pers. comm., 1978); (5) Burckle et al. (1982); (6) Hole 575A—Barron interpretation. Ages of other datum levels from extrapolation. The paleomagnetic time scale of Berggren et al. (in press) is utilized.

Remarks: The interval of the *R. vigilans* Zone is generally poorly preserved in Leg 85 sediments. At Site 574, the first occurrence of *Rocella vigilans* Fenner coincides with the base of the zone, so the zone is exactly equivalent to the *R. vigilans* Zone of Fenner (1984). Poor preservation in the basal part of the zone at Site 573, however, obscures the first occurrence of *R. vigilans* there. At both Site 573 and Site 574, the first occurrence of *Synedra jouseana* Sheshukova-Poretzkaya corresponds to a restricted occurrence of *Kozloviella edita* Jousé and *K. minor* Jousé in Samples 573B-26,CC and 574C-21,CC at the base of Subzone B. The first occurrence of *Coscinodiscus rhombicus* Castracane, which marks the base of Fenner's (in press) Subzone C of her *R. vigilans* Zone, is in Sample 574C-20,CC, immediately below the first occurrence of *Bogorovia veniamini* in Sample 574C-19,CC, or top of the *R. vigilans* Zone. Preservation at Site 573 is too poor to allow recognition of the first-occurrence datum of *C. rhombicus*.

Characteristic flora: *Rocella vigilans* is the most consistently present species throughout the *R. vigilans* Zone, as it is robust and resistant to dissolution. *Cestodiscus mukhinae* is fairly consistent within Subzone A, and *Synedra jouseana* is fairly consistent within Subzone B. *Cestodiscus robustus* is present sporadically in the lower part of the zone at Site 573, as are *Coscinodiscus oligocenicus* and *Cestodiscus pulchellus* sensu Jousé (1973).

Correlation: As already stated, the *Coscinodiscus excavatus/Rocella vigilans* zonal boundary correlates with the lowermost part of calcareous nannofossil Zone CP18 and the base of the radiolarian *Dorcadospyris ateuchus* Zone. The Subzone A/Subzone B boundary falls within Zone P21 and the *D. ateuchus* Zone, and within either CP18 or CP19 (calcareous nannofossils) (Barron et al., this volume).

The *R. vigilans/Bogorovia veniamini* zonal boundary lies within Zone P22, Zone CP19, and in the upper part of the *D. ateuchus* Zone at Sites 573 and 574; this is slightly younger than Fenner's (in press) boundary at Site 369.

Correlation with other diatom zones: If the first occurrence of *Rocella vigilans* is truly coincident with the last occurrence of *Coscinodiscus excavatus*, the *R. vigilans* Zone is equivalent to Fenner's (1984) *R. vigilans* Zone. The *R. vigilans* Zone also correlates with the upper part of the *Cestodiscus mukhinae* Zone (= Subzone A), all of the *Craspedodiscus coscinodiscus* type Zone, and the lowermost part of the *Coscinodiscus vigilans* Zone of Jousé (1973) (Fig. 2). The ranges of *Kozloviella minor* and *Synedra jouseana* suggest that Subzone B of the *R. vigilans* Zone correlates with the *Kozloviella minor* and *Rocella vigilans* zones of Gombos and Ciesielski (1983). By superposition and the correlation suggested for the *C. excavatus* Zone, Subzone A of the *R. vigilans* Zone correlates with the upper *Rhizosolenia gravida* Zone to the middle *K. minor* Zone of Gombos and Ciesielski (1983) (Fig. 2).

Bogorovia veniamini Zone

Category: Partial-range zone

Author: Fenner (1984).

Definition: Interval from the first occurrence of *Bogorovia veniamini* to the first occurrence of *Rocella gelida* (Mann) Bukry.

Age: Late Oligocene, about 26.5 to 24.0 Ma. (Ages extrapolated, Barron et al., this volume.)

Remarks: Sediments assigned to the *Bogorovia veniamini* Zone at Sites 573 and 574 contain poorly preserved diatoms.

Characteristic flora: *Rocella vigilans* s. ampl. is the most common species in the *B. veniamini* Zone at Site 574, followed by *Synedra jouseana* and *S. jouseana* f. *linearis* Sheshukova-Poretzkaya. Other characteristic diatoms include *Coscinodiscus rhombicus*, *C. oligocenicus*, *C. lewisi* var. *rhomboides* Barron, n. var., *Cestodiscus pulchellus*, and *Melosira architecturalis*.

Correlation: As stated, the *R. vigilans/B. veniamini* zonal boundary falls within planktonic foraminiferal Zone P22, calcareous nannofossil Zone CP19, and radiolarian *D. ateuchus* Zone. The *B. veniamini/Rocella gelida* zonal boundary is well represented at Site 574, where it is placed immediately below the first occurrence of *Rocella gelida* in Sample 574C-17,CC. As such, the upper boundary of the *B. veniamini* Zone occurs in the uppermost parts of Zones P22 and CP19 and within the lowermost part of the *Lychnocanoma elongata* Zone (radiolarians).

Correlation with other diatom zones: The *B. veniamini* Zone correlates with the middle part of the *Rocella vigilans* Zone of Jousé (1973), the lowermost part of the *Bogorovia veniamini* Zone of Weaver and Gombos (1981), and the upper *Rocella vigilans* Zone and the *Triceratium gronigenensis* Zone of Gombos and Ciesielski (1983) (Fig. 2).

Rocella gelida Zone

Category: Partial-range zone.

Author: Barron (1983).

Definition: Interval from the first occurrence of *Rocella gelida* to the first occurrence of *Rossiella paleacea* (Grunow) Desikachary and Maheshwari.

Secondary markers: The last occurrence of *Rocella gelida* is a secondary marker for the top of the zone (Barron, 1983).

Age: Latest Oligocene to earliest Miocene, 24.0 to 22.7 Ma. (Ages extrapolated, Barron et al., in press and this volume.)

Remarks: Site 574 provides a seemingly complete section of the *R. gelida* Zone, in that it contains an interval below the first occurrence of *R. gelida* var. *schraderi* (Bukry) Barron (Sample 574-16,CC) and above the first occurrence of *R. gelida* s. ampl. (Sample 574C-17,CC). At Site 71, this interval is removed at a hiatus (hiatus PH of Keller and Barron, 1983) (Barron, 1983). *Rocella vigilans* last occurs within the upper part of the *R. gelida* Zone.

Characteristic flora: *Rocella gelida*, *Coscinodiscus oligocenicus*, and *Synedra jouseana* are the dominant diatoms of the *R. gelida* Zone. Other characteristic diatoms include *Coscinodiscus lewisiensis* var. *rhomboides*, *C. rhombicus*, *Craspedodiscus coscinodiscus* sensu Jousé (1977) (coarse, indented form), *Bogorovia veniamini*, and *Actinodiscus barbadensis* sensu Jousé (1977).

Correlation: At Site 574, the base of the *R. gelida* Zone lies in the uppermost parts of planktonic foraminiferal Zone P22 and calcareous nannofossil Zone CP19, and within the lowermost part of the *L. elongata* Zone of radiolarians. The top of the *R. gelida* Zone falls within lower planktonic foraminiferal Zone N4 and the upper part of the *L. elongata* Zone, and it approximates the Subzone CN1a/Subzone CN1b boundary, a correlation consistent with the results of Barron (1983).

Correlation with other diatom zones: The *R. gelida* Zone correlates with the upper part of the *Coscinodiscus vigilans* Zone of Jousé (1973), the middle part of the *Bogorovia veniamini* Zone of Weaver and Gombos (1981), and the lower part of the *R. gelida* Zone of Gombos and Ciesielski (1983) (Fig. 2).

Rossiella paleacea Zone

Category: Concurrent-range zone.

Author: Barron (1983).

Definition: Interval from the first occurrence of *Rossiella paleacea* to the last occurrence of *Bogorovia veniamini*.

Subzones: The last occurrence of *Thalassiosira primalabiata* Gombos defines the Subzone A/Subzone B boundary. The last occurrence of *Coscinodiscus oligocenicus* marks the Subzone B/Subzone C boundary.

Secondary markers: At Site 574, the last occurrence of *Rocella gelida* coincides with the base of the *R. paleacea* Zone, a relationship observed by Barron (1983) at Site 71. As indicated by Barron (1983), the first occurrences of *Thalassiosira fraga* Schrader and *Coscinodiscus lewisiensis* var. *robustus* Barron at Sites 574 and 575 closely approximate the top of the *R. paleacea* Zone (Tables 2 and 3); however, the last occurrence of *Actinocyclus hajosiae* Barron at Site 575 lies substantially above the top of the zone (Table 3).

Age: Early Miocene, 22.7 to 19.6 Ma. Subzone A/Subzone B boundary, 21.7 Ma; Subzone B/Subzone C boundary, 20.2 Ma. (Extrapolated ages, Barron et al., in press and this volume.)

Remarks: Sites 574 and 575 have good sequences of the *R. paleacea* Zone, although drilling at Site 575 was terminated in the upper part of Subzone A. Within Subzone A are the last occurrence of *Coscinodiscus lewisiensis* var. *rhomboides* (Sample 574C-15,CC), near its base, and the first occurrences of *Coscinodiscus praenodulifer* Barron (Sample 574C-14,CC) and *Thalassiosira spumellaroides* Schrader (Sample 574C-13,CC). *Raphidodiscus marylandicus* and *Craspedodiscus elegans* Ehrenberg are too sparse and sporadic

at Site 574 to determine whether their first occurrences fall within Subzone A, as is reported by Barron (1983).

The first occurrence of *Actinocyclus hajosiae* is within Subzone B at Site 574 (Sample 574C-11,CC) and within Subzone A at Site 575 (Sample 575A-31,CC) (Table 3). Either that datum or the last occurrence of *Thalassiosira primalabiata*, the top of Subzone A, is diachronous between Sites 574 and 575. Radiolarian biostratigraphy at Site 71 (Dunn, 1982, compared with Barron, 1983), Site 574, and Site 575 (Nigrini, this volume) suggests that the first occurrence of *A. hajosiae* is isochronous, occurring in the lowermost part of the *Stichocorys delmontensis* Zone at all three sites. Placement of the Subzone A/Subzone B boundary at Sites 71 and 575 is consistent with these results, but placement of the boundary at Site 574 may be as much as two cores too low. With further study, it may be found that the first occurrence of *Actinocyclus hajosiae* is a more consistent datum level to define the Subzone A/Subzone B boundary than the last occurrence of *Thalassiosira primalabiata*.

Subzone B contains the last occurrence of *Melosira architectalis* (20.9 to 20.6 Ma) (Table 3), which varies somewhat between Sites 574 and 575, and the first occurrence of *Actinocyclus radionovae* Barron (21.2 Ma).

Characteristic flora: *Synedra jouseana* is the most consistently common diatom of the *R. paleacea* Zone. *Cestodiscus pulchellus* Greville, *Coscinodiscus marginatus*, *C. oligocenicus*, *C. rhombicus*, and *Bogorovia veniamini* also become important members of the assemblages in various parts of the zone.

Correlation: The correlations of Barron (1983) are supported in general by Leg 85 results at Sites 574 and 575. The base of the *R. paleacea* Zone falls in lower planktonic foraminiferal Zone N4 and the uppermost part of the *Lychnocanoma elongata* Zone of radiolarians, and approximates the CN1a/CN1b subzonal boundary of calcareous nannofossils. The top of the *R. paleacea* Zone correlates with Zone N5, upper Zone CN1, and middle *Stichocorys delmontensis* Zone at Site 574, but near the N4/N5 boundary at Site 575.

Correlation with other diatom zones: The *R. paleacea* Zone is equivalent to the lower part of the *Bogorovia veniamini* Zone of Jousé (1973), the upper part of the *B. veniamini* Zone of Weaver and Gombos (1981), and the upper part of the *Rocella gelida* Zone of Gombos and Ciesielski (1983) (Fig. 2).

Craspedodiscus elegans Zone

Category: Partial-range zone.

Author: Barron (1983).

Definition: Interval from the last occurrence of *Bogorovia veniamini* to the last occurrence of *Craspedodiscus elegans*.

Secondary markers: The first occurrences of *Thalassiosira fraga* (19.9 Ma) and *Coscinodiscus lewisiensis* var. *robustus* (20.0 Ma) approximate the base of the *C. elegans* Zone. At Sites 574 and 575, the first occur-

rences of *Nitzschia maleinterpretaria* Schrader (18.8 Ma) and *Triceratium pileus* Ehrenberg (18.8 Ma) approximate the zone's top, ranges slightly younger than those reported by Barron (1983) at Sites 71 and 495. Age: Early Miocene, 19.9 to 18.7 Ma (extrapolated ages, Barron et al., in press and this volume).

Remarks: Site 575 has an exceptionally thick (22 m), well preserved section of the *C. elegans* Zone.

Characteristic flora: *Thalassiosira fraga* is a common diatom within the *C. elegans* Zone, although *T. spinosa* Ehrenberg dominates over *T. fraga* in the lowermost part of the zone (Barron, 1983). *Synedra jouseana* and *Cestodiscus pulchellus* are secondarily common, and *Actinocyclus radionovae*, *Coscinodiscus rhombicus*, and *C. marginatus* are also characteristic.

Correlation: As reported by Barron (1983), the *C. elegans* Zone correlates with upper planktonic foraminiferal Zone N5, upper calcareous nanofossil Zone CN1, and the upper *Stichocorys delmontensis* Zone (radiolarians) at Site 575. Coincidence of the top of the *C. elegans* Zone with the tops of CN1 and the *S. delmontensis* Zone at Site 574 suggests a possible short hiatus there at about 237 m sub-bottom (Core 574C-5).

Correlation with other diatom zones: The *C. elegans* Zone is equivalent to the middle part of the *B. veniamini* Zone of Jousé (1973), and it closely approximates the limits of the *Coscinodiscus rhombicus* Zone of Weaver and Gombos (1981) and Gombos and Ciesielski (1983) (Barron, 1983) (Fig. 2).

Triceratium pileus Zone

Category: Interval zone.

Author: Barron (1983).

Definition: Interval containing *Triceratium pileus* between the last occurrence of *Craspedodiscus elegans* and the first occurrence of *Denticulopsis nicobarica* (Grunow) Simonsen.

Secondary markers: As stated, the first occurrences of *Nitzschia maleinterpretaria* and *Triceratium pileus* approximate the base of the *T. pileus* Zone in Leg 85 sediments. The last occurrence of *Triceratium pileus* (17.6 Ma) slightly postdates the zone's top.

Age: Early Miocene, 18.7 Ma (extrapolated age) to 17.8 Ma (paleomagnetic tie, Hole 575A).

Remarks: The *T. pileus* Zone is well represented at Sites 574 and 575, where it contains the last occurrences of *Thalassiosira spinosa* (17.9 Ma) and *Actinocyclus radionovae* (18.0 Ma).

Characteristic flora: *Cestodiscus pulchellus* and *Synedra jouseana* are common diatoms within the *T. pileus* Zone. Assemblages in the lower part of the zone at Site 575 are dominated by fragments of a diatom similar to *Ethmodiscus rex* (Wallich) Hendey (Samples 575A-9,CC through 575A-12,CC).

Correlation: At Site 575, the *T. pileus* Zone brackets the CN1c/CN2 (calcareous nanofossil) and *Stichocorys delmontensis*/S. *wolffii* (radiolarian) zonal boundaries, and is equivalent to the upper part of planktonic foraminiferal Zone N5; these correlations are consis-

tent with the results of Barron (1983) and Barron et al. (in press).

Correlation with other diatom zones: The *T. pileus* Zone is equivalent to the upper middle part of the *Bogorovia veniamini* Zone of Jousé (1973) and the lower part of the *Nitzschia maleinterpretaria* Zone of Weaver and Gombos (1981) (Barron, 1983) (Fig. 2).

Denticulopsis nicobarica Zone

Category: Partial-range zone.

Author: Barron (1983).

Definition: Interval from the first occurrence of *Denticulopsis nicobarica* to the first occurrence of *Cestodiscus peplum*.

Subzones: The last occurrence of *Thalassiosira bukryi* Barron (17.0 Ma) marks the top of Subzone A and the base of Subzone B.

Secondary markers: The last occurrence of *Triceratium pileus* (17.6 Ma) approximates the base of the *D. nicobarica* Zone, and the last occurrences of *Synedra miocenica* Schrader (16.5 Ma) and *Thalassiosira fraga* (16.3 to 16.1 Ma) approximate the top of the zone.

Age: Early Miocene, 17.8 to 16.4 Ma (paleomagnetic calibration, Hole 575A).

Remarks: The *D. nicobarica* Zone also contains the last occurrences of *Thalassiosira spumellaroides* (17.5 Ma), *Coscinodiscus lewisiatus* var. *robustus* (17.4 Ma), and *Raphidodiscus marylandicus* (16.7 Ma), and the first occurrences of *Cestodiscus pulchellus* var. *maculatus* (17.4 Ma), *Coscinodiscus lewisiatus* var. *similis* Rattray (17.4 Ma), *Craspedodiscus coscinodiscus* Ehrenberg s. str. (17.3 Ma), *Annellus californicus* (17.3 Ma), and *Denticulopsis* sp. cf. *D. kanayaee* Akiba (16.9 Ma) (Table 3; Barron, 1983).

Characteristic flora: See Table 4 (Hole 575A) and Table 5 (Hole 574) for quantitative diatom data on the *D. nicobarica* Zone.

Correlation: At Sites 573, 574, and 575, the *D. nicobarica* Zone correlates with upper Zone N6 to lower Zone N8 (planktonic foraminifers), upper Zone CN2 to upper Zone CN3 (calcareous nannofossils), and middle *Stichocorys wolffii* Zone to middle *Calocyctella costata* Zone (radiolarians), correlations supported by Barron (1983) and Barron et al. (in press).

Correlation with other diatom zones: The *D. nicobarica* Zone is correlative with the *Actinocyclus ingens* Zone of Barron (1980a) of the North Pacific and with the upper part of the *Nitzschia maleinterpretaria* Zone of Weaver and Gombos (1981) (Fig. 3).

Cestodiscus peplum Zone

Category: Taxon-range zone.

Author: Barron (1983).

Definition: Interval of the total range of *Cestodiscus peplum* Brun.

Subzones: The last occurrence of *Annellus californicus* Tempere within the *C. peplum* Zone (15.0 Ma) defines the top of Subzone A and the base of Subzone B.

Table 4. Percent planktonic diatoms through the *Denticulopsis nicobarica* Zone of Hole 575A.

Zone and subzone	Core-Section interval (cm)	Sub-bottom depth (m)	<i>Actinocyclus aff. ellipticus</i>	<i>Annelus californicus</i>	<i>Asteromphalus/Asterolampra</i>	<i>Cestodiscus peplum</i>	<i>C. pulchellus</i>	<i>C. pulchellus</i> var. <i>maculatus</i>	<i>Coscinodiscus blysmos</i>	<i>C. lewisiensis</i>	<i>C. lewisiensis</i> var. <i>similis</i>	<i>C. lewisiensis</i> var. <i>robustus</i>	<i>C. praenodulifer</i>	<i>C. radiatus</i> s. ampl.	<i>C. rhombicus</i>	<i>C. salisburyanus</i>	<i>C. tabularis</i> s. ampl.	<i>C. spp.</i>	<i>Craspedodiscus cosmodiscus</i> s. str.	<i>C. rydei</i>	<i>Denticulopsis nicobarica</i> s. ampl.	<i>Nitzschia maleinterpretaria</i>	<i>Raphidodiscus marylandicus</i>	<i>Rhizosolenia</i> spp.	<i>Synedra isoëstacea</i> S. miocenica	<i>Thalassionema nitzschioïdes</i> S. ampl.	<i>Thalassiosira bakryi</i>	<i>T. fraga</i>	<i>T. leptopus</i>	<i>T. spinosa</i>	<i>T. spumellaroides</i>	<i>Thalassiothrix longissima</i>	<i>Triceratium pileus</i>	Miscellaneous diatoms	Number counted	Estimated age (Ma) (from Fig. 5)
<i>Cestodiscus peplum</i>																																				
<i>Denticulopsis nicobarica</i>	A	1-1, 50-51	94.3	- + 1 1 40	- - 5 - -	- 1 - 4 8	+ - - 2 -	- 1 - 2 1 -	- 2 5 + 3	- 6 5 + 4	- 4 - 2 4	- 1 - 1 1	- 2 2 4 +	- 1 - 2 1	- 2 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
	B	1-2, 50-51	95.8	- - 3 - 47	+ - 2 + -	- 3 6 - 5 +	+ - - 1 -	- 1 - 2 20	- 4 -	- 2 5 +	- 4 - 2 4	- 1 - 1 1	- 2 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		1-3, 50-51	97.3	- 1 + - 40	- - 4 + -	- 4 - 2 -	- + - 2 -	- 5 16 - 3 2	- 1 - 2 4 +	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		2-2, 42-43	99.1	- + 4 - 24	- + 2 -	- 5 16 - 3 2	- 1 - 2 4 +	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		2-3, 42-43	100.6	- - 2 - 12	1 1 2 -	- 2 29 - 3 4	- 1 - 2 4 +	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		2-4, 42-43	102.1	- - 2 - 14	3 1 5 -	- + 24 - + 6	- 1 - 2 4 +	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		3-2, 42-43	103.0	- + 2 - 18	6 - 2 -	- 4 36 - + 1	- + + + 2 -	- 1 - 2 4 +	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		3-3, 42-43	104.5	- - 1 - 15	9 11 1 -	- 4 11 - 3 4	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		4-1, 42-43	105.6	4 - 2 - 16	9 9 3 +	- 6 4 + - 3	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		4-2, 42-43	107.1	1 1 2 - 14	11 6 2 1 -	- 6 4 + - 3	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		4-3, 42-43	108.6	1 + 1 - 12	6 - 1 + -	- 3 7 - - 4	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		4, CC	109.9	+ 1 1 - 15	13 1 + -	- 5 10 - + 3	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		5-2, 42-43	110.9	3 1 1 - 16	7 - + + -	- 3 12 - + 4	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		5-3, 42-43	112.4	- - + - 10	2 2 -	- 3 22 - + 2	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		5, CC	114.1	- + 1 - 24	- + - + -	- 2 14 - + 1	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		6-1, 42-43	114.5	- - 2 - 25	- + - + -	- 6 25 - + 3	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		6-2, 42-43	116.0	- + 47 -	- 1 - 15	- 2 + - 1 3	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		6-3, 42-43	117.5	- 1 - 34 -	- - - -	- 9 5 - + 4	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		6, CC	119.1	- 1 - 30 -	- - - -	- 8 + 7 - 2	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		7-2, 43-44	120.3	- 2 - 42 -	- 1 - 6	- 3 4 + 1 -	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		7-3, 43-44	121.8	- 2 - 30 -	- 2 - 7	- 7 2 10 + -	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										
		8-1, 42-43	123.5	- - 2 - 39 -	- 3 - 7	- 4 8 + - 2	- + + + 2 -	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 2 4	- 1 - 1 1	- 1 - 2 4 +	- 1 - 2 1	- 3 17	- 10 -	- 1 - 2 28	- 6 -	- 4 - 19	- 9 -	- 3 -	- 8 -	- 1 -	- 5 -	- 150	16.3										

Note: + means < 1% or encountered after the count; - means not encountered.

Secondary markers: As stated, the last occurrences of *Synedra miocenica* (16.5 Ma) and *Thalassiosira fraga* (16.3 to 16.1 Ma) approximate the base of the *C. peplum* Zone. The first occurrence of *Actinocyclus ellipticus* var. *spiralis* Barron, n. var. (14.2 to 14.1 Ma) corresponds closely to the top of the zone.

Age: Latest early Miocene to early middle Miocene, 16.4 Ma (paleomagnetic calibration, Hole 575A) to 14.2 Ma (paleomagnetic calibration, Burckle, 1978).

Remarks: The following last occurrences are within the *C. peplum* Zone: *Denticulopsis* sp. cf. *D. kanayae* (16.0 Ma), *Coscinodiscus lewisiensis* var. *similis* (15.7 Ma), *Nitzschia maleinterpretaria* (15.6 Ma), *Coscinodiscus praenodulifer* (15.5 to 15.4 Ma), and *C. blysmos* Barron (14.4 Ma). The first occurrences of *Actinocyclus ingens* Rattray in the tropics (15.5 Ma), *Thalassiosira tappanae* Barron, n. sp. (14.4 Ma), and *Actinocyclus ellipticus* (14.4 to 14.3 Ma) also fall within the *C. peplum* Zone. An isolated occurrence of the middle- to high-latitude species *Denticulopsis lauta* (15.9 to 15.9 Ma) in the lower part of the zone, reported by Barron (1983), has also been observed at Sites 573, 574, and 575 (Table 3). At Sites 572 and 574, isolated specimens of *Denticulopsis hustedtii* (Simonsen and Kanaya) Simonsen are observed as low as the 14.2-Ma level, the top of the *C. peplum* Zone. These occurrences more closely approximate the first occurrence of *D. hustedtii* in the middle- to high-latitude North Pacific (Barron, 1981a).

Characteristic flora: See Table 5 (Hole 574) and Table 6 (Hole 572D) for quantitative diatom data on the *C. peplum* Zone.

Correlation: In Leg 85 sediments, the *C. peplum* Zone correlates with lower Zone N8 to middle Zone N10 (planktonic foraminifers), middle Zone CN3 to upper Zone CN4 (calcareous nannofossils), and middle *Calocyctella costata* Zone to lower *Dorcadospirys alata* Zone (radiolarians). These results are generally consistent with those of Barron (1983) and Barron et al. (in press), although the top of CN4 appears relatively lower in Leg 85 sediments.

Coscinodiscus lewisiensis Zone

Category: Partial-range zone.

Author: Barron (in press).

Definition: Interval from the last occurrence of *Cestodiscus peplum* to the last occurrence of *Coscinodiscus lewisiensis* Greville.

Secondary markers: The first occurrence of *Actinocyclus ellipticus* var. *spiralis* (14.2 to 14.1 Ma) approximates the base of the *C. lewisiensis* Zone. The last occurrences of *Cestodiscus pulchellus* (13.6 to 13.5 Ma), *Coscinodiscus salisburyanus* Lohman (13.5 to 13.4 Ma), and *Annulus californicus* (13.5 to 13.4 Ma), and the first occurrence of *Coscinodiscus gigas* var. *diorama* (Schmidt) Grunow (13.6 to 13.5 Ma), all fall near the top of the zone.

Table 5. Percent planktonic diatoms in Cores 9 to 31 of Hole 574.

Zone and subzone	Core-Section, interval (cm)	Sub-bottom depth (m)	<i>Actinocyclus ehrenbergii</i>	<i>A. ellipticus</i> s. ampl.	<i>A. ingens</i>	<i>Asterorhaphis/Asterolampra</i>	<i>Cestodiscus peplum</i>	<i>C. pulchellus</i>	<i>C. pulchellus</i> var. <i>maculatus</i>	<i>Cocconodiscus blyssros</i>	<i>C. lewisiensis</i>	<i>C. marginatus</i>	<i>C. nodulifer</i>	<i>C. plicatus/C. yabei</i>	<i>C. praenudulifer</i>	<i>C. radiatus</i> s. ampl.	<i>C. salisburyensis</i>	<i>C. tabularis</i> s. ampl.	<i>C. temperata</i> var. <i>delicate</i>	<i>C. tuberculatus</i>	<i>Craspedodiscus coscinodiscus</i>	<i>Anellus californicus</i>	<i>Denticulopsis hustedtii</i>	<i>D. nicobarica</i>	<i>D. pseudomorpha</i>	<i>D. punctata f. hustedtii</i>	<i>Nitzschia midintermedia</i>	<i>N. spp.</i>	<i>Raphidodiscus marylandicus</i>	<i>Rhizosolenia spp.</i>	<i>Rosella polonica</i>	<i>Rouizia spp.</i>	<i>Syndra fuscema</i>	<i>Thalassionema nitzschiooides</i>	<i>T. nitzeckhoidea</i> var. <i>parva</i>	<i>T. robusta</i>	<i>Thalassiosira fraga</i>	<i>T. leptopus</i>	<i>T. tappanae</i>	<i>T. spp.</i>	<i>Thalassiosira longissima</i>	<i>Actinopyrulus</i> spp.	<i>Melosira silvatica</i>	Miscellaneous diatoms	Estimated age (Ma) (from Fig. 4)
Coscinodiscus yabei, Subzone A	9-1, 9-10	70.6	—	2	—	5	—	—	—	—	—	—	3	7	4	—	1	—	5	4	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10.8							
	9-2, 43-45	72.4	+	—	—	—	—	—	—	—	—	—	—	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10.95								
	9-3, 43-45	73.9	+	—	—	—	—	—	—	—	—	—	—	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.05								
	9-4, 43-45	75.4	—	2	—	—	—	—	—	—	—	—	—	1	12	1	—	1	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.15								
	9-6, 43-45	75.4	—	3	—	—	—	—	—	—	—	—	—	8	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.2								
	9, CC	80.0	+	4	—	—	—	—	—	—	—	—	—	10	2	—	—	3	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.2								
	10-1, 43-45	80.4	—	7	—	—	—	—	—	—	—	—	—	7	2	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.45								
	10-2, 43-45	81.9	—	9	—	—	—	—	—	—	—	—	—	6	1	—	—	2	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.4								
	10-3, 43-45	83.4	+	4	—	—	—	—	—	—	—	—	—	10	2	—	—	2	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.45								
	10-4, 43-45	84.9	—	5	—	—	—	—	—	—	—	—	—	6	1	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.6								
Actinocyclus moronensis	10-5, 43-45	86.4	+	4	—	—	—	—	—	—	—	—	—	6	2	—	—	5	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.7								
	10-6, 43-45	87.9	—	2	—	—	—	—	—	—	—	—	—	9	5	—	—	5	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.9								
	10, CC	89.3	—	9	—	—	—	—	—	—	—	—	—	+	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.95								
	11-1, 43-45	89.9	3	2	—	—	—	—	—	—	—	—	—	10	2	—	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.3								
	11-2, 43-45	91.4	10	1	—	—	—	—	—	—	—	—	—	2	1	—	—	7	2	4	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	12.1								
Craspedodiscus coscinodiscus	11-4, 43-45	94.4	2	5	—	—	—	—	—	—	—	—	—	4	4	—	—	3	1	36	—	—	2	—	+	—	8	—	—	—	—	—	—	—	—	—	12.2								
	11, CC	98.6	+	1	—	—	—	—	—	—	—	—	—	8	2	—	—	2	1	21	—	—	3	—	—	—	6	—	—	—	—	—	—	—	—	—	12.35								
	12-2, 43-45	100.5	+	4	—	2	—	—	—	—	—	—	—	2	1	—	—	5	27	1	2	—	—	9	—	—	—	—	—	—	—	—	—	—	—	12.45									
	12-4, 43-45	103.5	+	4	—	2	—	—	—	—	—	—	—	1	3	—	—	10	3	—	—	—	—	5	23	2	—	7	—	—	—	—	—	—	—	—	—	12.5							
Coscinodiscus gigas var. diorama	12, CC	108.1	3	6	2	—	—	—	—	—	—	—	—	2	7	—	—	10	1	6	2	—	—	5	—	—	—	—	—	—	—	—	—	—	—	12.0									
	13-2, 43-45	110.0	3	13	2	1	—	—	—	—	—	—	—	1	2	5	—	9	3	9	—	—	15	—	—	—	—	—	—	—	—	—	—	—	—	12.75									
	13-4, 43-45	113.0	7	10	—	—	—	—	—	—	—	—	—	2	2	5	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12.85									
	13-6, 43-45	116.0	+	12	—	3	—	—	—	—	—	—	—	3	8	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.0									
	14-2, 42-43	119.5	5	6	5	1	—	—	—	—	—	—	—	1	2	2	—	7	—	3	3	—	—	5	24	—	—	1	—	—	—	—	—	—	—	—	13.1								
Coscinodiscus lewisiensis	14, CC	122.5	6	1	1	—	—	—	—	—	—	—	—	2	2	5	—	12	6	1	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	13.2									
	15-2, 42-43	124.5	8	13	1	—	—	—	—	—	—	—	—	1	4	3	—	17	11	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	13.25									
	15, CC	128.7	10	21	1	4	—	—	—	—	—	—	—	1	3	2	—	7	8	—	—	7	1	—	—	—	—	—	—	—	—	—	—	—	—	13.4									
	16-2, 42-43	129.5	+	6	11	2	—	—	—	—	—	—	—	8	—	—	—	1	—	—	—	—	—	5	23	2	—	7	—	—	—	—	—	—	—	—	13.45								
	16, CC	132.6	+	4	16	2	—	3	—	3	3	2	—	6	—	2	3	—	6	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.55									
Coscinodiscus pulchellus	17-2, 42-43	134.5	+	7	3	1	—	—	—	—	—	—	—	1	3	2	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.6									
	17, CC	137.6	+	7	4	1	—	—	—	—	—	—	—	3	8	1	2	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.65									
	18-2, 42-43	139.5	—	4	9	—	2	—	—	—	—	—	—	4	—	—	—	4	—	—	—	—	—	6	32	—	—	—	—	—	—	—	—	—	—	13.75									
	18, CC	142.2	—	2	13	2	—	9	—	4	2	—	—	1	10	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.85									
	19-2, 43-44	144.5	—	2	2	—	5	—	3	6	—	—	—	8	—	—	4	—	19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.9									
Cestodiscus peplum	19, CC	148.2	+	7	—	+	3	—	1	6	—	—	—	+	2	3	3	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14.0									
	20-2, 43-44	149.5	—	5	—	+	3	—	4	1	—	—	—	1	7	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14.1									
	20, CC	152.5	—	2	2	—	3	—	3	2	—	—	—	1	1	9	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14.15									
	21-2, 43-44	154.4	—	1	—	+	2	1	2	1	—	—	—	6	4	11	—	—	21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14.4									
	22, CC	162.6	—	5	2	1	8	2	3	3	1	—	—	6	4	—	2	—	24	—	—	2	—	—	—	—	—</td																		

Table 6. Percent planktonic diatoms in Cores 12 to 33 of Hole 572D.

Zone and subzone	Core-Section, interval (cm)	Sub-bottom depth (m)	<i>Actinocyclus ethrenbergii</i>	<i>A. ellipticus s. ampl.</i>	<i>A. ingens</i>	<i>Asteromphalus/Asterolempa</i>	<i>Cestodiscus peplum</i>	<i>C. pulchellus s. ampl.</i>	<i>Coscinodiscus bilobatus</i>	<i>C. lewisiensis</i>	<i>C. marginatus</i>	<i>C. nodulifer</i>	<i>C. plicatus/C. yahei</i>	<i>C. radians s. ampl.</i>	<i>C. temperei var. delicata</i>	<i>C. tuberculatus</i>	<i>C. spp.</i>	<i>Craspedodiscus coscinodiscus</i>	<i>Annellus californicus</i>	<i>Denticulopsis hustedtii</i>	<i>D. nicobarica</i>	<i>D. praedimorpha</i>	<i>D. punctata f. hustedtii</i>	<i>Hemidiscus cuneiformis</i>	<i>Nitzschia spp.</i>	<i>Rhizosolenia spp.</i>	<i>Rosselia paleacea</i>	<i>Rouvia spp.</i>	<i>Synedra jousseaumei</i>	<i>Thalassionema nitzschiae</i>	<i>T. nitzschiae var. parva</i>	<i>T. robusta</i>	<i>Thalassiosira leptopus</i>	<i>T. tappanae</i>	<i>T. spp.</i>	<i>Thalassiosira longissima</i>	<i>Actinopychus spp.</i>	Miscellaneous diatoms	Estimated age (Ma)				
<i>Coscinodiscus yabei</i> , Subzone A	12-2, 50-52	257.5	+	+	+	-	-	-	-	-	-	-	5	1	2	2	2	-	-	-	-	-	8	7	-	+	+	+	-	-	-	1	5	-	3	10.7							
	12,CC	261.8	-	1	-	-	-	-	-	-	-	-	-	-	+	4	+	-	-	-	-	-	-	+	7	-	+	-	-	-	-	-	4	-	2	10.85							
	13-2, 50-52	267.0	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	7	-	+	-	-	-	-	-	4	-	1	11.15							
	13,CC	270.0	-	+	-	-	-	-	-	-	-	-	-	-	+	3	2	+	2	-	-	-	-	9	-	-	2	15	-	-	-	-	-	7	-	1	11.2						
	14-2, 50-52	272.4	-	1	-	+	-	-	-	-	-	-	-	-	1	+	-	-	-	-	-	-	-	39	-	-	3	7	-	-	-	-	17	21	-	-	1	11.25					
	14-4, 50-52	276.5	-	2	-	+	-	-	-	-	-	-	-	-	+	4	3	-	4	-	-	-	-	1	6	-	-	-	-	-	-	1	+	-	15	-	+11.35						
	14,CC	279.5	+	2	-	+	-	-	-	-	-	-	-	-	10	1	-	4	1	-	-	-	-	18	-	-	2	1	-	-	-	-	3	8	-	-	6	-	1	11.4			
	15-1, 50-52	281.9	1	3	-	+	-	-	-	-	-	-	-	-	7	1	-	4	-	-	-	-	1	26	-	-	-	-	-	-	1	4	+	11	22	-	2	8	-	3	11.45		
	15,CC	284.5	+	6	-	1	-	-	-	-	-	-	-	-	+	4	4	-	2	1	-	3	-	22	-	-	+	3	+	-	-	1	+	4	42	-	1	-	1	16	-	2	11.5
	16-2, 50-52	287.8	-	2	-	+	-	-	-	-	-	-	-	-	1	1	-	1	-	-	-	-	68	-	-	3	-	-	-	-	3	12	-	-	1	5	-	+11.55					
	16-4, 50-52	295.5	+	3	-	+	-	-	-	-	-	-	-	-	5	2	-	7	1	-	-	-	45	-	-	1	3	+	-	-	-	7	-	2	11.7								
	16,CC	298.5	+	2	-	1	-	-	-	-	-	-	-	-	+	2	-	5	2	+	-	-	62	-	-	1	4	-	-	-	-	3	8	-	-	4	-	2	11.75				
	17-1, 50-52	302.9	+	+	-	-	-	-	-	-	-	-	-	-	1	2	-	3	-	-	-	-	48	-	-	+	4	-	-	-	1	+	+33	4	3	-	5	-	1	11.85			
	17,CC	303.5	-	+	-	-	-	-	-	-	-	-	-	-	1	4	-	+	-	-	-	-	55	-	-	8	-	-	-	-	1	23	+3	-	3	-	+11.9						
	18-1, 50-52	306.4	-	-	-	-	-	-	-	-	-	-	-	-	+	1	-	2	-	-	-	-	57	-	-	+	4	+	-	-	1	-	1	20	2	-	8	-	2	11.95			
	18-3, 50-52	313.0	10	2	-	1	-	-	-	-	-	-	-	-	2	2	3	+	8	1	2	-	-	5	-	-	+	2	3	-	-	5	+	4	42	-	1	-	1	16	-	2	11.05
	18,CC	316.0	+	+	-	+	-	-	-	-	-	-	-	-	10	3	-	5	+	5	+	-	12	-	-	+	4	-	-	-	+	+12	34	+3	+	+	9	-	2	12.15			
	19-1, 50-52	321.1	+	1	-	1	-	-	-	-	-	-	-	-	1	3	2	2	6	2	34	+	-	5	-	-	-	-	1	+	1	20	-	-	5	+	4	12.2					
	19-3, 50-52	322.5	+	2	-	+	-	-	-	-	-	-	-	-	4	1	-	3	-	12	+	-	3	-	-	6	9	-	-	1	51	-	-	+	2	12.25							
	19,CC	325.5	+	3	-	+	-	-	-	-	-	-	-	-	2	2	-	5	+	9	-	-	17	-	-	1	4	-	-	-	1	48	-	-	4	-	1	12.3					
	20-2, 50-52	325.7	-	2	-	+	-	-	-	-	-	-	-	-	2	1	-	7	3	24	-	1	13	-	-	5	+	2	-	1	27	-	-	3	+	+12.35							
	20,CC	333.5	-	1	-	+	-	-	-	-	-	-	-	-	+	2	-	3	+	13	-	-	1	4	-	-	-	-	-	1	3	57	-	-	5	-	1	12.5					
	21-3, 50-52	335.0	2	12	-	2	-	-	-	-	-	-	-	-	3	3	1	-	9	5	+	5	-	-	16	-	-	3	-	5	2	14	-	1	1	12.55							
	21-4, 50-52	344.5	3	1	-	+	-	-	-	-	-	-	-	-	2	4	2	-	7	1	6	+	1	-	-	6	-	-	3	5	39	-	-	12	-	1	12.7						
	21,CC	346.0	4	1	-	+	-	-	-	-	-	-	-	-	1	3	3	-	10	5	+	5	-	-	10	-	-	2	-	3	31	-	-	1	13	+12.75							
	22-1, 50-52	348.5	1	5	-	3	-	-	-	-	-	-	-	-	2	3	3	-	12	1	5	+	2	-	-	18	1	3	-	3	25	-	-	6	-	1	12.8						
	22,CC	351.0	-	1	2	+	-	-	-	-	-	-	-	-	2	1	-	7	3	24	-	1	13	-	-	5	+	2	-	1	40	-	-	3	+	+12.85							
	23-3, 50-52	354.7	2	3	-	1	-	-	-	-	-	-	-	-	1	7	+	12	1	1	10	-	-	3	-	-	3	+	2	5	3	22	-	-	7	-	1	12.9					
	23,CC	363.5	+	11	7	+	-	-	-	-	-	-	-	-	5	1	4	1	9	-	1	+	-	7	-	-	1	+	1	1	11	11	-	2	-	20	2	+13.1					
	24-2, 50-52	369.4	10	8	1	2	-	-	-	-	-	-	-	-	7	-	13	6	+	2	2	-	+	1	-	-	3	-	4	8	20	-	4	-	4	2	13.2						
	24,CC	371.5	6	9	2	-	-	-	-	-	-	-	-	-	2	+	6	+	12	1	-	-	-	1	-	-	1	7	25	-	3	-	5	2	13.25								
	25-3, 50-52	371.8	+	4	36	1	-	-	-	-	-	-	-	-	2	4	2	-	4	1	+	1	16	1	-	-	-	-	-	-	3	4	14	-	2	-	8	-	+13.4				
	25,CC	382.5	-	6	9	-	-	-	-	-	-	-	-	-	+	4	4	-	5	-	-	1	6	4	-	-	-	-	-	-	1	20	21	-	3	-	6	-	13.5				
	26-3, 50-52	388.7	-	2	8	1	-	-	-	-	-	-	-	-	5	2	-	4	4	-	1	+	26	31	-	-	-	-	-	-	2	-	1	3	-	-	7	-	+13.6				
	26,CC	392.0	-	3	2	2	-	-	-	-	-	-	-	-	3	1	-	5	1	4	1	6	51	-	-	-	-	-	-	-	6	6	-	-	4	-	13.65						
	27-3, 50-52	397.0	-	4	2	-	-	-	-	-	-	-	-	-	1	2	-	6	1	5	9	49	-	-	-	-	-	-	-	1	3	4	-	7	-	4	13.75						
	27,CC	401.5	-	1	1	-	-	-	-	-	-	-	-	-	2	-	+	2	-	+	56	-	-	2	-	-	-	-	-	-	3	24	-	-	1	+	6	2	13.8				
	28-2, 50-52	407.6	-	4	2	+	-	-	-	-	-	-	-	-	5	6	-	3	2	10	1	+	21	-	-	-	-	-	-	-	3	13	-	-	6	+	13	2	13.9				
	28,CC	414.7	-	6	1	1	-	-	-	-	-	-	-	-	1	2	-	+	2	-	44	-	-	-	-	-	-	-	1	-	5	19	-	-	6	-	8	-	+13.95				
	29-2, 50-52	419.0	-	+	+	-	-	-	-	-	-	-	-	-	2	3	-	+	1	-	1	56	-	-	-	-	-	-	-	1	7	14	-	-	6	-	1	14.1					
	29,CC	424.0	-	2	+	+	1	-	-	-	-	-	-	-	1	-	-	2	1	-	1	62	-	-	-	-	-	-	-	10	2	-	-	15	-	2	14.2						
	30-1	427.0	-	+	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	77	-	-	-	-	-	-	-	2	12	-	-	7	-	+14.25							
	30,CC	433.8	-	13	+	1	-	-	-	-	-	-	-	-	3	7	-	+	-	-	50	-	-	-																			

aminifers), and it brackets the CN5a/CN5b subzonal boundary of calcareous nannofossils. At Sites 574 and 575, the *C. gigas* var. *diorama* Zone correlates with the upper *Dorcaspyris alata* Zone of radiolarians, whereas at Sites 572 and 573 a correlation with the lower *Diatrus petterssoni* Zone is suggested. Correlation with the upper *D. alata* Zone is favored by Barron et al. (in press); comparison of the various microfossil biostratigraphies (Barron et al., this volume) suggests that the *D. alata/D. petterssoni* zonal boundary is diachronous between Sites 572–573 and Sites 574–575.

Correlation with other diatom zones: The *C. gigas* var. *diorama* Zone correlates with Subzone b of the *Denticulopsis hustedtii*–*D. lauta* Zone of the North Pacific, and with a lower part of the *Nitzschia denticuloides* Zone of the Southern Ocean (Barron, in press) (Fig. 3).

Craspedodiscus coscinodiscus Zone

Category: Concurrent-range zone.

Author: Barron (in press).

Definition: Interval from the first occurrence of *Coscinodiscus temperei* var. *delicata* to the last occurrence of *Craspedodiscus coscinodiscus*.

Secondary markers: The last occurrence of *Actinocyclus ingens* in the tropics approximates the base of the *C. coscinodiscus* Zone. The last occurrences of *Coscinodiscus gigas* var. *diorama* (12.3 Ma) and *Synedra jouseana* (12.3 to 12.1 Ma) and the first occurrences of *Thalassionema robusta* Schrader (12.3 to 12.2 Ma) and *Rossiella paleacea* var. *elongata* Barron (12.3 to 12.2 Ma) all nearly coincide with the zone's top.

Age: Middle Miocene, 12.8 Ma (paleomagnetic calibration, Burckle et al., 1982) to 12.2 Ma (extrapolated age, Barron et al., in press).

Remarks: The first occurrences of *Rossiella praepaleacea* (Schrader) Gersonde (12.7 Ma) and *Hemidiscus cuneiformis* Wallich (12.5 Ma) and the last occurrence of *Actinocyclus ellipticus* var. *spiralis* (12.4 to 12.3 Ma) are within the *C. coscinodiscus* Zone.

Characteristic flora: See Table 5 (Hole 574) and Table 6 (Hole 572D) for quantitative diatom data on the *C. coscinodiscus* Zone.

Correlation: The *C. coscinodiscus* Zone is equivalent to planktonic foraminiferal Zone N13, calcareous nannofossil Subzone CN5b to lower Zone CN6, and the lower *Diatrus petterssoni* Zone of radiolarians in Leg 85 sediments. These correlations are supported by Barron et al. (in press).

Correlation with other diatom zones: The lower part of Subzone c of the *Denticulopsis hustedtii*–*D. lauta* Zone of the North Pacific, and a middle part of the *Nitzschia denticuloides* Zone of the Southern Ocean, are correlative with the *C. coscinodiscus* Zone (Barron, in press) (Fig. 3).

Actinocyclus moronensis Zone

Category: Partial-range zone.

Author: Barron (in press).

Definition: Interval from the last occurrence of *Craspedodiscus coscinodiscus* to the last occurrence of *Actinocyclus moronensis* Deby.

Secondary markers: The last occurrences of *Coscinodiscus gigas* var. *diorama* and *Synedra jouseana* and the first occurrences of *Thalassionema robusta* and *Rossiella paleacea* var. *elongata* correspond closely to the base of the *A. moronensis* Zone. The first occurrence of *Actinocyclus ellipticus* f. *lanceolata* Kolbe (11.4 Ma) slightly predates the top of the zone.

Age: Latest middle Miocene to earliest late Miocene, 12.2 Ma (extrapolated age, Barron et al., in press) to 11.3 Ma (paleomagnetic calibration, Burckle, 1978).

Remarks: The last occurrence of *Denticulopsis punctata* f. *hustedtii* (12.1 Ma) and the last consistent occurrence of *Coscinodiscus tuberculatus* (12.0 Ma) fall within the *A. moronensis* Zone.

Characteristic flora: See Table 5 (Hole 574) and Table 6 (Hole 572D) for quantitative diatom data on the *A. moronensis* Zone.

Correlation: The *A. moronensis* Zone is equivalent to planktonic foraminiferal Zones N14 and N15, calcareous nannofossil Zone CN7, and the middle part of the *Diatrus petterssoni* Zone of radiolarians in Leg 85 sediments. These correlations are supported by Barron et al. (in press).

Correlation with other diatom zones: The *A. moronensis* Zone correlates with the upper part of Subzone C of the *Denticulopsis hustedtii*–*D. lauta* Zone of the North Pacific and with the upper part of the *Nitzschia denticuloides* Zone of the Southern Ocean (Barron, in press) (Fig. 3).

Coscinodiscus yabei Zone

Category: Partial-range zone.

Author: Burckle, 1972 (top); Barron, in press (base).

Definition: Interval from the last occurrence of *Actinocyclus moronensis* to the last occurrence of *Coscinodiscus yabei* Kanaya.

Subzones: Barron (in press) proposed the first occurrence of *Thalassiosira burckliana* to define the Subzone A/Subzone B boundary.

Secondary markers: The first occurrence of *Actinocyclus ellipticus* f. *lanceolata* slightly predates the base of the zone, and the first occurrence of *Nitzschia cylindrica* Burckle s. ampl. (8.7 to 8.6 Ma) coincides with the top of the zone.

Age: Late Miocene, 11.3 to 8.6 Ma (paleomagnetic calibrations, Burckle, 1978).

Remarks: Restricted ranges of *Coscinodiscus vetustissimus* var. *javanica* Reinhold (11.2 to 10.7 Ma, Burckle, 1978), *C. loeblichii* Barron, n. sp. (about 10.5 to 9.4 Ma), and *C. yabei* var. *ellipticus* Barron, n. var. (about 9.8 to 9.4 Ma) all fall within the *C. yabei* Zone. *Nitzschia fossilis* (Frenguelli) Kanaya (9.8 Ma) and *Coscinodiscus nodulifer* var. *cyclopus* Jousé (8.9 to 8.8 Ma) have first occurrences within the *C. yabei* Zone, and *Denticulopsis hustedtii* last occurs (11.2 to 10.5 Ma) within the tropics within the zone.

Burckle (1978) correlated the first occurrence of *Thalassiosira burckliana* with the uppermost part of

paleomagnetic Chron 9 in the equatorial Pacific, but admitted that Chron 9 appears greatly abbreviated in many of his piston cores (L. H. Burckle, pers. comm., 1981). Hiatus NH5 of Keller and Barron (1983) removes sediments equivalent to Chron 9 throughout the equatorial Pacific, so it is possible that Burckle's calibration of the first occurrence of *T. burckliana* to paleomagnetics was affected by a hiatus in his piston cores. On Figure 2, the sediment accumulation rate curve for Site 572, the middle late Miocene trend established by paleomagnetically calibrated diatom datums has been continued to intersect the late middle Miocene trend established by diatom datums, and the extrapolated age of 10.5 Ma (Table 3) has been obtained for the first occurrence of *T. burckliana*. Site 572 was within the high-productivity zone along the equator in the eastern Pacific during the early late Miocene, and it is the most likely of the Leg 85 sites to have a complete section representing that interval. Indeed, compression of datum levels within the 10.5 to 9.8 Ma interval at Sites 573, 574, and 575 (Table 3) indicates the likelihood of hiatuses there. However, see also Barron et al. (this volume).

Characteristic flora: See Tables 5 and 7 (Hole 574) and Tables 6 and 7 (Hole 572D) for quantitative diatom data through the *C. yabei* Zone.

Correlation: The *C. yabei* Zone is equivalent to planktonic foraminiferal Zone N16 to lowermost Zone N17, calcareous nannofossil Subzone CN8, and upper *Diatrurus petterssoni* Zone to lower *Didymocystis antepenultima* Zone (radiolarians) in Leg 85 sediments.

Correlation with other diatom zones: The *C. yabei* Zone correlates with Subzone d of the *Denticulopsis hustedtii*-*D. lauta* Zone through Subzone a of the *D. hustedtii* Zone of the North Pacific, and with the uppermost *Nitzschia denticuloides* Zone through the *D. hustedtii*-*D. lauta* Zone of the Southern Ocean (Barron, in press; Ciesielski, 1983) (Fig. 3).

Nitzschia porteri Zone

Category: Interval zone.

Author: Burckle (1972).

Definition: Interval containing *Nitzschia porteri* between the last occurrence of *Coscinodiscus yabei* and the first occurrence of *Nitzschia miocenica*.

Subzones: Barron (in press) proposed the last occurrence of *Thalassiosira burckliana* (8.0 Ma) to define the Subzone A/Subzone B boundary.

Secondary markers: The first occurrence of *Nitzschia cylindrica* s. ampl. approximates the base of the *N. porteri* Zone, and the last occurrence of *Rossiella paleacea* (7.4 Ma) slightly predates the top of the zone.

Age: Late Miocene, 8.6 to 7.3 Ma (paleomagnetic calibrations, Burckle, 1978).

Remarks: The *N. porteri* Zone contains the first occurrences of *Nitzschia reinholdii* Kanaya and Koizumi s. ampl. (8.0 Ma) and *N. marina* Grunow (8.2 to 8.1 Ma) and the last occurrences of *Actinocyclus ellipticus* var. *javanica* Reinhold (8.0 Ma) and *Coscinodiscus nodulifer* var. *cyclopis* (7.9 Ma—within the Miocene). The first occurrence of *N. reinholdii* predates by more than 1 m.y. Burckle's (1978) calibration of that datum with

lower paleomagnetic Chron 6, but it is consistent with the results of Sancetta (1982), who found *N. reinholdii* to range to the equivalent of the middle of Chron 7 at DSDP Site 503 in the eastern equatorial Pacific.

Characteristic flora: See Table 7 (Holes 574 and 572D) for quantitative diatom data on the *N. porteri* Zone.

Correlation: In Leg 85 sediments, the *N. porteri* Zone is equivalent to lower planktonic foraminiferal Zone N17 and to part of calcareous nannofossil Zone CN8, and it brackets the *Didymocystis antepenultima*/*D. penultima* zonal boundary of radiolarians. The calcareous nannofossil correlation appears somewhat old, because elsewhere in the Pacific, the *N. porteri* Zone contains the CN8/CN9 boundary within Subzone A (Barron et al., in press; Keller et al., 1982) (Fig. 3).

Correlation with other diatom zones: The *N. porteri* Zone correlates with the lower part of Subzone B of the *Denticulopsis hustedtii* Zone of the North Pacific, the lower part of Barron's (1981b) *Thalassiosira antiqua* Zone of the California area, and the lower part of the *D. hustedtii* Zone of the Southern Ocean (Barron, in press).

Nitzschia miocenica Zone

Category: Partial-range zone.

Author: Burckle (1972).

Definition: Interval between the first occurrence of *Nitzschia miocenica* Burckle and the first occurrence of *Thalassiosira convexa* Mukhina.

Subzones: The first occurrence of *Thalassiosira praecox* Burckle (6.3 Ma) defines the Subzone A/Subzone B boundary (Burckle, 1972).

Secondary markers: The last occurrence of *Rossiella paleacea* slightly predates the base of the *N. miocenica* Zone, and the first occurrence of *Thalassiosira miocenica* (6.1 Ma) closely approximates the zone's top.

Age: Late Miocene, 7.3 to 6.1 Ma (paleomagnetic calibration, Burckle, 1978).

Remarks: *Nitzschia porteri* sensu Burckle (1972) has its last occurrence within the *N. miocenica* Zone (at about 6.8 Ma). Burckle (1978) noted only a slight overlap between the first occurrence of *N. miocenica* (7.3 Ma) and the last occurrence of *N. porteri*. At DSDP Site 503 in the eastern equatorial Pacific, Sancetta (1982) records an overlap of more than three cores between the two species, but Sancetta's (1982) extinction level for *N. porteri* coincides with the first occurrence of *Thalassiosira praecox* (6.3 Ma). Thus, the Leg 85 result for the extinction level of *N. porteri* lies approximately halfway between the results of Burckle (1978) and Sancetta (1982).

Characteristic flora: See Table 7 (Holes 574 and 572D) for quantitative diatom data on Subzone A and Baldau (this volume; Holes 573, 572A, and 572D) for quantitative diatom data on Subzone B of the *N. miocenica* Zone.

Correlation: The *N. miocenica* Zone is equivalent to middle planktonic foraminiferal Zone N17, upper calcareous nannofossil Zone CN8, and the upper *Didymocystis penultima* Zone (radiolarians) in Leg 85 sediments. Elsewhere in the Pacific, the zone is restricted

Table 7. Percent planktonic diatoms in Cores 5 to 11 of Hole 572D and Sample 574-6-6, 43-44 cm and Cores 7 and 8 of Hole 574.

Note: + means <1% or encountered after the count; — means not encountered. 300 specimens were counted.

to Zone CN9 and brackets the CN9a/CN9b boundary (Keller et al., 1982; Barron, in press; Haq et al., 1980). It therefore appears that the CN8/CN9 boundary is placed substantially above its generally accepted position in Leg 85 sediments.

Correlation with other diatom zones: The *Nitzschia micrenica* Zone correlates with the upper part of Sub-zone b of the *D. hustedtii* Zone to lowermost *D. kamtschatica* Zone of the North Pacific, the upper part of the *Thalassiosira antiqua* Zone to lowermost *Nitzschia reinholdii* Zone (Barron, 1981b) of the California area, and the middle part of the *D. hustedtii* Zone of the Southern Ocean (Barron, in press; Ciesielski, 1983) (Fig. 3).

Thalassiosira convexa Zone

Category: Partial-range zone.

Author: Burckle (1972).

Definition: Interval from the first occurrence of *Thalassiosira convexa* to the first occurrence of *Nitzschia iouseae* Burckle.

Subzones: Burckle (1972) defined three subzones: Subzone A, from the base of the zone to the last occur-

rence of *Thalassiosira praecconvexa* (5.8 Ma); Subzone B, from the top of Subzone A to the last occurrence of *Thalassiosira miocenica* Schrader (5.1 Ma); and Subzone C, from the top of Subzone B to the top of the zone.

Secondary markers: The first occurrence of *Thalassiosira miocenica* closely approximates the base of the *T. convexa* Zone.

Age: Latest Miocene to earliest Pliocene, 6.1 to 4.6 Ma (paleomagnetic calibrations, Burckle, 1978). The Sub-zone B/Subzone C boundary coincides with the Miocene/Pliocene boundary (Burckle, 1978).

Remarks: The *Thalassiosira convexa* Zone contains the last occurrences of *Rossiella praepaleacea* (6.0 Ma), *Nitzschia miocenica* Burckle (5.6 Ma), *Nitzschia miocenica* var. *elongata* Burckle (5.65 Ma), and *Asterolampra acutiloba* Forti (5.35 Ma). *Thalassiosira oestrupii* (Ostenfeld) Proshkina-Lavrenko s. str. first occurs at the Subzone B/Subzone C boundary or Miocene/Pliocene boundary (5.1 Ma).

Correlation: The *Thalassiosira convexa* Zone is equivalent to upper planktonic foraminiferal Zone N17 to lower N19 and to calcareous nannofossil Zone CN9

through Subzone CN10b, and it closely approximates the *Stichocorys peregrina* Zone of radiolarians in Leg 85 sediments.

Correlation with other diatom zones: The *T. convexa* Zone correlates with most of Subzones a and b of the *Denticulopsis kamtschatica* Zone of the North Pacific, with the upper *Nitzschia reinholdii* Zone to lower *Thalassiosira oestrupii* Zone (Barron, 1981b) of the California area, and the upper *D. hustedtii* Zone of the Southern Ocean (Barron, in press; Ciesielski, 1983) (Fig. 3).

Nitzschia jouseae Zone

Category: Partial-range zone.

Author: Burckle (1972).

Definition: Interval from the first occurrence of *Nitzschia jouseae* to the first occurrence of *Rhizosolenia praebengonii* Mukhina.

Age: Early Pliocene to early late Pliocene, 4.5 to 3.0 Ma (paleomagnetic calibration, Burckle, 1978).

Remarks: Within the *N. jouseae* Zone are the last occurrences of *Nitzschia cylindrica* (4.4 Ma) and *Actinocyclus ellipticus* f. *lanceolata* (3.5 to 3.2 Ma; oldest at Site 572—Table 3) and the first occurrences of *Asterolampra elegans* Greville (3.9 Ma) and *Thalassiosira convexa* var. *convexa* Schrader (3.6 Ma). Burckle (1978) also records the first occurrence of *Coscinodiscus africanus* Janisch at about 3.7 Ma, but this datum was not searched for in Leg 85 sediments.

Characteristic flora: See Baldauf (this volume) for quantitative diatom data from the *N. jouseae* Zone of Sites 572 and 573.

Correlation: In Leg 85 sediments, the *Nitzschia jouseae* Zone is equivalent to upper planktonic foraminiferal Zone N19, Subzone CN10c and Zone CN11 of calcareous nannofossils, and the *Spongaster pentas* Zone of radiolarians.

Correlation with other diatom zones: The *N. jouseae* Zone correlates with Subzone c of the *Denticulopsis kamtschatica* Zone of the North Pacific. For the Southern Ocean, the *N. jouseae* Zone is equivalent to the *Nitzschia reinholdii* to upper *N. interfrigidaria* zones of Weaver and Gombos (1981) and the *Nitzschia reinholdii* to middle *N. interfrigidaria*–*Coscinodiscus vulnificus* zones of Ciesielski (1983) (Barron, in press; Ciesielski, 1983) (Fig. 3).

Rhizosolenia praebengonii Zone

Category: Partial-range zone.

Author: Burckle (1972).

Definition: Interval from the first occurrence of *Rhizosolenia praebengonii* to the first occurrence of *Pseudoeunotia doliolus* Wallich.

Subzones: Burckle (1972) defined three subzones: Subzone A, from the base of the zone to the last occurrence of *Nitzschia jouseae* (2.6 Ma); Subzone B, from the top of Subzone A to the last occurrence of *Thalassiosira convexa* (2.1 Ma); and Subzone C, from the top of Subzone B to the top of the zone.

Secondary markers: The last occurrence of *Rhizosolenia praebengonii* (1.8 Ma) slightly predates the top of the zone (Burckle and Trainer, 1979).

Age: Late Pliocene, 3.0 to 1.8 Ma (paleomagnetic calibrations, Burckle, 1978).

Characteristic flora: Quantitative diatom data for the *R. praebengonii* Zone of Sites 572 and 573 are given in Baldauf (this volume).

Correlation: The *R. praebengonii* Zone is equivalent to planktonic foraminiferal Zone N21 and to calcareous nannofossil Zone CN12, and it brackets the *Spongaster pentas*/*Pterocanium prismaticum* zonal boundary of radiolarians in Leg 85 sediments.

Correlation with other diatom zones: The *R. praebengonii* Zone correlates with the *Denticulopsis seminae* var. *fossilis*–*D. kamtschatica* and *D. seminae* var. *fossilis* zones of the North Pacific. For the Southern Ocean, the *R. praebengonii* Zone correlates with the upper part of the *Nitzschia interfrigidaria* through *Coscinodiscus kolbei*–*Rhizosolenia barboi* zones of Weaver and Gombos (1981), and with the upper *N. interfrigidaria*–*C. vulnificus* through *Coscinodiscus kolbei*–*Rhizosolenia barboi* zones of Ciesielski (1983) (Barron, in press; Ciesielski, 1983) (Fig. 3).

Nitzschia reinholdii Zone

Category: Concurrent-range zone.

Author: Burckle (1977).

Definition: Interval from the first occurrence of *Pseudoeunotia doliolus* to the last occurrence of *Nitzschia reinholdii*.

Subzones: Burckle (1977) proposed two subzones, A and B, with the last occurrence of *Rhizosolenia praebengonii* var. *robusta* Burckle and Trainer (1.55 Ma) defining the subzonal boundary.

Secondary markers: The last occurrence of *Rhizosolenia praebengonii* var. *praebengonii* slightly predates the base of the *P. doliolus* Zone (Burckle and Trainer, 1979).

Age: Latest Pliocene to Quaternary, 1.8 to 0.65 Ma (paleomagnetic calibration, Burckle, 1978). The Subzone A/Subzone B boundary closely approximates the Pliocene/Quaternary boundary.

Remarks: Although Sancetta (1982) reported that *Nitzschia reinholdii* disappeared just below the Jaramillo Event of the Matuyama paleomagnetic Chron at DSDP 503 in the eastern equatorial Pacific, its extinction in Leg 85 sediments is within the lower part of the Brunhes Chron (Table 3 and Weinreich and Theyer, this volume), consistent with the results of Burckle (1977) and Burckle and Opdyke (1977).

Characteristic flora: *Thalassionema nitzschiooides* Grunow and *Coscinodiscus nodulifer* are common diatoms within the *N. reinholdii* Zone; *Pseudoeunotia doliolus*, *Nitzschia marina*, and *N. reinholdii* are frequent species. *Rhizosolenia praebengonii* var. *robusta* is fairly common within Subzone A.

Correlation: The *N. reinholdii* Zone is equivalent to planktonic foraminiferal Zone N22, lower calcareous nannofossil Zone CN13 to middle Zone CN14, and the upper part of the *Pterocanium prismaticum* Zone to uppermost *Amphirhopalum epsilon* Zone of radiolarians in Leg 85 sediments.

Correlation with other diatom zones: The *N. reinholdii* Zone correlates with the *Actinocyclus oculatus* Zone through Subzone a of the *Rhizosolenia curvirostris*

Zone of the North Pacific, and with the *Rhizosolenia barboi*-*Nitzschia kerguelensis* and *Coscinodiscus elliptopora*-*Actinocyclus ingens* zones of the Southern Ocean (Barron, in press; Ciesielski, 1983) (Fig. 3).

Pseudoeunotia doliolus Zone

Category: Partial-range zone.

Author: Burckle (1972, 1977).

Definition: Interval above the last occurrence of *Nitzschia reinholdii* containing *Pseudoeunotia doliolus*.

Age: Late Quaternary, 0.65 to 0 Ma (paleomagnetic calibration, Burckle, 1977).

Remarks: See comments under *N. reinholdii* Zone.

Characteristic flora: Assemblages are dominated by *Coscinodiscus nodulifer* and *Thalassiosira oestrupii*. *Nitzschia marina*, *Pseudoeunotia doliolus*, *Thalassiosira nitzschiooides*, and *Asteromphalus* spp. are secondarily common.

Correlation: The *P. doliolus* Zone is equivalent to upper planktonic foraminiferal Zone N22 and Zone N23, upper calcareous nannofossil Zone CN14 and Zone CN15, and the *Collospheara tuberosa* and *Buccinosphaera invaginata* zones of radiolarians in Leg 85 sediments.

Correlation with other diatom zones: The *P. doliolus* Zone correlates with Subzone b of the *Rhizosolenia curvirostris* Zone and the *Denticulopsis seminae* Zone of the North Pacific, and with the *Coscinodiscus lentigenosus* Zone of the Southern Ocean (Barron, in press; Ciesielski, 1983) (Fig. 3).

AGE-VERSUS-DEPTH PLOTS

Estimated ages of diatom datum levels that have been calibrated directly and indirectly with paleomagnetic stratigraphy (Tables 1 to 3) and direct Leg 85 paleomagnetic stratigraphy (Weinreich and Theyer, this volume) have been used on Figure 4 to construct age-versus-depth plots for the upper Cenozoic of Sites 572 to 575. The datums used include those of Burckle (1978), along with additions and modifications suggested by Barron et al. (in press). As stated in the preceding section, these plots allow the ages of secondary datum levels to be extrapolated and compared within the Leg 85 sections. In addition, rates of sediment accumulation can be compared between the sites, and hiatuses and greatly compressed intervals can be detected.

Sediment Accumulation Rates

Figure 4 shows that rates of sediment accumulation at eastern equatorial Site 572 were at least 1.7 times greater than those at central equatorial Sites 573 to 575 throughout the middle Miocene, late Miocene, and earliest Pliocene. Of the three central equatorial sites, Site 573 shows the highest rates of sediment accumulation between 0 and 11 Ma, reflecting its present position with the equatorial region of high productivity. Sediment accumulation rates between 1 and 4 Ma are roughly comparable (15 m/m.y.) between eastern Site 572 and central Site 573. For the middle Miocene (15.5 to 11 Ma), the central equatorial Pacific rates are higher (20 to 30 m/m.y.) at Site 574 than at Sites 573 and 575, correspond-

ing to a time when Site 574 was within the high-productivity zone and Sites 573 and 575 were not. Early Miocene sediment accumulation rates were relatively high (18 to 20 m/m.y.) at Sites 574 and 575, indicating that both those sites were then within the region of high productivity.

Hiatuses

The near coincidence of the last occurrences of *Craspedodiscus elegans* (18.7 Ma; Sample 574C-5, CC) and *Actinocyclus radionovae* (18.0 Ma; Sample 574C-5-3, 43–45 cm) indicates the possibility of a hiatus at about 235 m sub-bottom at Site 574. This hiatus would correspond in part to hiatus NH1 of Keller and Barron (1983), which is present throughout much of the central equatorial Pacific.

Compression of diatom datum levels in the upper part of Core 573B-14 (Table 3) suggests a hiatus from about 17.6 to 17.0 Ma at Site 573 (Fig. 4). This hiatus (NH1b) has also been recognized at nearby Site 77 by Keller and Barron (1983). A sharp lithologic contact at 262.1 m sub-bottom in upper Core 573B-14, where white radiolarian-nannofossil oozes rest on white to very light brown radiolarian-nannofossil oozes and chalks and siliceous nannofossil oozes and chalks (see site chapter), is consistent with this hiatus.

Keller and Barron (1983) also proposed a second hiatus (NH1a) at Site 77, approximately 20 m below NH1b, at the base of Core 77B-30. Poor preservation of diatoms below 270 m at Site 573 hinders recognition of this second hiatus, which spans the interval of Subzone A of the *Rossiella paleacea* Zone (20.6 to 19.9 Ma), according to Barron et al. (in press); but a sharp lithologic contact in uppermost Core 573B-17 (290.6 m), between light brown nannofossil oozes above and white nannofossil oozes below, may correspond to this hiatus.

At Site 575 sediment accumulation rates decreased dramatically between 15.5 and 14.4 Ma (82 to 74 m sub-bottom depth). This is also indicated by a relatively compressed planktonic foraminiferal Zone N9 at Site 575 (Saito, this volume). Although no hiatus is apparent, this interval does correspond in part with widespread hiatus NH2 (16.0 to 15.0 Ma) of Keller and Barron (1983).

Figure 4 also shows decreased sediment accumulation rates for Site 573 between 12.0 and 11.4 Ma, corresponding to the compression of the last-occurrence datum level of *Coscinodiscus tuberculatus* (12.0 Ma) (Sample 573B-5-1, 68–70 cm) and the last common occurrence of *Denticulopsis hustedtii* (11.5 Ma; see section on quantitative stratigraphy) (Sample 573B-4-5, 68–70 cm). This compressed interval corresponds in part to hiatus NH4 of Keller and Barron (1983) (12.0 to 11.0 Ma), which is widespread in the northeast Pacific, and also coincides with severe calcium carbonate dissolution at all the Leg 85 sites.

Hiatuses between 10.5 and 9.8 Ma (hiatus NH4 of Keller and Barron, 1983) are present at Sites 573, 574, and 575 (Fig. 4), although Core 572D-11 (255.5 to 246 m sub-bottom) apparently is complete across that interval (Fig. 2). Compression of diatom datum levels in Section 1 of Core 573B-3, in lowermost Core 574-8, and in low-

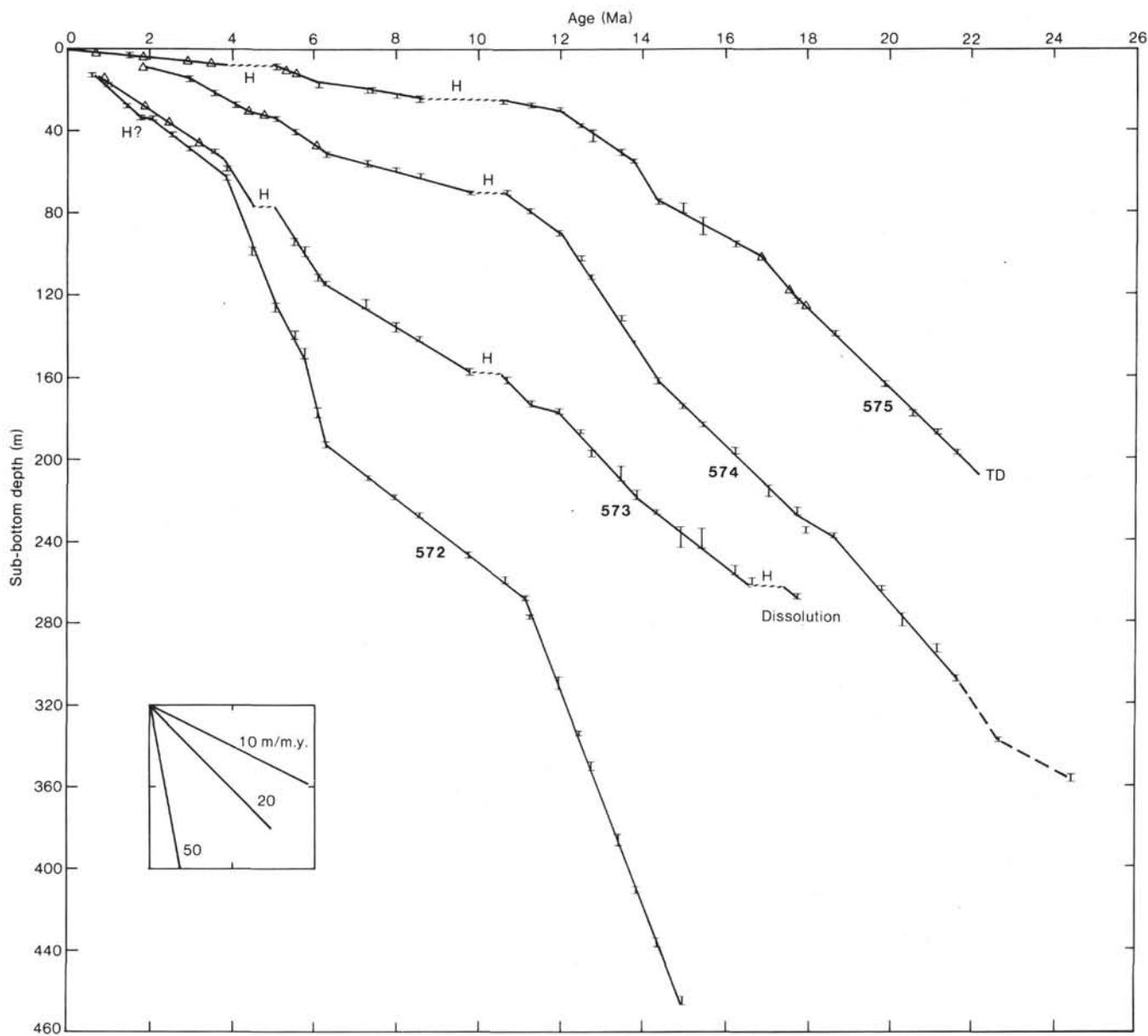


Figure 4. Age-versus-depth curves for the upper Cenozoic of DSDP Sites 572 to 575. Δ = paleomagnetic calibrations after Weinreich and Theyer (this volume); H = hiatus; TD = total depth. Vertical bars represent depth intervals in which diatom datums occur (see Tables 2 and 3). See also Barron et al. (this volume).

ermost Core 575-3 (Table 3) indicates hiatuses. At Sites 573 and 574, the hiatuses coincide with distinctive purple-banded sediment units (see site chapters), but such a unit was not observed at Site 575, where the hiatus is more extensive (10.5 to 8.6 Ma).

Near coincidence of the last occurrence of *Thalassiosira miocenica* (5.1 Ma; Sample 573-10-1, 65–66 cm) with the first occurrence of *Nitzschia jouseae* (4.5 Ma; Sample 573-9-5, 67–68 cm) indicates the probability of a hiatus (NH7 of Keller and Barron, 1983) at 76 m sub-bottom at Site 573. At Site 574, paleomagnetic stratigraphy suggests that this interval is present (Weinreich and Theyer, this volume; Fig. 4), but it is much compressed. At Site 575 a more extensive hiatus (5.1 to 3.6 Ma) removes sediments at the interval between Samples 575-2-1, 52–53 cm and 575-1,CC.

Finally, a possible hiatus or greatly compressed interval is present in Section 4 of Core 572A-4, as indicated by the near coincidence of the last occurrence of *Thalassiosira convexa* (2.1 Ma; Sample 572A-4-5, 66–67 cm) and the first occurrence of *Pseudoeunotia doliolus* (1.8 Ma; Sample 572A-4-3, 66–67 cm).

PALEOMAGNETIC CORRELATION, HOLE 575A

On Figure 5 the paleomagnetic data of Weinreich and Theyer (this volume) for Cores 1 to 10 of Hole 575A are correlated with the polarity sequence from the middle of paleomagnetic Chron 16 (Anomaly 5C) to middle Chron 17 (Anomaly 5D). This interpretation supports paleomagnetic calibrations for the N6/N7 planktonic foraminiferal zonal boundary and the CN2/CN3 calcareous nannofossil zonal boundary proposed by Ryan et al.

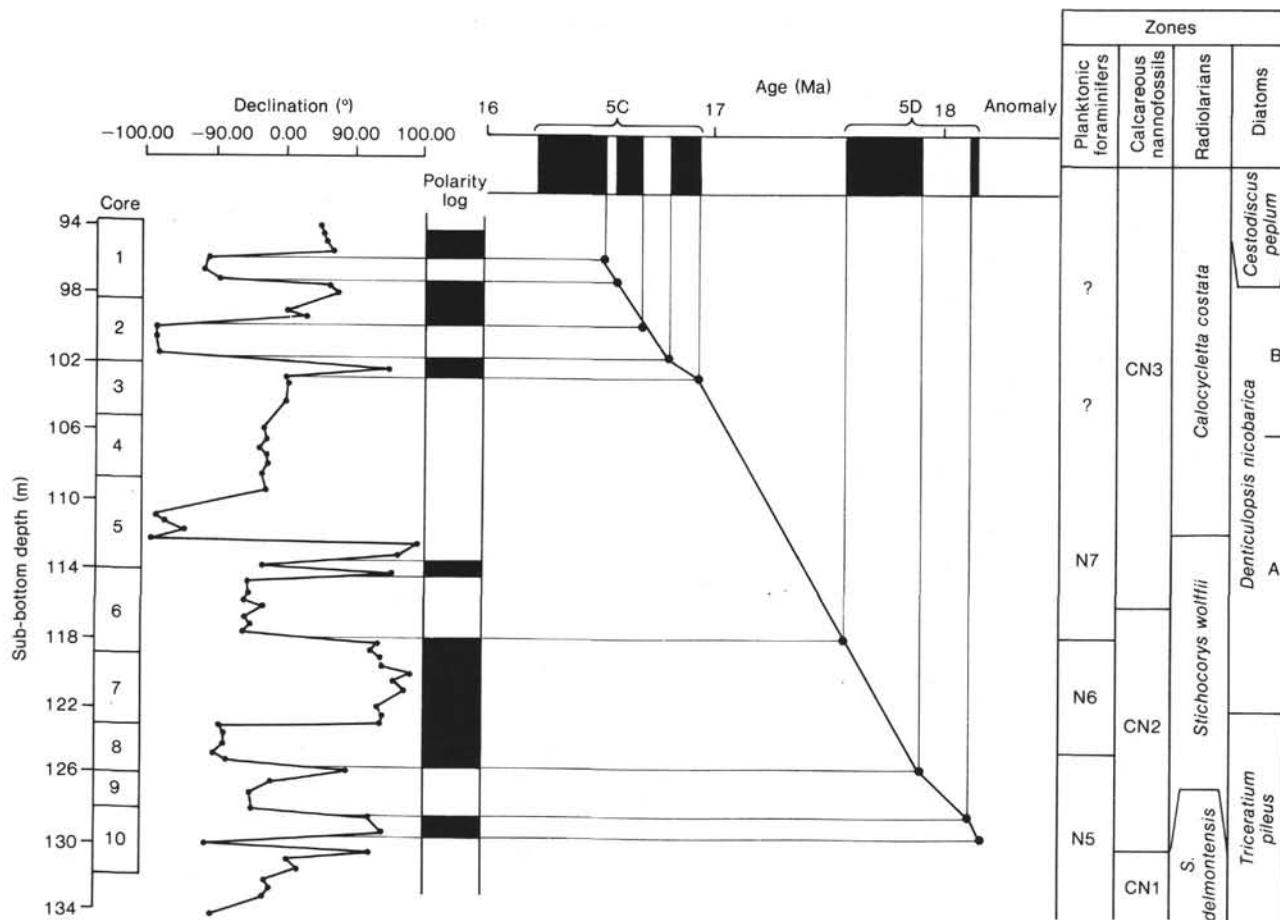


Figure 5. Suggested correlation of the polarity sequence of Weinreich and Theyer (this volume) for Cores 575A-1 through 575A-10 with the paleomagnetic time scale of Berggren et al. (in press). Planktonic foraminifer, calcareous nannofossil, and radiolarian zones are after the site chapter.

(1974) and Berggren (1981). It also is compatible with the paleomagnetic correlations (Poore et al., 1983) of planktonic foraminiferal Zone N8 and calcareous nannofossil Zones CN3 and CN4 with the upper reversed event of paleomagnetic Chron 16. In addition, the correlation of Figure 5 produces a relatively straight age-versus-depth curve for the lower Miocene of Sites 574 and 575 when coupled with younger diatom datum levels tied directly to paleomagnetics (by Burckle, 1978) and older diatom datum levels calibrated indirectly with paleomagnetics (by Barron et al., in press).

The ranges of key diatoms in Cores 1 to 10 of Hole 575A are presented on Figure 6. The sequence of datums in the interval from the middle part of the *Triceratium pileus* Zone to the lowermost *Cestodiscus peplum* Zone agrees well with the sequence at Sites 574 and 575 (Table 3), and with the sequences at Sites 71, 77, and 495 (Barron, 1983). As discussed by Barron (1983), Burckle's (1978) correlations of the first occurrence of *Annellus californicus* with upper Chron 16 and of the first occurrence of *Cestodiscus peplum* with uppermost Chron 17 are discounted, because these datums consistently occur in the reverse order. The *Annellus californicus* first-occurrence datum of Burckle (1978), however, may represent a recurrence, because the species becomes sparse to

absent above its initial occurrences (Barron, 1983). The remaining diatom datum levels on Figure 6 are correlated directly with paleomagnetic stratigraphy for the first time. Occurrence data are presented, in part, on Table 4. The *Thalassiosira spinosa* and *T. spumellaroides* last-occurrence datums are regarded with some doubt, because they represent isolated sparse occurrences. The other datum levels are placed above or below continuous occurrences, although *Annellus californicus*, *Craspedodiscus coscinodiscus* s. str., and *Triceratium pileus* are generally sparse.

QUANTITATIVE DIATOM BIOSTRATIGRAPHY

Quantitative diatom data for the late early Miocene to latest Miocene (17.8 to 6.3 Ma) of Sites 572, 574, and 575 are presented on Tables 4 to 7. These data are supplemented by data from DSDP Sites 77 (within 10 km of Site 573) and 158 (Tables 8 to 10) to complete a transect from the easternmost equatorial Pacific to the central Pacific (Fig. 1). For the late early and middle Miocene, one to two samples per 100,000-yr. span in the section were counted from Sites 158, 572, 574, and 575. For the late Miocene and for Site 77, sampling intervals average one per 200,000 to 300,000 yrs. The age-versus-depth curves (Figs. 4 and 5) were used to assign absolute ages

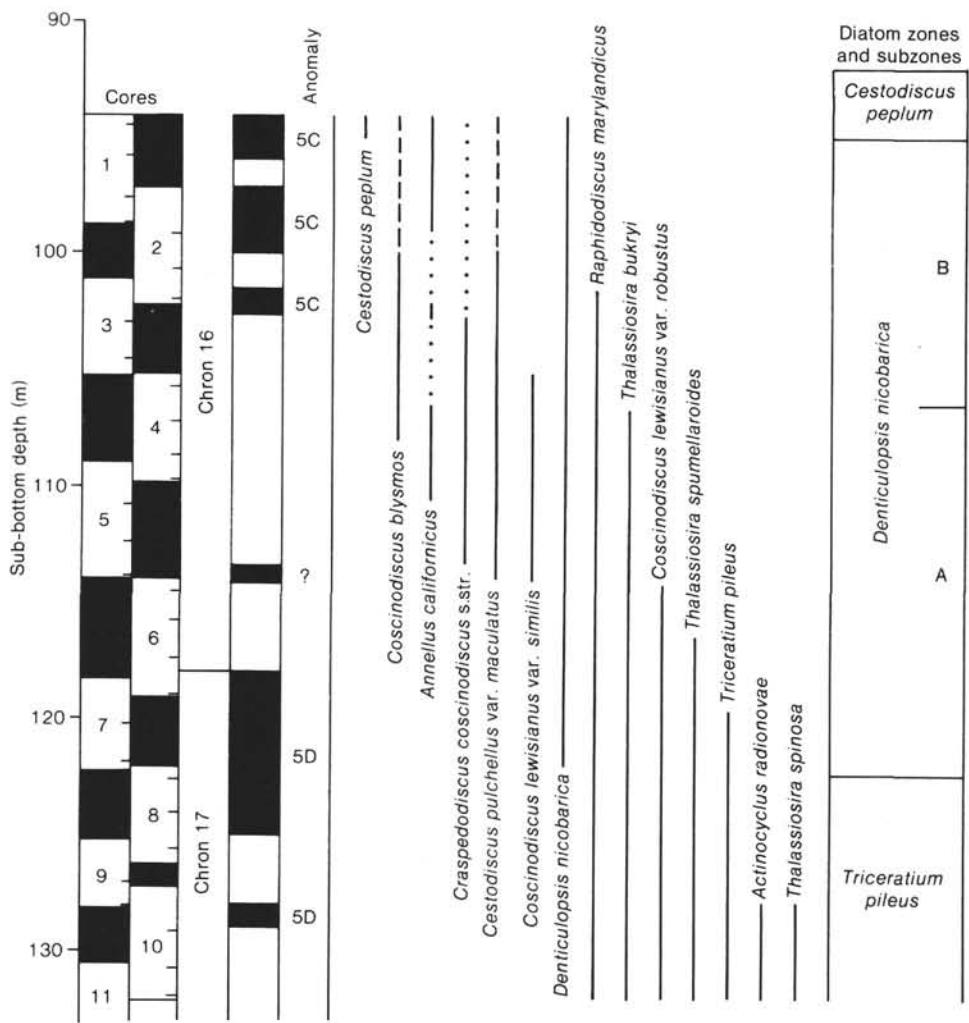


Figure 6. Correlation of diatom ranges in Cores 575A-1 through 575A-10 with paleomagnetic stratigraphy. Refer to Figure 5 and Table 3.

to the Leg 85 samples, whereas curves constructed with the same datums and time scale (Barron et al., in press) were used to assign ages to the Site 77 and Site 158 samples. These ages, therefore, are assigned solely by diatom datum level and paleomagnetic control, and they provide a framework for evaluating the abundance trends of individual diatom species and assessing their use for biostratigraphy. Where quantitative changes have been induced by abrupt region-wide changes in paleoceanography, these changes should approach isochroneity in the equatorial Pacific sections (Burkle and Trainer, 1979; Barron and Keller, 1983). In addition, quantitative data obtained from the sections can be useful in directly establishing the paleogeography of individual species during the late early Miocene to latest Miocene in the equatorial Pacific, and in determining paleoceanographic and paleoclimatic changes.

In the following section, quantitative trends of individual species will be discussed in the light of their stratigraphic value, and differences in the abundance of these species across the equatorial Pacific will be noted. Pale-

oceanographic and paleoclimatic interpretations are treated in Barron (this volume). The error in assigning absolute ages to the samples from the age-versus-depth curves is believed to be as much as 100,000 yrs., so that distinctive quantitative changes occurring at two or more sites within 100,000 yrs. of each other will be treated as isochronous. It is hoped that CaCO_3 and isotope stratigraphy will provide the stratigraphic resolution necessary to test the isochroneity of these changes.

Actinocyclus ehrenbergii has two brief abundance spikes in the middle Miocene, where abundance values double to triple. One event at about 13.2 Ma is apparent at Site 574 (Table 5) and Site 572 (Table 6), where *A. ehrenbergii* increases to 10% of the assemblage. This event seems more abrupt at Site 572, so it may be more distinctive in the eastern equatorial Pacific. The event was apparently missed by the broader sampling interval at Site 77, and it predates the Site 158 sedimentary record. The second *A. ehrenbergii* abundance spike at about 12.1 Ma is recognizable at Sites 547, 77, 572, and 158 (Tables 5, 6, 8, and 9). Again, abundance values reach 8

Table 8. Percent planktonic diatoms in Cores 17 to 28 of Hole 77B

Note: + means < 1% or encountered after the count; — means not encountered. 300 specimens were counted.

to 10%, with the exception of Site 158, where values reach 6%. Overall, *A. ehrenbergii* seems slightly more abundant in the west than in the east.

Actinocyclus ellipticus s. ampl. shows no distinctive trends for biostratigraphy, although it is generally most common in the *Coscinodiscus gigas* var. *diorama* Zone (13.5 to 12.8 Ma) at all sites, and exhibits a slight preference for the western sites.

Actinocyclus ingens was introduced to the tropics from middle latitudes (Barron, 1983), and it was excluded from the tropics before its extinction at higher latitudes (Burckle, 1978). It is generally present in low numbers (< 10%) in middle Miocene sediment, but it reaches values of 20 to 50% in isolated samples from the middle Miocene of Sites 574, 77, 572, and 158 (Tables 5, 6, 8, and 9). Some of these events appear to be roughly isochronous (about 50% at 14.8 Ma, Sites 574 and 572; about 25 to 30% at 14.5 Ma, Sites 574 and 572; and about 30% at 13.5 Ma, Sites 77 and 574). Other isolated abundance spikes, especially those at Site 77, show little comparison in site-to-site correlations. *Actinocyclus ingens* is a robust diatom that would be concentrated by dissolution of other less resistant diatoms. Dissolution, however, is not solely responsible for the abundance spikes

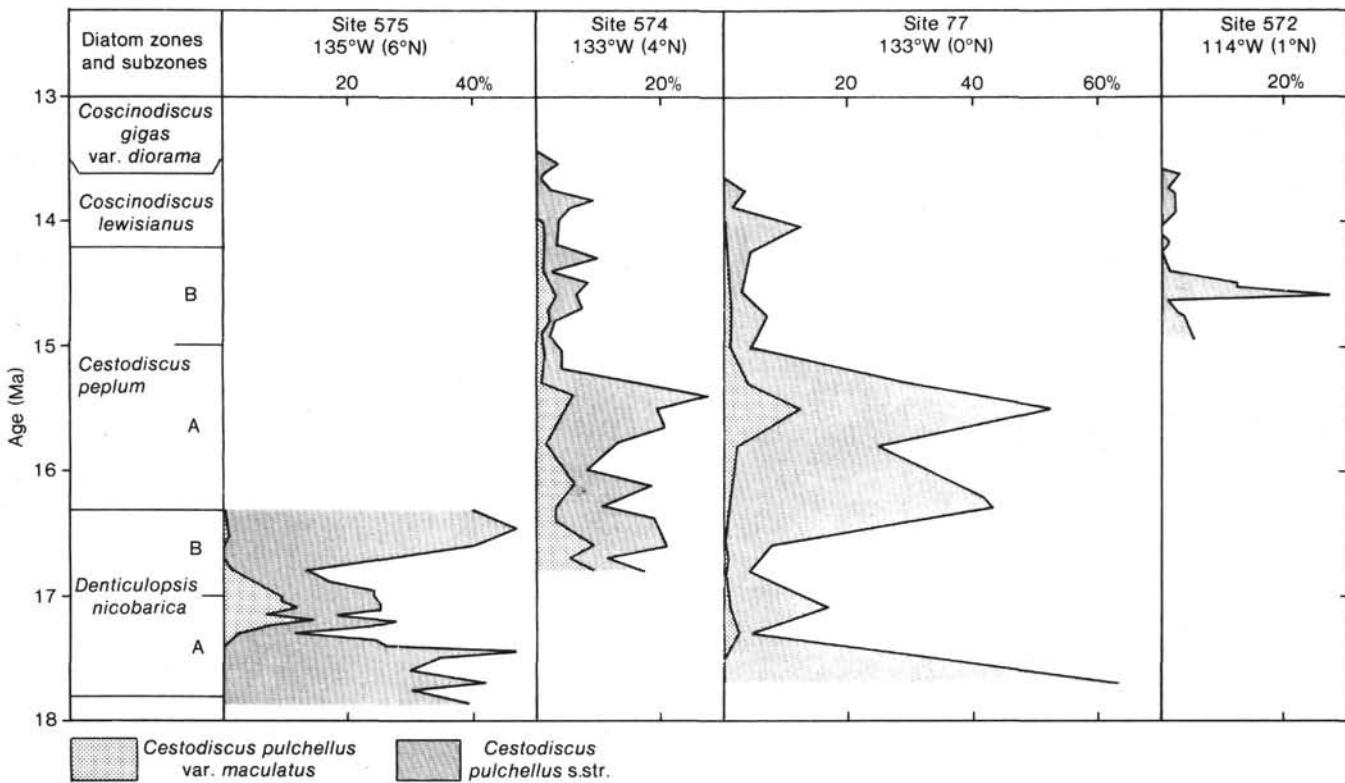
of *A. ingens*, because other resistant diatoms such as *Cestodiscus pulchellus* and *Coscinodiscus radiatus* are not concentrated in the same samples and less resistant species (*Denticulopsis* spp.) are not selectively removed from the same samples. Core 77B-21 (13.1 to 12.9 Ma) and Sample 158-34-1, 50-51 cm (12.65 Ma) do, however, appear to have dissolved assemblages along with increased numbers of *A. ingens*.

Quantitative trends for *Cestodiscus pulchellus* and *C. pulchellus* var. *maculatus* are shown on Figure 7. Sites 575 and 77 show good comparison in abundance trends of *C. pulchellus* s. ampl. between 18 and 16 Ma, with abundant *C. pulchellus* s. ampl. at 17.5 Ma declining sharply by one half or more (to 10 to 20%) by 17.3 Ma. *Cestodiscus pulchellus* s. ampl. increases again at about 16.6 Ma to values around 40% of the assemblage at Sites 575 and 77, but it declines abruptly at 15.4 to 15.2 Ma to values that remain low (<10%) for the remainder of its range. Where they can be compared, Sites 575 and 77 have similar abundances of *C. pulchellus* s. ampl., but Site 574 has abundances roughly half of those sites between 16.6 and 15.3 Ma. These lower values at Site 574 possibly reflect the site's position at 16.6 to 15.3 Ma: just south of the equator, within the area corre-

Table 9. Percent planktonic diatoms in Cores 22 to 34 of Hole 158.

Zone and subzone	Core-Section, interval (cm)	Sub-bottom depth (m)	<i>Actinocyclus ehrenbergii</i>	<i>A. ellipticus</i> s. ampl.	<i>A. ingens</i>	<i>Asteromphalus/Asterolampra</i>	<i>Coscinodiscus marginatus</i>	<i>C. nodulifer</i>	<i>C. plicatus/C. yabei</i>	<i>C. radiatus</i> s. ampl.	<i>C. tabularis</i> s. ampl.	<i>C. temperi</i> var. <i>delicata</i>	<i>C. tuberculatus</i>	<i>C. spp.</i>	<i>Craspedodiscus coscinodiscus</i> s. str.	<i>Denticulopsis hustedtii</i>	<i>D. punctata</i> f. <i>hustedtii</i>	<i>Hemidiscus cuneiformis</i>	<i>Nitzschia</i> spp.	<i>Rhizosolenia</i> spp.	<i>Rosselia paleacea</i> s. ampl.	<i>Rouvia</i> spp.	<i>Syndra joussea</i>	<i>Thalassionema nitzschioides</i>	<i>T. nitzschioides</i> var. <i>parva</i>	<i>T. robusta</i>	<i>Thalassiosira leptopus</i>	<i>T. spp.</i>	<i>Thalassiothrix longissima</i>	<i>Actinopychus</i> spp.	Miscellaneous diatoms	Estimated age (Ma)		
Coscinodiscus yabei, Subzone A	22-2, 30-32	190.8	—	6	—	1	1	2	4	6	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10.8				
	22-6, 30-32	196.8	—	4	—	1	—	4	8	4	9	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10.9					
	23-2, 30-32	199.8	—	2	—	+	+	7	+	3	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10.95					
	23-5, 30-32	204.3	—	+	—	—	—	9	2	1	1	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.05					
	24-1, 108-110	208.1	—	+	—	+ —	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.1					
	24-3, 30-32	210.3	—	+	—	—	—	1	2	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.15					
	25-2, 30-32	217.8	—	+	—	—	—	3	+	+	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.25					
	25-6, 30-32	223.8	—	2	—	—	—	3	7	+	6	—	—	—	—	—	—	10	—	2	—	—	—	—	—	—	—	—	11.35					
	26-2, 30-32	226.8	—	3	—	+	—	3	+	—	—	—	—	—	—	—	—	50	—	+	+	1	—	—	—	—	—	—	11.4					
	26-6, 30-32	232.8	+	3	—	—	—	4	1	—	1	—	—	—	—	—	—	35	—	+	1	—	—	—	—	—	—	—	11.5					
<i>Actinocyclus moronensis</i>	27-2, 30-32	235.8	—	1	—	+	—	3	+	+	+	+	—	—	—	—	—	22	—	—	—	—	—	—	—	—	—	—	11.55					
	27-6, 30-32	241.8	—	—	—	—	—	2	1	—	1	+	—	—	—	—	—	70	—	+	+	—	—	—	—	—	—	—	11.65					
	28-1, 30-32	243.3	—	3	—	+	—	1	3	1	3	—	—	—	—	—	—	61	—	+	+	—	—	—	—	—	—	—	11.7					
	28-3, 30-32	246.3	—	1	—	—	+	2	2	—	2	1	+	+	—	—	—	68	—	+	1	+	—	—	—	—	—	—	11.75					
	29-3, 30-32	255.3	—	2	—	+	—	+	3	—	3	+	—	—	—	—	—	61	—	+	1	+	1	+	—	—	—	—	11.95					
Craspedodiscus coscinodiscus	30-1, 30-32	261.3	+	1	—	—	4	2	5	13	5	1	1	1	—	1	—	1	2	—	—	—	—	—	—	—	—	12.05						
	30-5, 30-32	267.3	2	3	—	+	3	8	2	2	2	+	18	1	—	2	+	1	2	—	—	—	—	—	—	—	—	12.15						
	31-1, 30-32	270.3	6	2	—	1	3	3	3	2	3	2	4	2	—	4	2	4	2	—	2	+	1	—	—	—	—	12.2						
	32-2, 30-32	280.8	+	3	—	+	—	5	3	—	3	—	17	+	+	5	+	—	2	—	2	—	—	+	9	42	—	—	7	—	—	12.35		
	32-4, 30-32	283.8	+	1	+	—	—	4	4	+	7	+	13	1	1	7	+	+	+	—	+	+	—	—	11	29	—	—	—	13	—	5	12.4	
	33-2, 30-32	288.3	4	+	—	+	+	1	3	1	7	2	9	1	+	2	+	—	+	+	—	—	—	—	—	17	23	—	—	—	18	+	2	12.5
	34-1, 50-51 ^a	296.5	2	15	23	1	7	—	4	1	1	1	10	1	—	1	1	—	1	—	—	—	—	—	17	5	—	—	—	11	—	1	12.65	

Note: + means <1% or encountered after the count; — means not encountered. 300 specimens were counted.

^a 200 specimens were counted.Figure 7. Relative abundance of *Cestodiscus pulchellus* and *C. pulchellus* var. *maculatus* at DSDP Sites 575, 574, 77, and 572 (after 17.8 Ma), plotted against age. Refer to Tables 4, 5, 6, and 8.

sponding to maximum primary productivity and opal accumulation in the Holocene ocean (van Andel et al., 1975). *Cestodiscus pulchellus* var. *maculatus* typically makes up less than half of the *C. pulchellus* s. ampl. populations, except between 17.2 and 17.0 Ma at Site 575, where it is roughly equivalent in numbers with the type form.

Quantitative trends of *Coscinodiscus nodulifer* s. ampl. across the equatorial Pacific are shown on Figure 8. *C. nodulifer* is typically less than 10% of the assemblage for the middle Miocene and most of the late Miocene, and it shows no definitive abundance peaks that can be correlated between the four sites. At about 8 Ma, however, *C. nodulifer* approaches values of 20% at easternmost Site 158, and it remains at comparable values through 6.2 Ma. During this same interval (8.0 to 6.2 Ma), values of *C. nodulifer* at the other sites are gener-

ally half of those at Site 158. L. H. Burckle (pers. comm., 1983) relates *C. nodulifer* to equatorial upwelling in the modern Pacific Ocean, so it is possible that the greater values of *C. nodulifer* after 8 Ma at easternmost Site 158 reflect enhanced upwelling there with respect to the more western sites.

The quantitative trends of *Coscinodiscus radiatus* s. ampl. before 14.2 Ma are shown on Figure 9. Late early Miocene and early middle Miocene forms tabulated as *C. radiatus* s. ampl. may include some forms allied with *C. blysmos*, which differs from *C. radiatus* only by the presence of a central indentation. The *C. radiatus* morphology is relatively simple, and it is entirely possible that different species can achieve it independently. The biostratigraphically most definitive trends in *C. radiatus* abundance include abundance spikes (20% or more) at 17.0 to 16.7 Ma at Sites 575 and 574 (not as pronounced

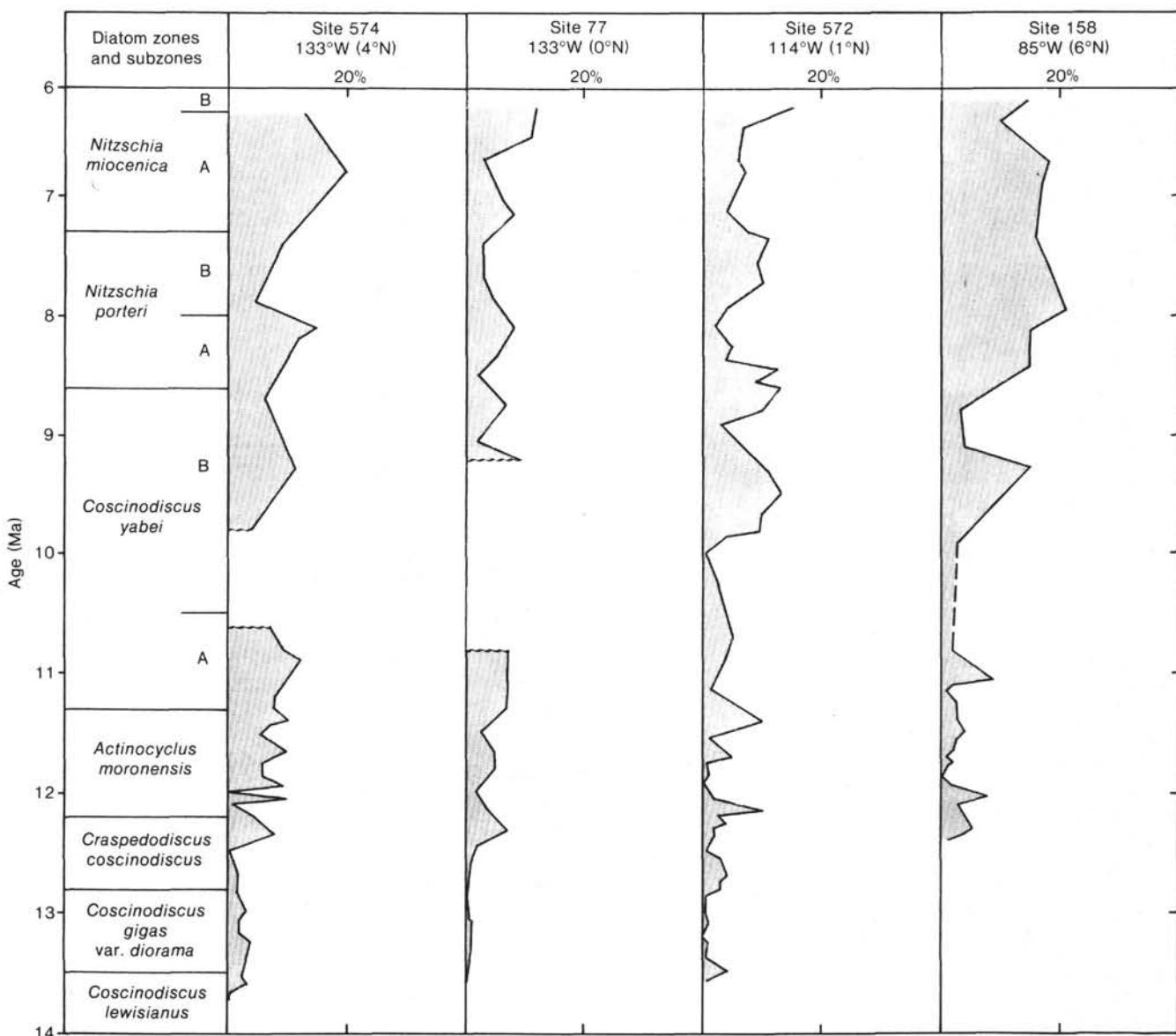


Figure 8. Relative abundance of *Coscinodiscus nodulifer* s. ampl. (before 6.1 Ma) at DSDP Sites 574, 77, 572, and 158, plotted against age. Refer to Tables 5 to 10.

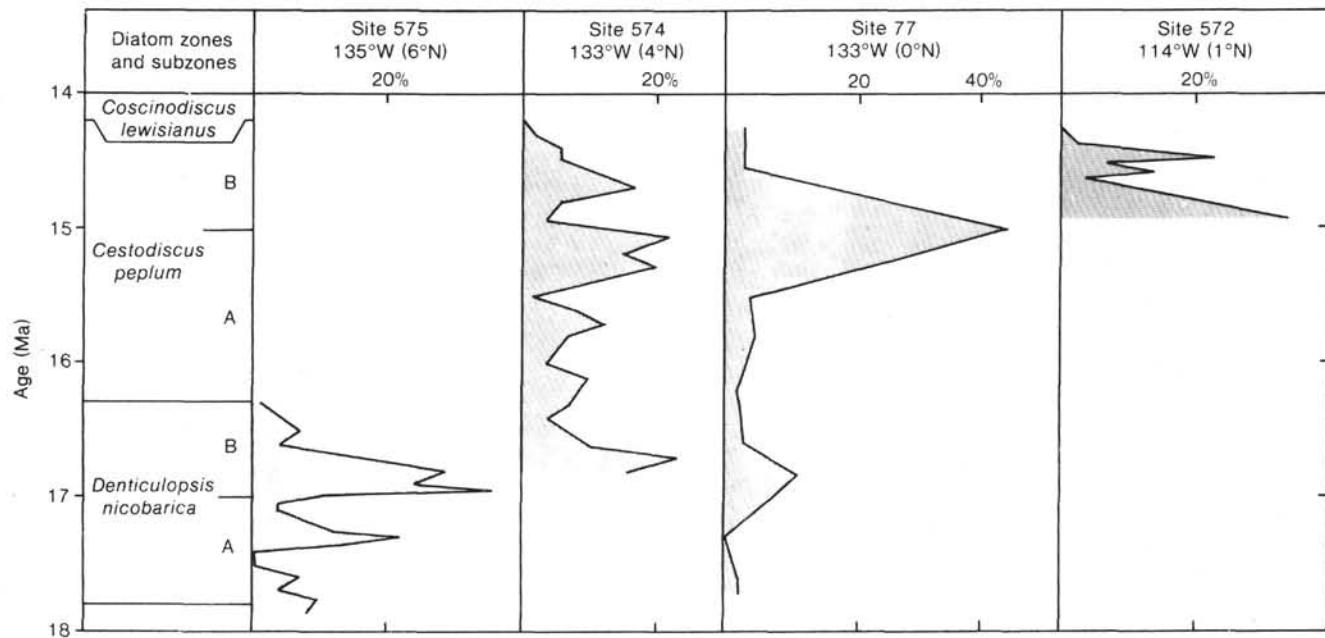


Figure 9. Relative abundance of *Coscinodiscus radiatus* s. ampl. (between 17.8 and 14.2 Ma) at DSDP Sites 575, 574, 77, and 572, plotted against age. Refer to Tables 4, 5, 6, and 8.

at Site 77) and at about 15.3 to 14.7 Ma at Sites 574, 77, and 572. *Coscinodiscus radiatus* is robust and relatively resistant to dissolution, but other less resistant diatoms (including *Denticulopsis* spp.) do not appear to have been selectively removed in samples containing common *C. radiatus*, and dissolution alone cannot explain the abundance spikes. *Coscinodiscus radiatus* s. ampl. shows no noticeable differences in its abundance at the various sites, although the abundance spikes (e.g., 16.8 and 15.0 Ma) at Site 574 are typically one half the size of the corresponding spikes at Sites 575 and 77. It should also be pointed out that between 18 and 14.5 Ma there appears to be an antithetical relationship between the abundance peaks for *Coscinodiscus radiatus* and *Cestodiscus pulchellus* (compare Figs. 7 and 9).

Coscinodiscus tabularis s. ampl. generally is most common (10% or more) between 13.5 and 12.5 Ma at Sites 574, 77, and 572, although it is also typically common between 14.6 and 13.7 Ma at Site 574. The species appears to show a slight preference for the central Pacific after 12.5 Ma, as compared with easternmost Pacific Site 158.

Coscinodiscus tuberculatus remains generally sparse to few (10% or less) throughout much of its range (14.0 to 12.0 Ma), but it abruptly increases in abundance to 20 to 36% at 12.4 to 12.2 Ma, immediately before its last consistent occurrence (12.0 Ma). Abundance values are somewhat greater at the western sites (574 and 77) and least of all at easternmost Site 158. At all four sites (574, 77, 572, and 158), *C. tuberculatus* declines sharply in abundance to values of 1 to 2% between 12.2 and 12.1 Ma.

Figure 10 gives the quantitative trends of *Denticulopsis hustedtii* across the equatorial Pacific. As discussed by Burckle (1978) and Barron (in press), this high- to middle-latitude species was introduced into the tropics

in the middle Miocene and was excluded from the tropics by the early late Miocene, well before its extinction at higher latitudes in the early Pliocene. After a brief incursion into low latitudes at about 14.2 Ma (Sites 572 and 574), *D. hustedtii* became established in the region by about 13.9 Ma. Thereafter, *D. hustedtii* persisted at relatively low abundances (5 to 10% at Sites 574 and 77; 10 to 15% at Site 572) until about 12.0 Ma, when the abundance increased dramatically to 50 to 60% at all sites except Site 77. The lack of such a dramatic increase at Site 77 either reflects the greater sample spacing there or may indicate a hiatus (see greatly reduced sediment accumulation rate between 12.0 and 11.5 Ma at nearby Site 573, Fig. 2). At about 11.5 Ma, *D. hustedtii* declines just as abruptly to values of 10%. By 11.1 Ma it has dropped to 2% or less, and by 10.5 Ma it has disappeared from the tropical Pacific. *Denticulopsis hustedtii* is more abundant at the eastern sites (Sites 572 and 159) even during its abundance spike (12.0 to 11.5 Ma), where only two single points at Site 574 exceed 50% abundance and values at 11.9 to 11.8 Ma drop abruptly but briefly to below 10%.

Denticulopsis nicobarica exhibits a curiously bimodal distribution in its range (17.8 to 13.2 Ma) in the equatorial Pacific (Fig. 11). It is generally common to abundant (>20%) between 17.5 and 17.1 Ma, but drops off sharply in abundance to values of 5% or less for the interval from 16.9 to 15.7 Ma. Between 15.5 and 15.0 Ma, *D. nicobarica* increases gradually in abundance to 30 to 50%, and it remains abundant through 13.6 Ma. Thereafter, *D. nicobarica* decreases abruptly to values of 5% or less by 13.4 Ma. Undoubtedly, dissolution and/or winnowing of the small, relatively fragile *D. nicobarica* tests are responsible for much of the decline of *D. nicobarica* between 16.9 and 15.7 Ma, because other small delicate species (*Nitzschia* spp., *Thalassionema* spp.,

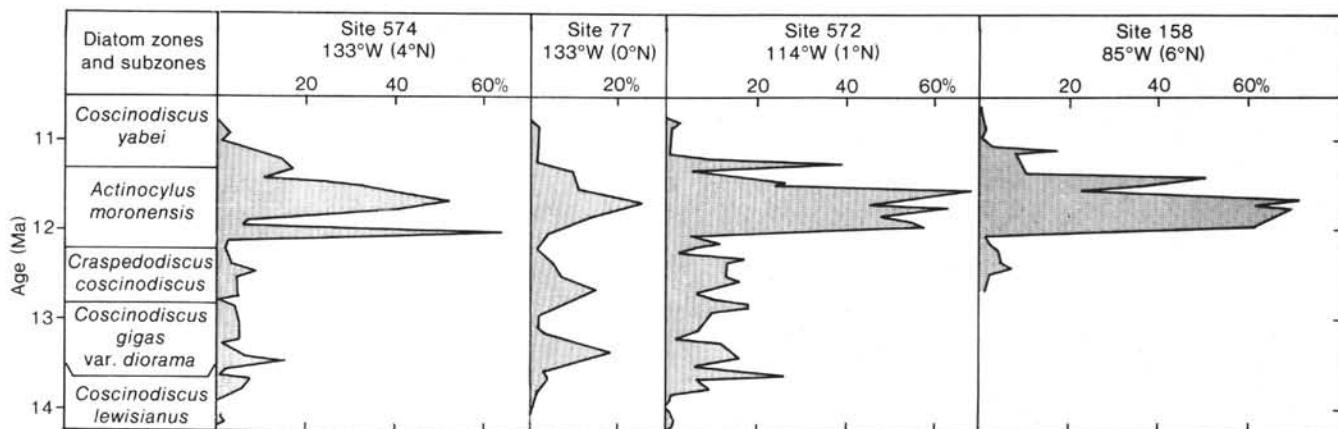


Figure 10. Relative abundance of *Denticulopsis hustedtii* at DSDP Sites 574, 77, 572, and 158, plotted against age. Refer to Tables 5, 6, 8, and 9.

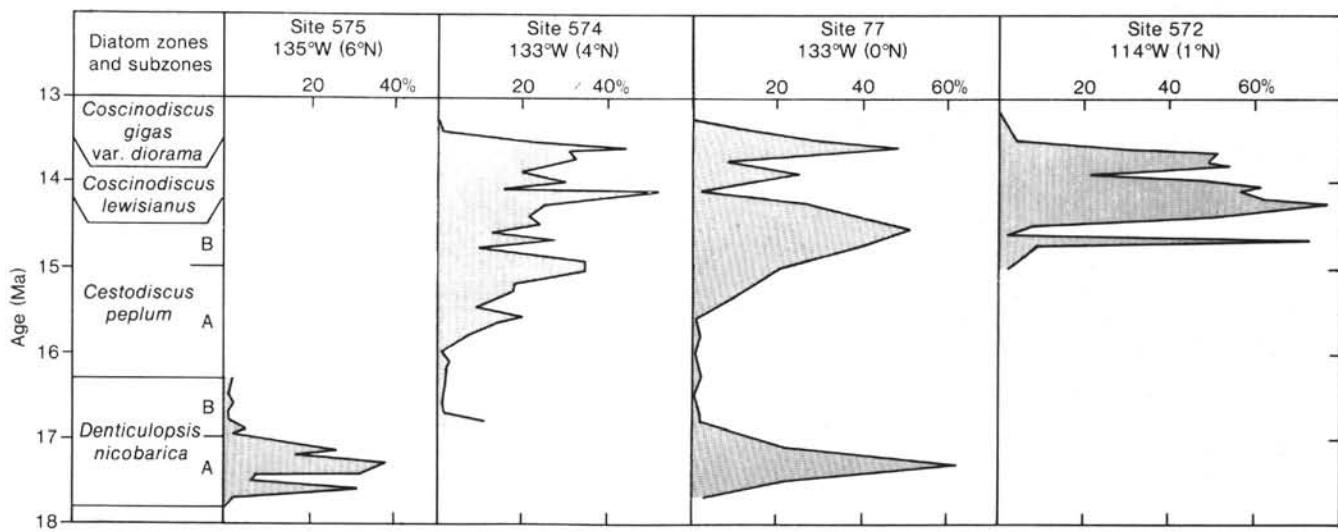


Figure 11. Relative abundance of *Denticulopsis nicobarica* at DSDP Sites 575, 574, 77, and 572, plotted against age. Refer to Tables 4, 5, 6, and 8.

and *Thalassiothrix* spp.) are also sparse in that interval. This decline in *D. nicobarica* abundance corresponds to the interval of warmest isotopic temperatures of the Miocene (Savin et al., 1981) and may reflect decreased opal productivity caused by decreased equatorial upwelling (Barron, this volume).

Denticulopsis praedimorpha is a high- to middle-latitude diatom which had a brief incursion into the tropics between 12.9 and 12.6 Ma (Tables 5, 6, and 8). The most pronounced incursion is at about 12.6 Ma; values of 20% or more are encountered at the corresponding level at Sites 574 and 77. This horizon was not observed at eastern Sites 572 and 158, possibly because of its brevity and the sampling interval. Alternatively, concentration of *D. nicobarica* at this horizon at the western sites may reflect transportation of the species from higher southern latitudes by bottom waters, because hiatus NH3 of Keller and Barron (1983) was more dominant in the western Pacific than in the eastern Pacific at that time.

Hemidiscus cuneiformis is generally rare throughout its early range, but it triples in abundance (to about

10%) at about 11.0 Ma at Sites 574, 77, and 158. Abundance values are typically greatest at easternmost Site 158, especially in the late Miocene (Tables 7 and 10).

Figure 12 shows the abundance trends for *Nitzschia porteri* sensu Burckle (1972) and *N. miocenica* between 10 and 6.2 Ma. (*N. porteri* was not separated from other *Nitzschia* species below the 10-Ma level.) The record at Site 572 indicates an abundance spike (40% or more) for *N. porteri* between 10.3 and 9.8 Ma. This interval is removed by hiatuses at Sites 574 and 77 (Fig. 4 and Barron et al., in press) and is greatly compressed at Site 158 (Keller et al., 1982); but the Site 574 and Site 158 curves both show a decline in abundance of *N. porteri* from 9.8 Ma (20 to 30%) to 9.3 Ma (4 to 12%). The *N. porteri* curves between 9 and 7 Ma show little correlation between the sites, possibly reflecting the relatively broad (200,000 to 300,000 yrs.) sampling interval; *N. porteri* appears to be slightly more common at the western sites in this interval. From 7.4 to 6.8 Ma, *N. porteri* declines in abundance as *N. miocenica* develops and expands, reflecting the evolutionary transition between the two species proposed by Burckle (1972). *N. miocenica* also seems

Table 10. Percent planktonic diatoms in Sample 158-15-6, 30-32 cm and Cores 16 to 21 of Hole 158 and in Cores 12 to 16 of Hole 77B.

Zone and subzone	Core-Section, interval (cm)	Sub-bottom depth (m)	<i>Actinocyclus ehrenbergii</i>	<i>A. ellipticus</i> s. ampl.	<i>Asteromphalus/Asterolampra</i>	<i>Coscinodiscus marginatus</i>	<i>C. nodulifer</i>	<i>C. pilatus/C. yabei</i>	<i>C. radiatus</i> s. ampl.	<i>C. tabularis</i> s. ampl.	<i>C. temperei</i> var. <i>delicata</i>	<i>C. spp.</i>	<i>Hemidiscus cuneiformis</i>	<i>Nitzschia cyclindrica</i> s. ampl.	<i>N. fossilis</i>	<i>N. marina</i>	<i>N. miocenica</i> s. ampl.	<i>Rhizosolenia</i> spp.	<i>Rosselia paleacea</i> s. ampl.	<i>R. praepaleacea</i>	<i>Rouxia</i> spp.	<i>Thalassionema nitzschioides</i>	<i>T. nitzschioides</i> var. <i>parva</i>	<i>T. robusta</i>	<i>Thalassiosira bucklandiana</i>	<i>T. eccentrica</i>	<i>T. leptopus</i>	<i>T. preconvexa</i>	<i>T. spp.</i>	<i>Thalassiothrix longissima</i>	<i>Triceratium cinnomomeum</i>	Miscellaneous diatoms	Estimated age (Ma) (after Barron et al., in press)
Hole 158																																	
<i>Nitzschia miocenica</i>	B	15-6, 30-32	133.8	— 2 2 — 15	— + + — —	2 — 1 2 1	— — 1 2 5	— + — 36 6	— — 3 + 1	1 15 1 1	6.2																						
	A	16-2, 30-32	136.8	— 3 1 — 10	— + — 2	3 — + 4	— 1 1 1	— 6 36 3	— 1 + —	+ 21 1 3	6.35																						
	A	16-6, 30-32	142.8	— 2 2 — 18	— 1 + + 4	— 1 + 8	— 2 4	— 2 31 2	— 4 + —	- 14 2 +	6.7																						
	B	17-2, 30-32	145.8	— 4 1 + 17	— 1 —	4 — 1 + 2	+ — + 2	— 3 27 5	— — 7	+ 27 + +	6.9																						
	A	17-6, 30-32	151.8	— + 1 — 16	— + + 1	1 + 1 1 3	3 — 1 3 5	— 4 + 39 1	— + +	+ 17 + +	7.3																						
	B	18-2, 30-32	154.8	+ 2 2 — 18	— + + +	8 1 2 + —	— 1 1 5 1	— 2 1 27 6	— 2 —	- 18 + +	7.55																						
<i>Nitzschia porteri</i>	B	18-6, 30-32	160.8	1 4 + — 21	— + 1 + + 6	3 + 1 — 3	— + 4 1	— 1 + + 19 4	— + 2	+ 22 — 3	7.9																						
	A	19-2, 30-32	163.8	— 4 3 — 15	— 1 4 — 2	2 1 1 + —	— 1 — 4 5 2	— 29 2	— + 2	- 2 27 1 1	8.05																						
	A	19-6, 30-32	169.8	— 3 + — 14	— 2 4 + —	5 + + —	— 1 — 1 2	— — 35 13 1	— 2 —	+ 14 1 1	8.45																						
	B	20-3, 30-32	174.3	— 2 3 — 3	3 + + 2 + —	2 1 1 —	— 5 — 2 10	— + 24 14 1	— 1 —	+ 23 + 1	8.8																						
	B	20-6, 30-32	178.8	— 3 + — 4	4 + 1 2 + —	+ 1 —	— 6 + 5 5	— + 53 3	— + +	- 2 10 — 2	9.1																						
	B	21-2, 30-32	181.8	— 7 1 1 15	3 2 16 1 5	— — —	— 3 + — 2 1 + + —	— 15 1	— 1 —	+ 15 4 1	9.25																						
<i>Coscinodiscus yabei</i>	B	21-5, 30-32	186.3	— 2 + — 3 5 1 7 + 1	+ — — —	— 17 + — 2 + 3 1 — 27 3	— + + —	— + —	+ 20 1 3	9.9																							
	Hole 77B																																
	B	12-3, 94-98	113.6	+ 1 1 — 12	— + + — +	+ + + + 19	— — 3 1 — 1 34 7	— — 1 + + 1 12 1 2	6.25																								
	A	12-6, 30-32	117.4	— 2 + — 11	— + — —	1 + + 1 23	— + 4 + — 1 29 8	— 1 1 — 2 11 1 3	6.5																								
	A	13-2, 30-32	120.6	+ 3 + — 3	— 1 —	+ + 4 1 5	— 2 5 1 — 3 54 7	— 1 + — 2 5 + 2	6.7																								
	A	13-4, 102-106	124.3	+ 2 3 — 6	— 1 —	2 + + + 6	3 — 1 4 1 — 3 49 4	— 2 1 — + 8 2 1	7.0																								
	A	13-6, 30-32	126.6	+ 3 3 — 8	— + + — 1	+ + + + 6	5 — 4 7 1 — 2 1 38 2	— 1 1 — + 14 1 —	7.15																								
<i>Nitzschia porteri</i>	B	14-2, 30-32	129.8	+ + + — 4	— + 2 —	+ 3 3 2 — 14 + + 10	2 + + — 30 23	— + 1 — + 4 2 —	7.4																								
	B	14-4, 90-94	133.4	+ 1 + — 3	— 1 —	3 3 + 1 — 22 + — 6	1 1 + — 18 25	— + 1 — 1 7 1 4	7.7																								
	A	14-6, 30-32	135.8	+ 3 + — 4	— 2 + +	+ 2 + — 13 + — 6 1 1 — + 30 29	— + 2 — + 5 +	— + 2 — + 5 +	7.85																								
	A	15-2, 30-32	138.9	+ + + — 8	— 1 + + + —	13 + — 6 + + — 1 36 21	2 + + 5 — 1 2 3 —	— 1 2 3 — 8.1																									
	A	15-4, 100-104	142.6	+ + + — 5	— 4 — + + + —	31 + — 6 — + + 31 10 2 1 + 3	— 3 3 + 8.35																										
	A	15-6, 23-25	144.8	+ + 1 — 2	— + + + —	31 + — 9 — 3 2 5 25 10	+ 2 + 2 — 2 2 1 2	8.5																									
<i>Coscinodiscus yabei</i>	B	16-2, 23-25	147.9	— + + — 7	7 + + + — 1	+ 2 — 23 + — 2 + + 1 + 37 10	— 1 + 3 — 6 + 3	8.75																									
	B	16-4, 100-104	151.7	+ + + — 2 + — 7 —	+ + + — 12 2 — 1 1 — 1 28 26	— 3 + 2 — 1 3 1 1	9.05																										
	B	16-6, 23-25	153.9	— 1 1 — 9	2 — 3 — 2 + + + —	18 2 — 4 + — + + 45 6	— 1 + 3 — 6 + —	9.2																									

Note: + means <1% or encountered after the count; — means not encountered. 300 specimens were counted.

to prefer the western sites (574 and 77) and central site (572) over the easternmost site (158).

Quantitative trends for *Synedra jouseana* are shown on Figure 13. The prominent abundance spikes at 16.6 and 15.8 Ma, where *S. jouseana* increases to 30% or more of the assemblage, are the most noticeable features of the *S. jouseana* curves. The interval of common ($\geq 20\%$) *Synedra jouseana* (16.8 to 15.7 Ma) coincides precisely with the interval of sparse *Denticulopsis nicobarica* (Fig. 11) in the latest early Miocene. After about 15.3 Ma, *S. jouseana* is typically sparse (5% or less) at all sites. Early middle Miocene abundance values are greatest at Site 77, the site farthest from the equator (about 5°S) at that time.

Thalassionema nitzschioides becomes a dominant equatorial Pacific diatom in the late middle Miocene between 14.0 and 12.2 Ma, where abundance values increase from about 10% to 40–50% (Fig. 14). Close sampling intervals (100,000 yrs. or less) at Sites 572 and 574 reveal considerable variability in *T. nitzschioides* abundance during the late middle Miocene, so that individual abundance spikes are difficult to correlate. There is

some suggestion, however, that abundance peaks at about 14.0 Ma and 13.2 Ma, and a generalized abundant interval between 12.4 and 11.9 Ma, are correlative. Between about 11.2 and 11.0 Ma, *T. nitzschioides* reaches its greatest numbers (60 to 70%) for the Miocene interval investigated (18.2 to 6.2 Ma) at all sites (possibly earlier at Site 77). Middle Miocene assemblages are dominated by shorter forms of *T. nitzschioides* (length-to-width ratios < 3) (= *T. nitzschioides* var. *parva* s. ampl.). Longer forms (length-to-width ratios ≥ 3) (= *T. nitzschioides* s. str.) are more important in the late Miocene. Sites 574, 77, and 572 all show a generalized abundance peak for *T. nitzschioides* var. *parva* s. ampl. between 8.2 and 7.3 Ma, but Site 158 shows no such peak. Other late Miocene trends in *T. nitzschioides* are difficult to correlate, which may again reflect high variability and relatively broad sampling intervals.

Thalassionema robusta shows a minor abundance peak between 12.15 and 12.0 Ma at all sites (Tables 5, 6, 8, and 9), with values at the western sites (574 and 77) slightly higher than those at the eastern sites (572 and 158).

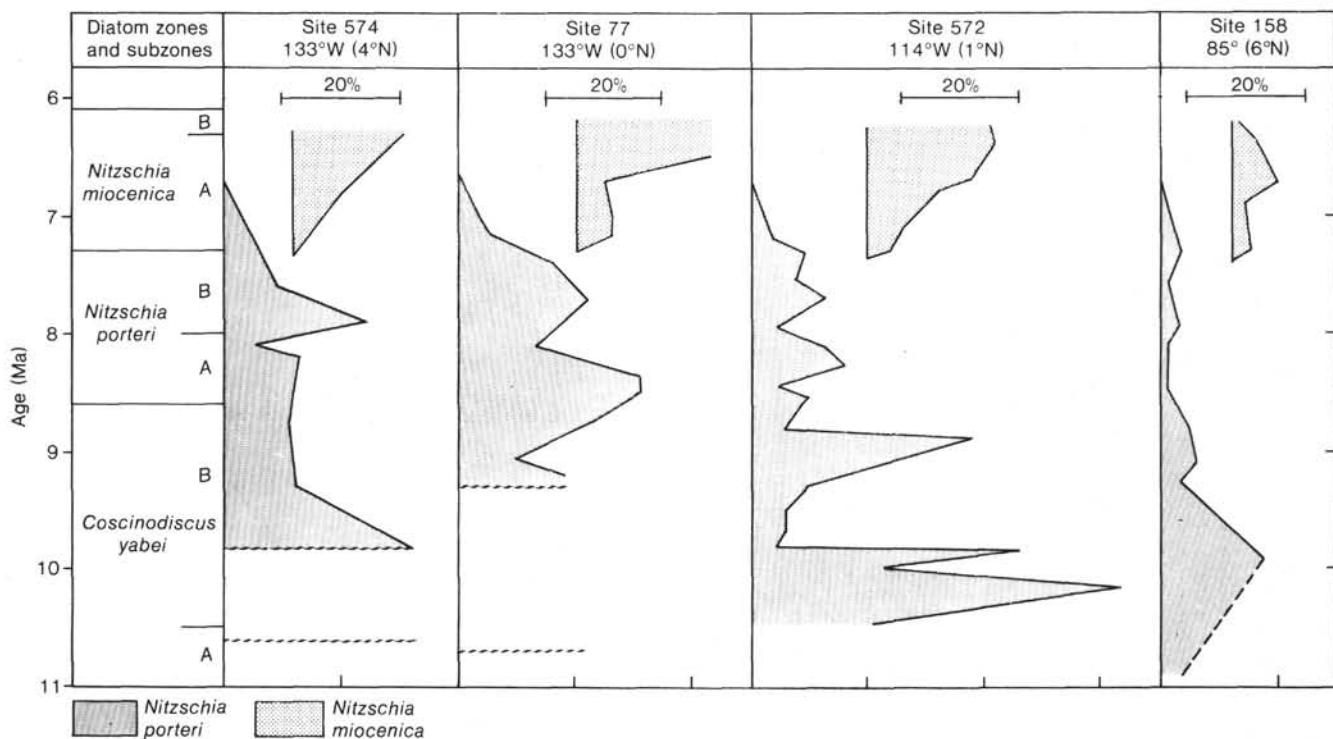


Figure 12. Relative abundance of *Nitzschia porteri* and *N. miocenica* s. ampl. (between 10.8 and 6.2 Ma) at DSDP Sites 574, 77, 572, and 158, plotted against age. Refer to Tables 7 and 10.

Quantitative trends for *Thalassiothrix longissima* (Fig. 15) reveal numerous correlative abundance spikes (labeled A to F) between the early middle Miocene and the earliest late Miocene (15.3 to 10.9 Ma). These peaks are most recognizable in the curves with the closest sampling intervals (Sites 574, 572, and 158), and they are strongly supportive of the diatom datum-level correlations between the sites (Tables 1 and 2). Estimated ages for these spikes are as follows: A, 15.2 Ma; B, 14.7 Ma; C, 13.0 Ma; C', 12.7 Ma; D, 12.1 Ma; D', 11.9 Ma; E, 11.5 Ma; E', 11.3 Ma; and F, 10.9 Ma. Absolute abundance values are comparable (5 to 20%) at Sites 574, 77, and 572, but slightly greater (10 to 25%) at easternmost Site 158.

REWORKING

Horizons of reworked diatoms are rare at Sites 572 and 573 and more common at Sites 574 and 575. The Quaternary through upper Miocene section (0 to 26 m) of Site 575 accumulated at a very slow rate (Fig. 4), and reworked middle Miocene to Oligocene diatoms are typically present in low numbers. Core 575B-3 (about 7.5 Ma) contains an anomalously thick sequence, and it is dominated by reworked diatoms from the upper middle Miocene, including *Coscinodiscus tuberculatus* and *Denticulopsis punctata* f. *hustedtii*.

At Site 574, upper lower Miocene diatoms are reworked into the lower middle Miocene (Samples 574-25,CC and 574-22,CC), and lower middle Miocene diatoms are reworked into the upper middle Miocene (Samples 574-16,CC and 574-14-2, 42-43 cm) (Table 5). Lower

and middle Miocene diatoms are also present in upper Miocene (Samples 574A-7,CC and 574A-8,CC) and Pliocene (Samples 574-2,CC; 574A-3,CC; and 574-4,CC) horizons.

SUMMARY

Excellent upper Eocene to Holocene reference sections were recovered on Leg 85 at four sites (572 to 575) in the central equatorial Pacific. Diatoms are generally common and well preserved at all sites, except in the upper Eocene and upper Oligocene. The upper Cenozoic diatom zonation of Barron (in press), which consists of the upper Miocene to Holocene zonation of Burckle (1972, 1977) and the lower Miocene zonation of Barron (1983), is readily applicable. In addition, 89 secondary datum levels have been identified in the Miocene and Pliocene and correlated between the sites. The Oligocene zonation used is a modification of Fenner's (in press), wherein the upper Oligocene zones are simplified to allow for the relatively poor diatom preservation in that interval. Paleomagnetic stratigraphy was obtained for the entire *Denticulopsis nicobarica* Zone at Site 575, from the middle of paleomagnetic Chron 17 to the middle of Chron 16, and 13 upper lower Miocene diatom datum levels are calibrated directly with paleomagnetic stratigraphy for the first time.

Site 572 in the east (114°W) contains a thick sequence of lower middle Miocene to Quaternary diatom-rich sediment. Sites 573 to 575 (133° to 135°W) have more carbonate-rich sediments accumulated at rates that were, at most, 60% those of Site 572. Hiatuses are more com-

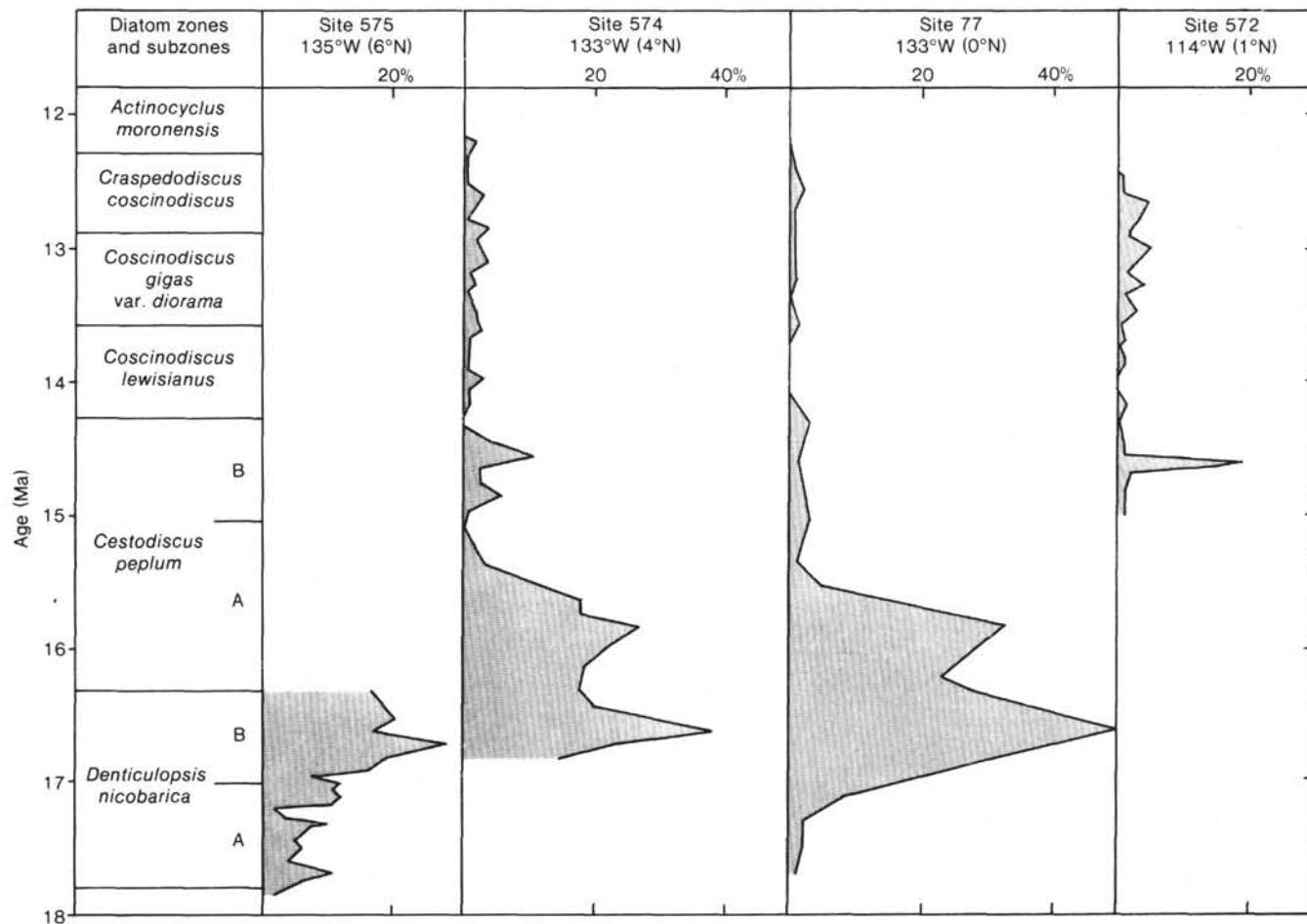


Figure 13. Relative abundance of *Synedra jouseana* s. ampl. (after 17.8 Ma) at DSDP Sites 575, 574, 77, and 572, plotted against age. Refer to Tables 4, 5, 6, and 8.

mon at the western sites, specifically in the intervals between about 18 and 17 Ma (NH1), 10.5 and 9.8 Ma (NH5), and 5.1 and 4.5 Ma (NH7).

Quantitative diatom studies of the upper lower Miocene to uppermost Miocene (18.0 to 6.2 Ma) of Sites 572, 574, and 575 are supplemented by quantitative diatom studies at Site 77 (about 10 km from Site 573) and Site 158 (85°W) to form transects across the eastern and central equatorial Pacific. Where the sampling interval represents 100,000 yrs. or less (lower Miocene of Sites 574 and 575 and middle Miocene of Sites 158, 572, and 574), quantitative trends in species such as *Cestodiscus pulchellus*, *Coscinodiscus radiatus*, *Denticulopsis hustedtii*, *D. nicobarica*, and *Thalassiothrix longissima* are readily correlatable, and greatly enhance the biostratigraphic resolution. Sampling intervals for the late Miocene represent an average of 200,000 to 300,000 yrs., and correlation of the individual peaks and troughs of the species abundance curves is more difficult. Comparison of species abundance reveals relatively minor differences between the eastern and western sites, especially in the lower and middle Miocene. *Thalassionema nitzschioides*, *Denticulopsis hustedtii*, and *D. nicobarica* show general eastern preferences, whereas *Cestodiscus pul-*

chellus, *Actinocyclus ellipticus*, *Coscinodiscus tuberculatus*, and *Nitzschia* spp. seem to prefer the western area.

DESCRIPTION OF NEW DIATOM TAXA

The taxonomy below follows that of Barron (1980a, b; 1981a, b; 1983; in press) for the uppermost Oligocene through Holocene, and that of Jousé (1977) and Fenner (in press) for the Oligocene.

Genus *ACTINOCYCLUS* Ehrenberg

Actinocyclus ellipticus Grunow in Van Heurck, 1883
Actinocyclus ellipticus var. *spiralis* n. var.
(Plate 7, Figs. 9-10; Plate 9, Fig. 5)

Description. This variety is distinguished from other forms of *A. ellipticus* Grunow by its areolation pattern, which closely resembles that of *Coscinodiscus lewisanus* Greville. Kolbe (1954) characterizes this *C. lewisanus*-type areolation as "apical straight or slightly rounded rows parallel to the apical axis; transapical rows curved and diverging from the transapical axis; central space forming irregular circular figures." Well-developed hyaline fields are present in the valve's center. At low power this taxon closely resembles *C. lewisanus*, but it is easily distinguished by the presence of a marginal pseudonodule. The valves of this variety are not as robust as those of *C. lewisanus*; and smaller specimens, comparable in size to *C. lewisanus*, have apices more tapered than those of *C. lewisanus*. Observed valve sizes range from 40 × 11 µm (length × width) to 70 × 55 µm.

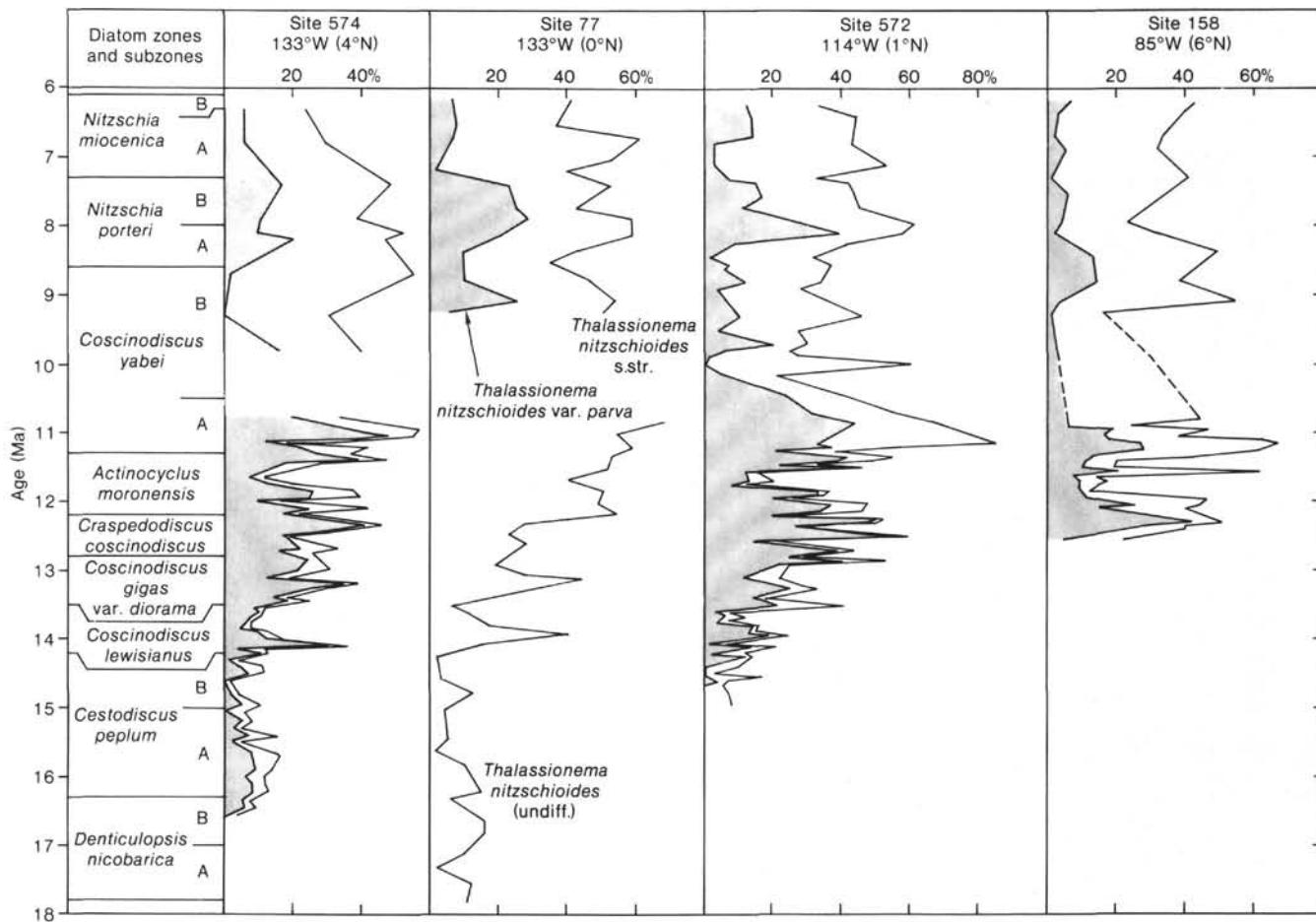


Figure 14. Relative abundance of *Thalassionema nitzschioides* and *T. nitzschioides* var. *parva* (between 17.8 and 6.2 Ma) at DSDP Sites 574, 77, 572, and 158, plotted against age. Refer to Tables 5 to 10.

Remarks. This variety is separated because it is restricted to the middle Miocene (about 14.2 to 12.3 Ma) (Table 3). Burckle (1978) reported *C. lewisi* to range above *Denticulopsis nicobarica* (Grunow) Simonsen in the equatorial Pacific, which conflicts with the results of Barron (1981a, b) and this report. It is possible that Burckle (1978) included *A. ellipticus* var. *spiralis* in this concept of *C. lewisi*.

Holotype. USNM 370301. Plate 9, Figure 5. DSDP Sample 575-5, 43–44 cm. Length 57 µm.

Genus *COSCINODISCUS* Ehrenberg

Coscinodiscus lewisi Greville 1866

Coscinodiscus lewisi var. *rhomboides*, n. var.
(Plate 7, Figs. 2, 3)

Coscinodiscus lewisi var. *similis* Rattray, Kolbe, 1954, pl. 2, fig. 22.

C. lewisi var. *similis* Rattray, Kanaya, 1971, pl. 40.5, figs. 7, 8.
C. lewisi var. *similis* Rattray, Jousé, 1977, pl. 57, figs. 8, 20–23.
C. lewisi var. *similis* Rattray, Barron, 1983, p. 512, pl. 1, fig. 8.

Description. This variety has distinctly rhombic valves ranging in size from 60 × 30 µm to 120 × 50 µm (length × width). It has been confused in the literature with *C. lewisi* var. *similis* Rattray, which is also rhombic in shape, although much less so (compare Plate 7, Figs. 2, 3, 6). In addition to being more elliptical in outline, *C. lewisi* var. *similis* possesses a distinct, finely areolated margin, which is much broader than the finely areolated margin of *C. lewisi* var. *rhomboides*. *C. lewisi* var. *rhomboides* is mainly an upper Oligocene diatom which ranges into the lowermost Miocene, whereas *C. lewisi* var. *similis* is restricted to the upper lower Miocene (about 17.4 to 15.7 Ma).

Remarks. Barron (1983) recognized the two rhombic forms of *C. lewisi*, but mistakenly called the older form *C. lewisi* var. *similis* Rattray and the younger form *C. lewisi* ("late early Miocene form resembling *C. lewisi* var. *similis*").

Holotype. USNM 370299. DSDP Sample 71-39-2, 87–89 cm. Length 114 µm.

Coscinodiscus loeblichii, n. sp.

(Plate 4, Figs. 1–3)

Stictodiscus truanii Witt, Jousé, 1977, pl. 48, fig. 13.

Description. Circular valve 14 to 40 µm in diameter with a large, asymmetric indentation at its center. The indentation is not as abrupt as that which is typical of *Craspedodiscus*, and typically makes up about 4/5 of the valve's face. On opposing sides of the valve, the raised marginal rim varies in thickness by a factor of 2. The areolar pattern is sublinear, and the polygonal areolae range from 9 per 10 µm on the valve's margin to 13 in 10 µm near the valve's center. Within the indentation itself, a small area near the valve's center is raised slightly above the surrounding area of the indentation. The valve's margin is simple and without spines.

Remarks. *Coscinodiscus loeblichii* has a brief range (representing about 10.5 to 9.4 Ma) in the lower upper Miocene of the equatorial Pacific.

Holotype: USNM 370304. Plate 4, Figure 1. DSDP Sample 572D-10, CC. Diameter 28 µm.

Isotypes. USNM 370305 and 370306. Plate 4, Figures 2, 3. Diameter 23 µm and 30 µm.

Derivation of name. Named in honor of Dr. Alfred R. Loeblich of the University of California at Los Angeles.

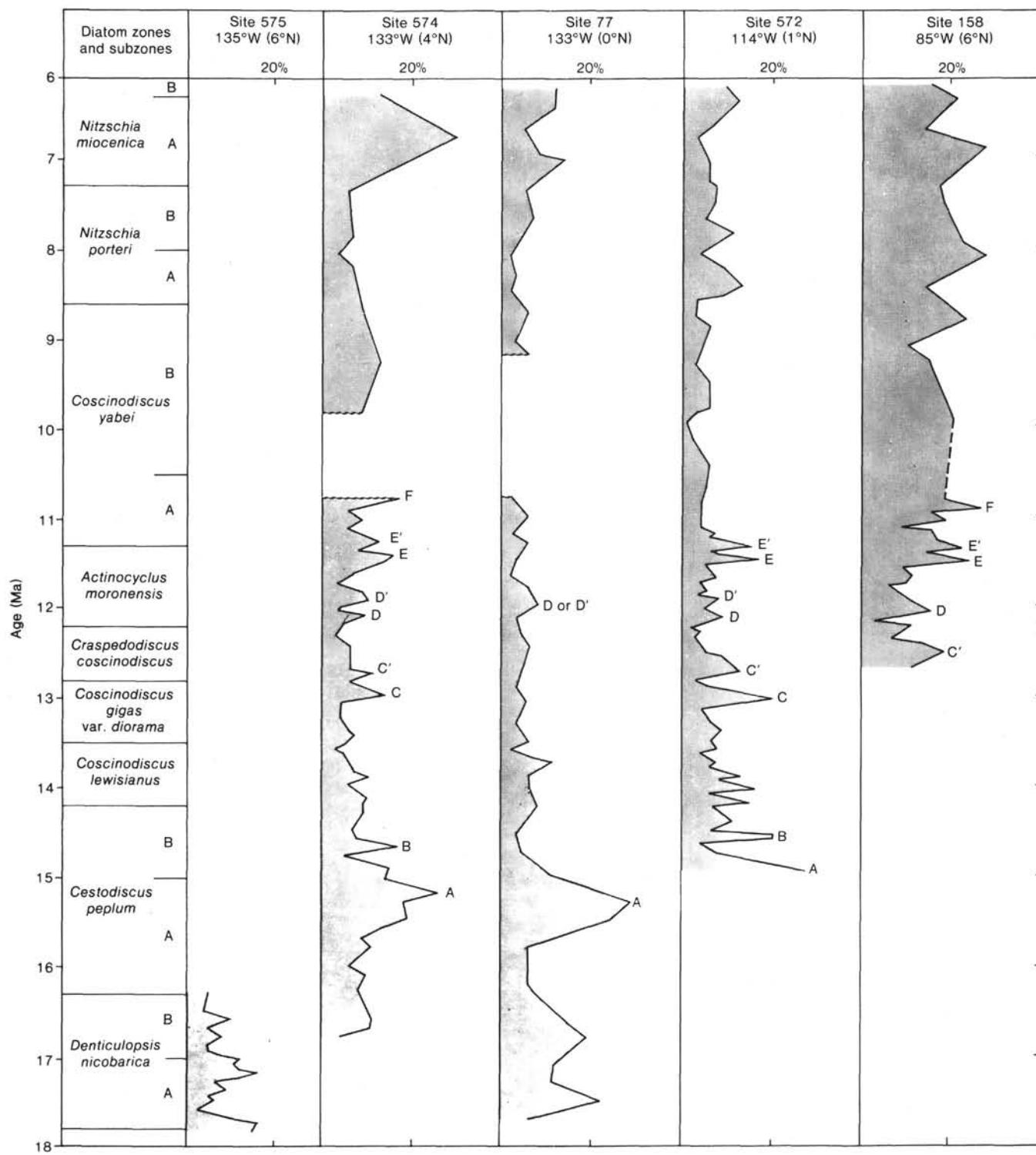


Figure 15. Relative abundance of *Thalassiothrix longissima* at DSDP Sites 575, 574, 77, 572, and 158 (between 17.8 and 6.2 Ma), plotted against age. Refer to Tables 4 to 10. Correlative abundance peaks are labeled A to F (see text).

***Coscinodiscus yabei* Kanaya, 1957**
***Coscinodiscus yabei* var. *ellipticus*, n. var.**
 (Plate 4, Fig. 9; Plate 9, Fig. 1)

Cymatotheca temperei (Brun) Hendey, Jousé, 1977, pl. 50, fig. 5.
Description. This variety is distinguished by its distinctive elliptical shape. Observed valves range in size from 42 × 23 µm to 96 × 57 µm (length × width). The plication is always along the transapical (short-

er) axis of the valve, in contrast to *C. temperei* Brun, which is always plicated along the apical (longer) axis. Smaller specimens of *C. yabei* var. *ellipticus* have their axis of plication at a slight angle to the transapical axis, producing an asymmetrical appearance of the plications. Larger specimens have flattened margins covering 1/5 of the transapical axis, with the plication restricted to the center of the valve.

Remarks. *C. yabei* var. *ellipticus* has a short range (representing 9.8 to 9.4 Ma) in the lower upper Miocene (Table 3).

Holotype. USNM 370307. Plate 4, Figure 9. DSDP Sample 572D-10-4, 50–52 cm. Length 63 μm .

Isotype. USNM 370308. Plate 9, Figure 1. Length 46 μm .

Genus *THALASSIOSIRA* Cleve

Thalassiosira tappanae, n. sp.
(Plate 6, Figs. 1–5, 7)

?*Stephanopyxis* sp., Bukry, 1978b, pl. 19, fig. 10.

Coscinodiscus sp. of Burckle (1978), Barron, 1981a, p. 139.

Description. Small (10 to 14 μm diameter), circular valves which are robust and slightly convex. Subpolygonal areolae are arranged in a linear to slightly eccentric pattern, and range in size from 9 per 20 μm near the valve center to 11 per 10 μm near the valve margin. Characteristic “gear-like” margin contains robust double spines (1 μm long) dispersed every 1.5 to 2 μm along a hyaline 1- μm -wide margin. There are typically 15 to 18 such spines per valve. Seven marginal strutted processes and one possible labiate process were observed on the interior face of the valve (Plate 6, Fig. 3).

Remarks. *T. tappanae* has a short range (representing 14.4 to 13.8 Ma) in the middle middle Miocene of the tropical Pacific. It was referred to as *Coscinodiscus* sp. by Burckle (1978) but was not described or figured.

Holotype. USNM 370309. Plate 6, Figure 7. DSDP Sample 572D-28-2, 50–52 cm. Diameter 12.5 μm .

Isotype. USNM 370310. Plate 6, Figure 5. Diameter 13 μm .

Derivation of name. Named in honor of Dr. Helen Tappan of the University of California at Los Angeles.

OTHER DIATOM TAXA OBSERVED

Actinocyclus ehrenbergii Ralfs

A. ellipticus Grunow

A. ellipticus f. *lanceolata* Kolbe

A. ellipticus var. *javanica* Reinhold

A. hajosiae Barron

A. ingens Rattray

A. moronensis Deby

A. radionovae Barron

Actinoptychus undulatus (Bailey) Ralfs

Anellus californicus Tempére

Asterolampra acutiloba Frenguelli

Asteromphalus elegans Greville

Bogorovia veniamini Jousé

Cestodiscus peplum Brun

C. pulchellus Greville

C. pulchellus Greville sensu Jousé, 1973

C. mukhinae Jousé

C. robustus Jousé

Coscinodiscus africanus Janisch

C. blysmos Barron

C. excavatus Ralfs

C. gigas var. *diorma* (Schmidt) Grunow

C. lewisiatus Greville

C. lewisiatus var. *robustus* Barron

C. lewisiatus var. *similis* Rattray

C. marginatus Ehrenberg

C. nodulifer A. Schmidt

C. nodulifer var. *cyclopus* Jousé

C. oligocenicus Jousé

C. platicatus Grunow

C. praenodulifer Barron

C. radiatus Ehrenberg

C. rhombicus Castracane

C. salisburyanus Lohman

C. tabularis Grunow

C. temperei var. *delicata* Barron

C. tuberculatus Greville

C. vetustissimus var. *javanica* Reinhold

C. yabei Kanaya

Craspedodiscus coscinodiscus Ehrenberg

C. elegans Ehrenberg

C. rydei Barron

Denticulopsis hustedtii (Simonsen and Kanaya) Simonsen

K. kanayaee (Aliba) Barron

- D. lauta* (Bailey) Simonsen
- D. nicobarica* (Grunow) Simonsen
- D. praedimorpha* (Akiba) Akiba
- D. punctata* f. *hustedtii* (Schrader) Simonsen
- Hemidiscus cuneiformis* Wallich
- Lisitzinia ornata* Jousé
- Melosira architecturalis* Brun
- M. sulcata* (Ehrenberg) Kutzing
- Nitzschia cyclindrica* Burckle
- N. fossilis* (Frenguelli) Kanaya and Koizumi
- N. jouseae* Burckle
- N. maleinterpretaria* Schrader
- N. marina* Grunow
- N. miocenica* Burckle
- N. miocenica* var. *elongata* Burckle
- N. porteri* Frenguelli sensu Burckle (1972)
- N. praereinholdii* Schrader
- N. reinholdii* Kanaya and Koizumi
- Pseudoeunotia doliolus* (Wallich) Grunow
- Raphidodiscus marylandicus* Christian
- Rhizosolenia matuyamai* Burckle
- R. praebergonii* Mukhina
- R. praebergonii* var. *robusta* Burckle and Trainer
- Rocella gelida* (Mann) Bukry
- R. gelida* var. *schraderi* (Bukry) Barron
- R. vigilans* Fenner
- Rossiella paleacea* (Grunow) Desikachary and Maheshwari
- R. paleacea* var. *elongata* (Barron)
- R. praepaleacea* (Schrader) Gersonde
- Rouxia* spp.
- Synedra miocenica* Schrader
- S. jouseana* Sheshukova-Poretskaya
- S. jouseana* f. *linearis* Sheshukova-Poretskaya
- Thalassionema nitzschioides* Grunow
- T. nitzschioides* var. *parva* Heiden and Kolbe
- T. robusta* Schrader
- Thalassiosira bukryi* Barron
- T. burckliana* Schrader
- T. convexa* Mukhina
- T. convexa* var. *aspinosa* Schrader
- T. eccentrica* (Ehrenberg) Cleve
- T. fraga* Schrader
- T. leptopus* (Grunow) Hasle and Fryxell
- T. miocenica* Schrader
- T. oestrupii* (Ostenfeld) Proshkina-Lavrenko
- T. praecoxvexa* Burckle
- T. primalabiata* Gombos
- T. spinosa* Schrader
- T. spumellaroides* Schrader
- Thalassiothrix longissima* Cleve and Grunow
- Triceratium cinnamomeum* Greville
- T. pileus* Ehrenberg

ACKNOWLEDGMENTS

I thank the Leg 85 Co-Chiefs, Larry Mayer and Fritz Theyer, and the entire staff for making Leg 85 rewarding and successful. This manuscript benefited from the reviews of William H. Abbott and Lloyd H. Burckle. Jack G. Baldauf and David Bukry provided helpful comments. Robert Oscarson of the U. S. Geological Survey assisted with scanning electron microscope studies. Samples were made available for study by the NSF through the Deep Sea Drilling Project.

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Date of Initial Receipt: 10 October 1983

Date of Acceptance: 6 March 1984

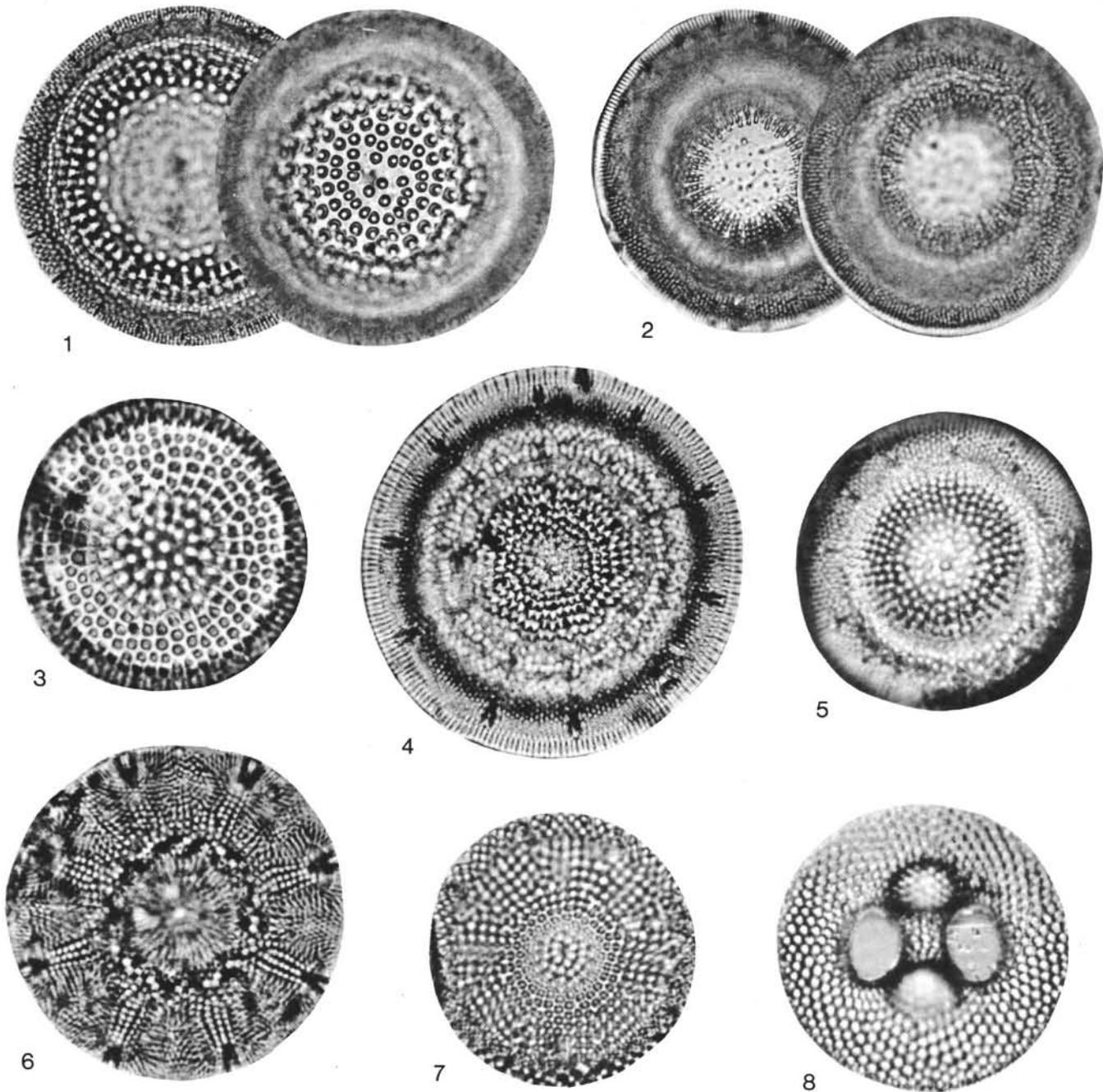


Plate 1. 1. *Cestodiscus robustus* Jousé, low and high focus, diameter 92 μm , Sample 574C-28,CC. 2. *Actinocyclus radionovae* Barron, low and high focus, diameter 75 μm , Sample 574C-6-2, 43-45 cm. 3. *Cestodiscus mukhinae* Jousé, diameter 33 μm , Sample 574C-22,CC. 4. *Cestodiscus pulchellus* var. *maculatus* Kolbe, diameter 40 μm , Sample 77B-28-2, 28-30 cm. 5. *Cestodiscus pulchellus* Greville sensu Jousé (1977), diameter 52 μm , Sample 574C-31,CC. 6. *Aulacodiscus* sp. (figured by Jousé [1977] as *Actinodiscus barbadensis* Greville), diameter 54 μm , Sample 574C-17,CC. 7. *Cestodiscus pulchellus* Greville, diameter 41 μm , Sample 77B-25-6, 20-22 cm. 8. *Coscinodiscus excavatus* Ralfs, diameter 130 μm , Sample 573B-37,CC.

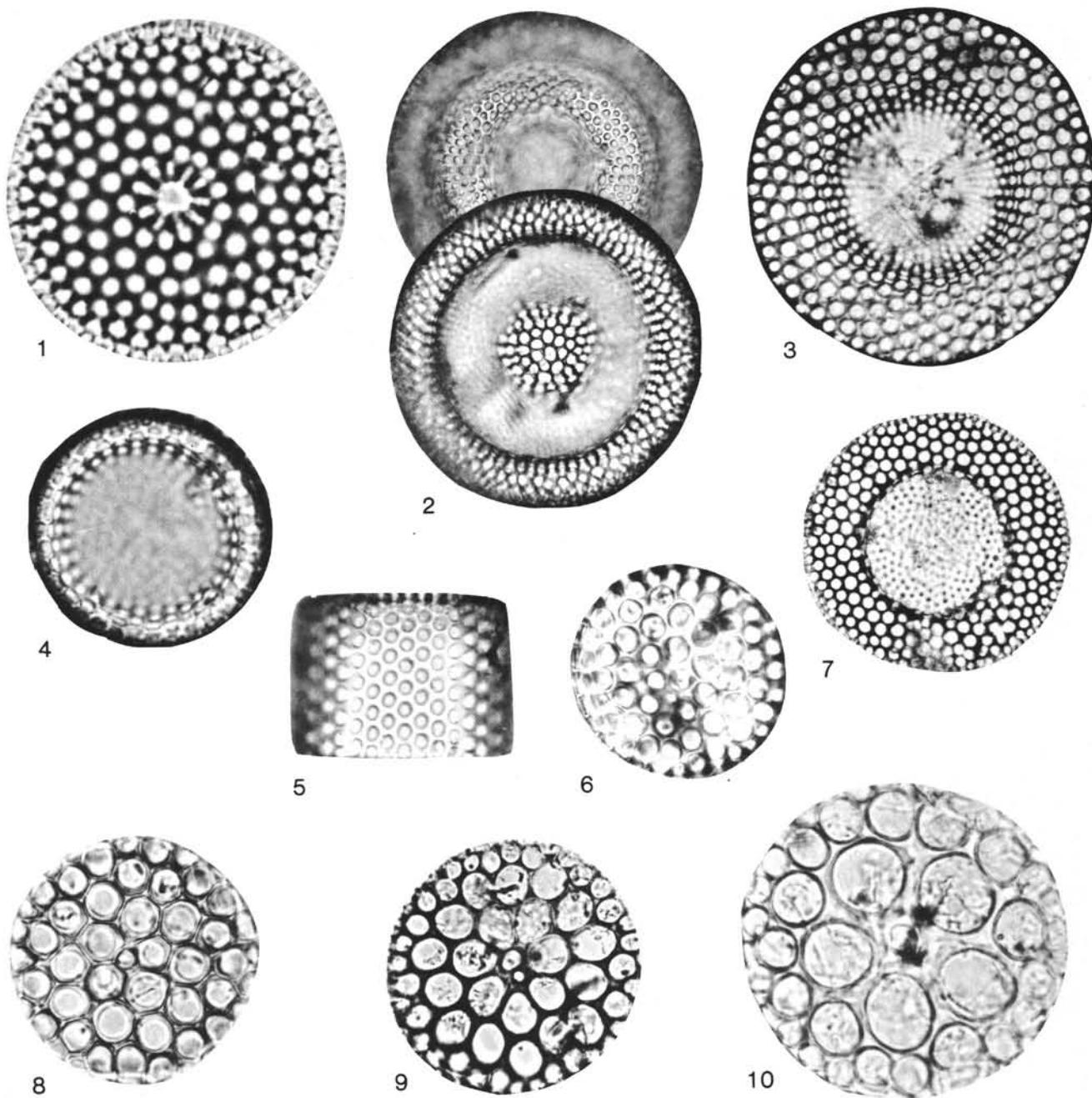


Plate 2. 1. *Coscinodiscus blysmos* Barron, diameter 40 μm , Sample 575A-2-3, 42–43 cm. 2. *Craspedodiscus elegans* Ehrenberg, low and high focus, diameter 107 μm , Sample 575A-17,CC. 3. *Craspedodiscus coscinodiscus* Ehrenberg s. ampl., coarse indented form of the late Oligocene, diameter 148 μm , Sample 574C-17-2, 43–45 cm. 4. *Craspedodiscus rydei* Barron, diameter 34 μm , Sample 575A-3-2, 42–43 cm. 5. *Annellus californicus* Tempère, width 39 μm , Sample 575B-12-6, 105–106 cm. 6. *Rocella vigilans* (Schmidt) Fenner, plicate form, diameter 30 μm , Sample 574C-17,CC. 7. *Craspedodiscus coscinodiscus* Ehrenberg s. str., diameter 72 μm , Sample 574-16-2, 42–43 cm. 8–9. *Rocella gelida* (Mann) Bukry, (8) diameter 34 μm , Sample 574C-17,CC, (9) diameter 66 μm , Sample 574C-17-2, 43–45 cm. 10. *Rocella gelida* var. *schraderi* (Bukry) Barron, diameter 47 μm , Sample 574C-16,CC.

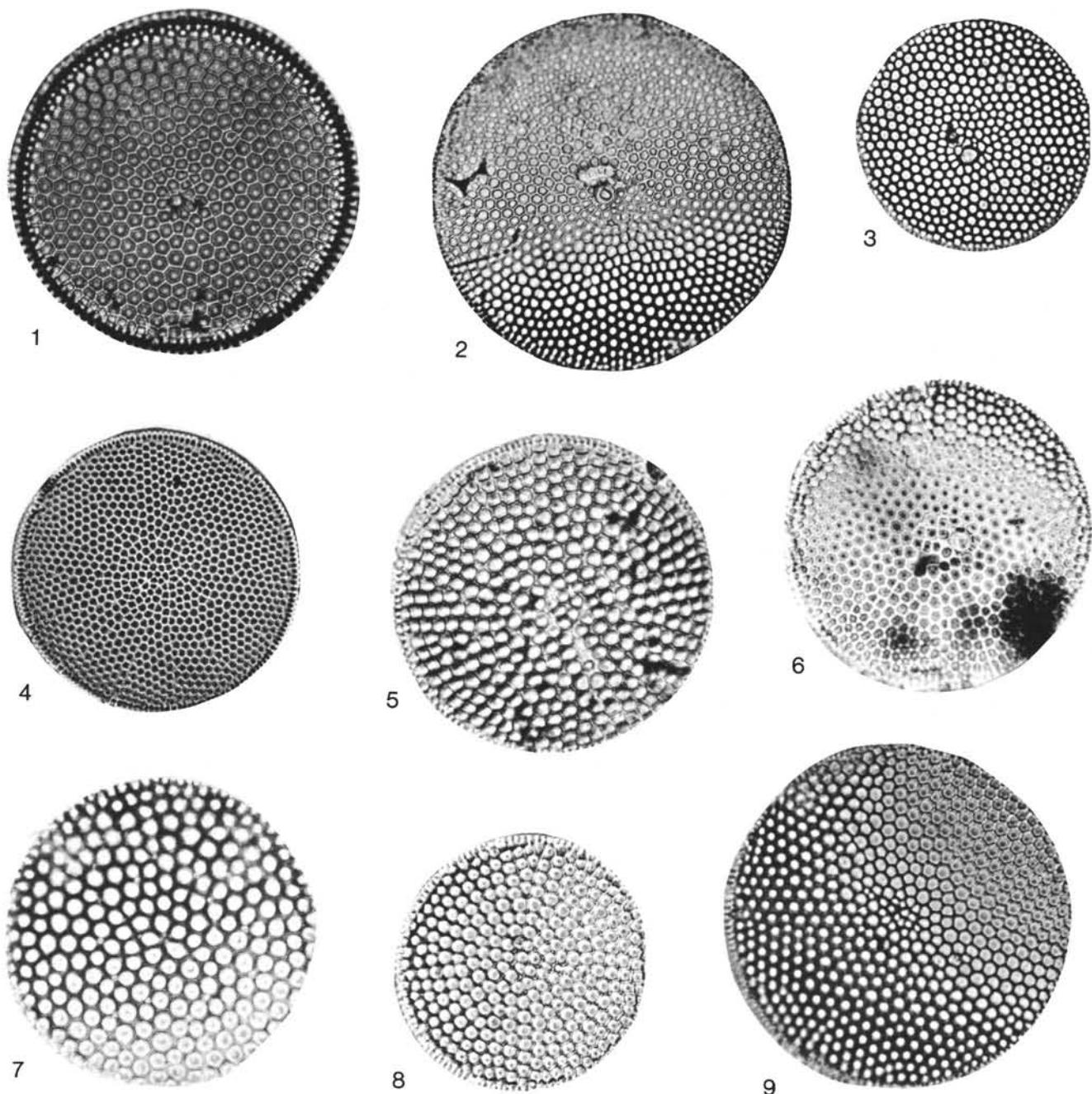


Plate 3. 1. *Coscinodiscus nodulifer* A. Schmidt, diameter 54 μm , Sample 572A-6-3, 42-43 cm. 2. *Coscinodiscus nodulifer* var. *cyclopus* Jousé, Miocene form, clear area above center is bubble in mounting medium; diameter 91 μm , Sample 574-8-1, 43-45 cm. 3. *Coscinodiscus nodulifer* var. *cyclopus* Jousé s. str., diameter 60 μm , Sample 573-8,CC. 4. *Coscinodiscus tabularis* Grunow, diameter 46 μm , Sample 574-10-6, 43-45 cm. 5. *Coscinodiscus oligocenicus* Jousé, diameter 39 μm , Sample 574C-31,CC. 6. *Coscinodiscus vetustissimus* var. *javanica* Reinhold, diameter 29 μm , Sample 77B-17-1, 18-20 cm. 7. *Coscinodiscus radiatus* Ehrenberg, diameter 59 μm , Sample 574-20,CC. 8. *Coscinodiscus tuberculatus* Greville, diameter 36 μm , Sample 574-11-4, 43-45 cm. 9. *Coscinodiscus salisburyanus* Lohman, diameter 47 μm , Sample 574-20-2, 43-44 cm.

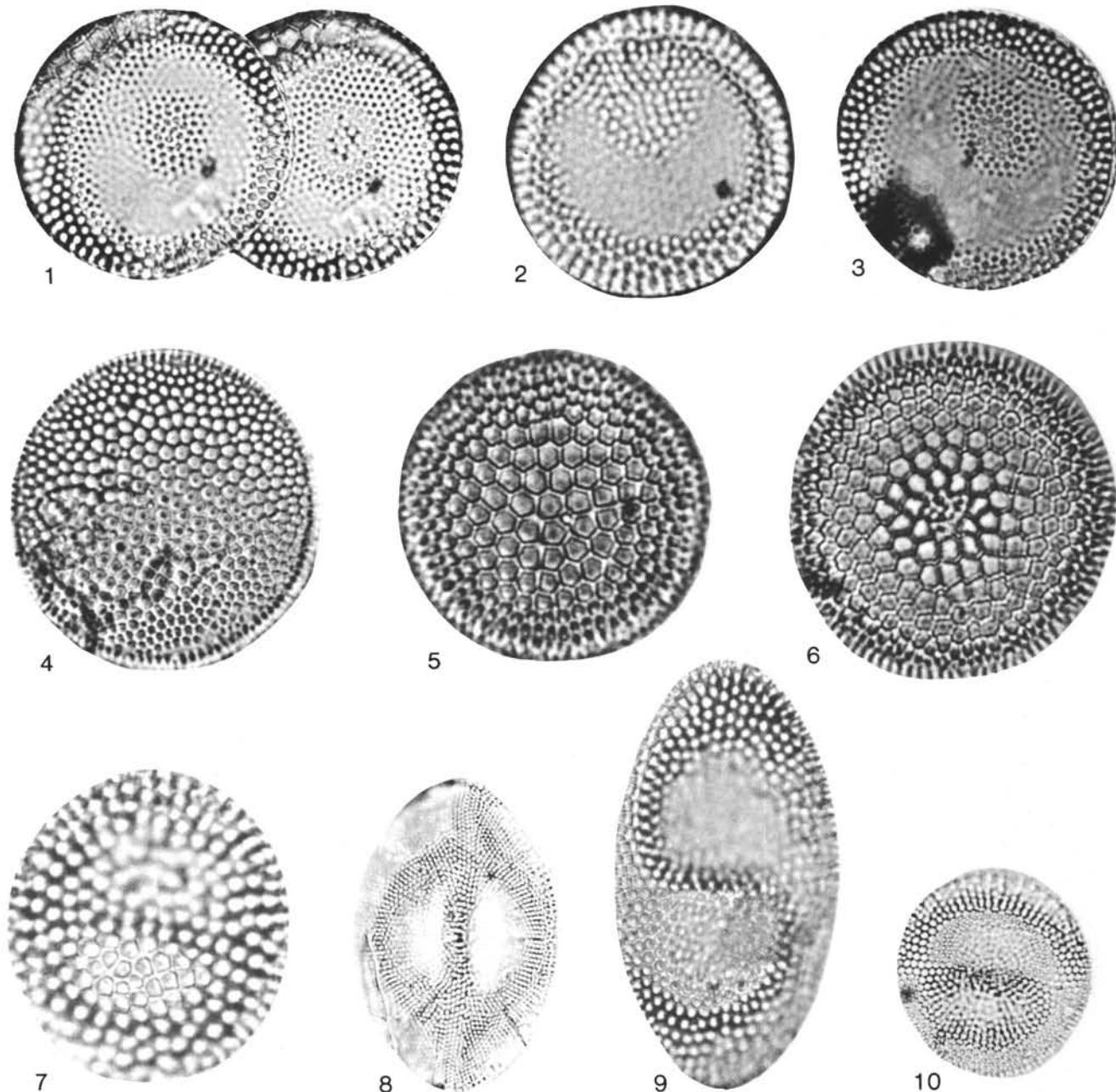


Plate 4. 1-3. *Coscinodiscus loeblichii* Barron, n. sp., Sample 572D-10,CC, (1) Holotype USNM 370304, high and low focus, diameter 28 μ m, (2) Isotype USNM 370305, diameter 23 μ m, (3) Isotype USNM 370306, diameter 30 μ m. 4. *Thalassiosira bukryi* Barron, diameter 33 μ m, Sample 575A-6-3, 42-43 cm. 5. *Thalassiosira oestrupii* (Ostenfeld) Proshkina-Lavrenko, diameter 24 μ m, Sample 572A-1-3, 67-68 cm. 6. *Thalassiosira burckiana* Schrader, diameter 15 μ m, Sample 77B-15-6, 23-25 cm. 7. *Coscinodiscus yabei* Kanaya, diameter 24 μ m, Sample 574-8,CC. 8. *Coscinodiscus temperi* var. *delicata* Barron, length 57 μ m, Sample 574-10-5, 43-45 cm. 9. *Coscinodiscus yabei* var. *ellipticus* Barron, n. var., Holotype USNM 370307, length 63 μ m, Sample 572D-10-4, 50-52 cm. 10. *Coscinodiscus plicatus* Grunow, diameter 46 μ m, Sample 574-10-5, 43-45 cm.

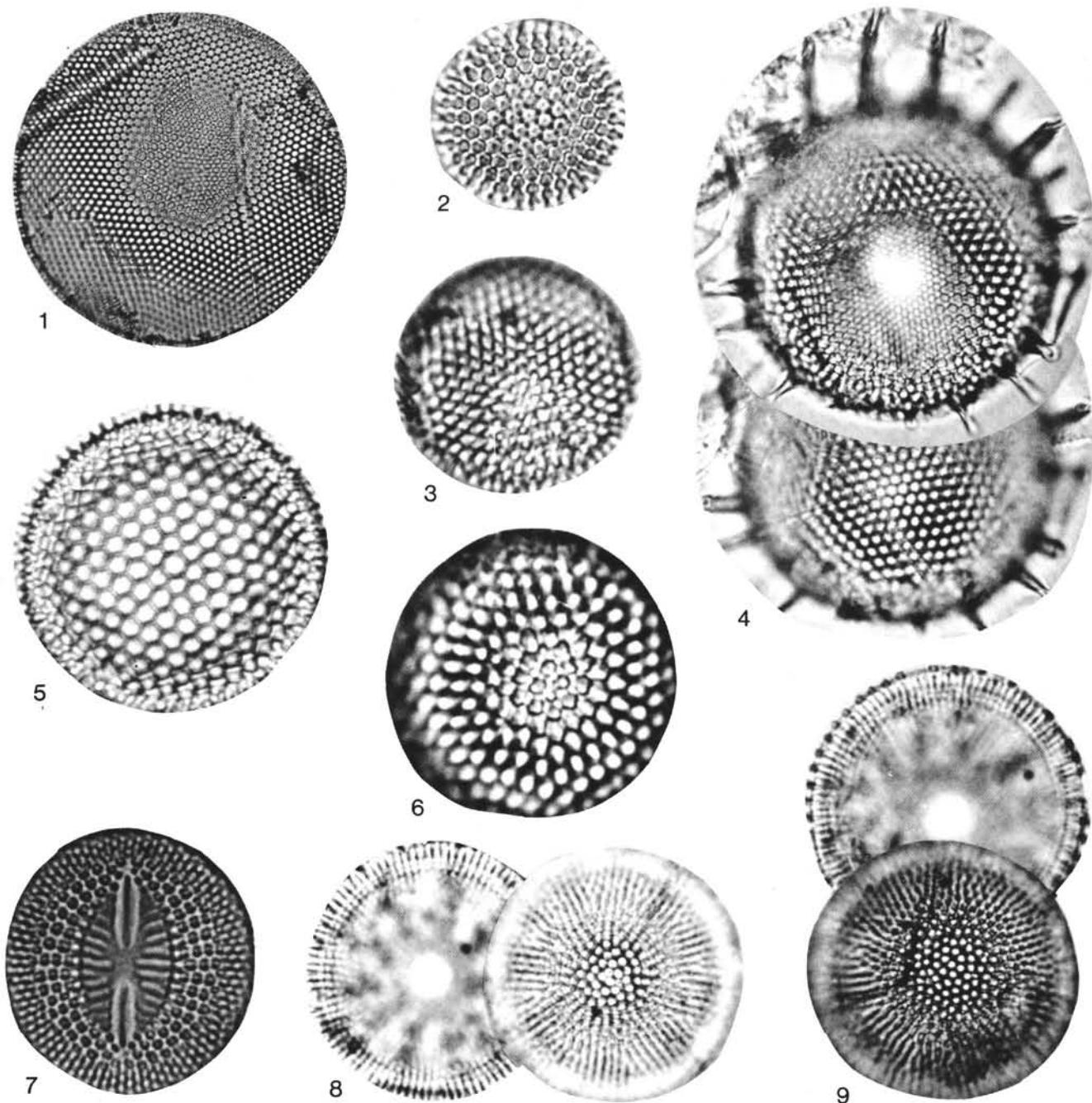


Plate 5. 1. *Thalassiosira eccentrica* (Ehrenberg) Cleve, diameter 78 μm , Sample 572A-4-3, 66-67 cm. 2. *Thalassiosira fraga* Schrader, diameter 18 μm , Sample 575A-1-1, 50-51 cm. 3. *Thalassiosira praeconvexa* Burckle, diameter 15 μm , Sample 573-12, CC. 4. *Thalassiosira spumelloides* Schrader, low and high focus, diameter 34 μm , Sample 574C-7-2, 43-45. 5. *Thalassiosira leptopus* (Grunow) Hasle and Fryxell, diameter 35 μm , Sample 574-18-2, 42-43 cm. 6. *Thalassiosira miocenica* Schrader, diameter 16 μm , Sample 77B-10-6, 30-32 cm. 7. *Raphidodiscus marylandicus* Christian, length 24 μm , Sample 575A-7-3, 43-44 cm. 8. *Thalassiosira convexa* var. *aspinosa* Schrader, low and high focus, diameter 34 μm , Sample 574-3-4, 129-130 cm. 9. *Thalassiosira convexa* var. *convexa* Mukhina, low and high focus, diameter 38 μm , Sample 574-3-4, 129-130 cm.

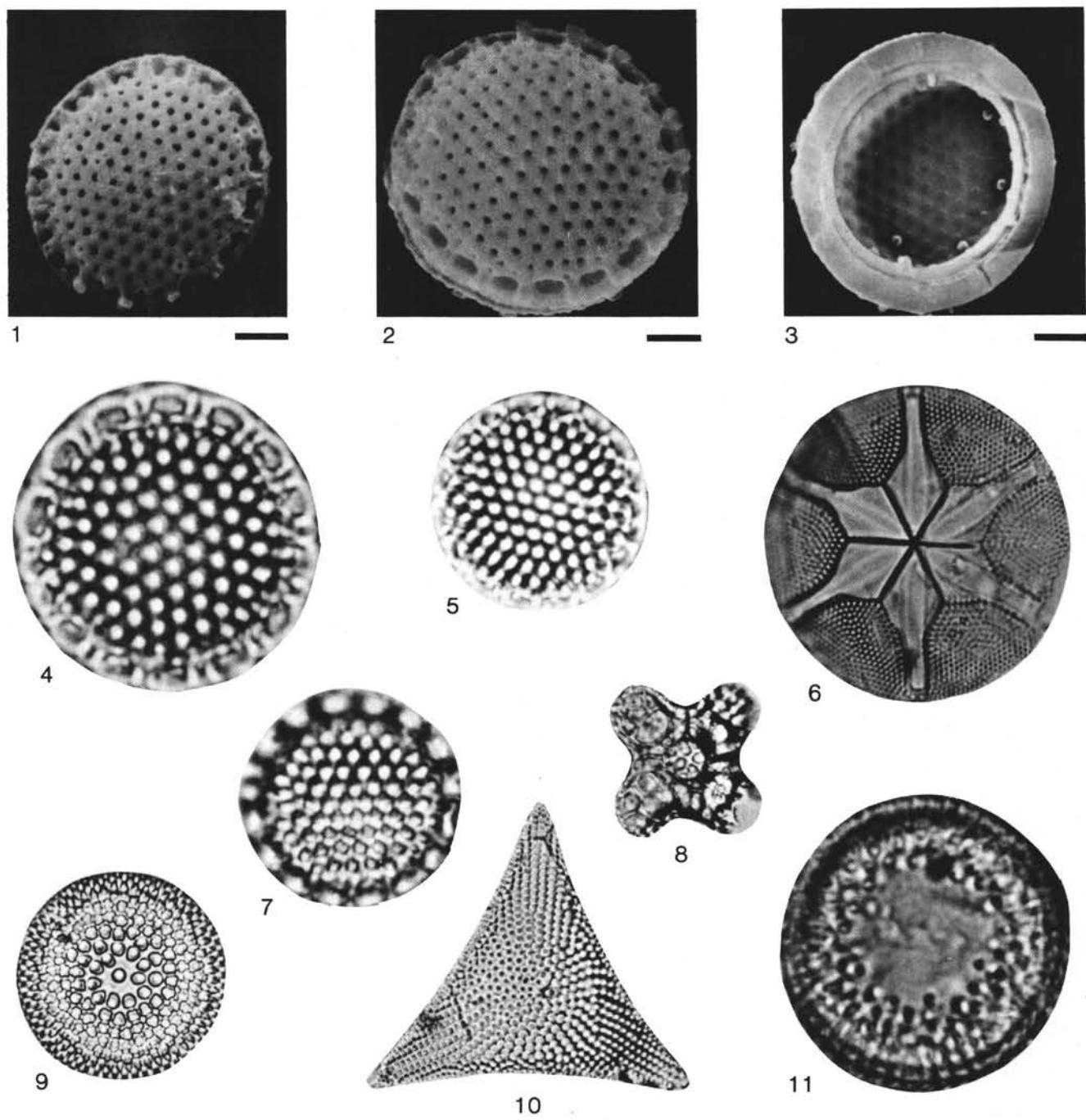


Plate 6. 1-3. *Thalassiosira tappanae* Barron, n. sp., scanning electron microscope pictures, Sample 574-19-2, 43-44 cm (scale bar = 3 μ m), (1) USNM 370311, showing small accessory pore midway along radius at 3 o'clock position, (2) USNM 370312, (3) USNM 370313, internal view of valve showing marginal struttated processes and single labiate process at 7 o'clock position. 4, 5, 7. *Thalassiosira tappanae* Barron, n. sp., (4) diameter 14 μ m, Sample 572-20-2, 43-44 cm, (5) Isotype USNM 370310, diameter 13 μ m, Sample 572D-28-2, 50-52 cm, (7) Holotype USNM 370309, diameter 12.5 μ m, Sample 572D-28-2, 50-52 cm. 6. *Asterolampra acutiloba* Frenguelli, diameter 48 μ m, Sample 573-12,CC. 8. *Lisitzinia ornata* Jousé, side 27 μ m, Sample 574C-17-2, 43-45 cm. 9. *Actinocyclus ingens* Rattray, diameter 35 μ m, Sample 574-16-2, 42-43 cm. 10. *Triceratium pileus* Ehrenberg, side 71 μ m, Sample 575A-7-2, 43-44 cm. 11. *Melosira architecturalis* Brun, diameter 18 μ m, Sample 574C-22,CC.

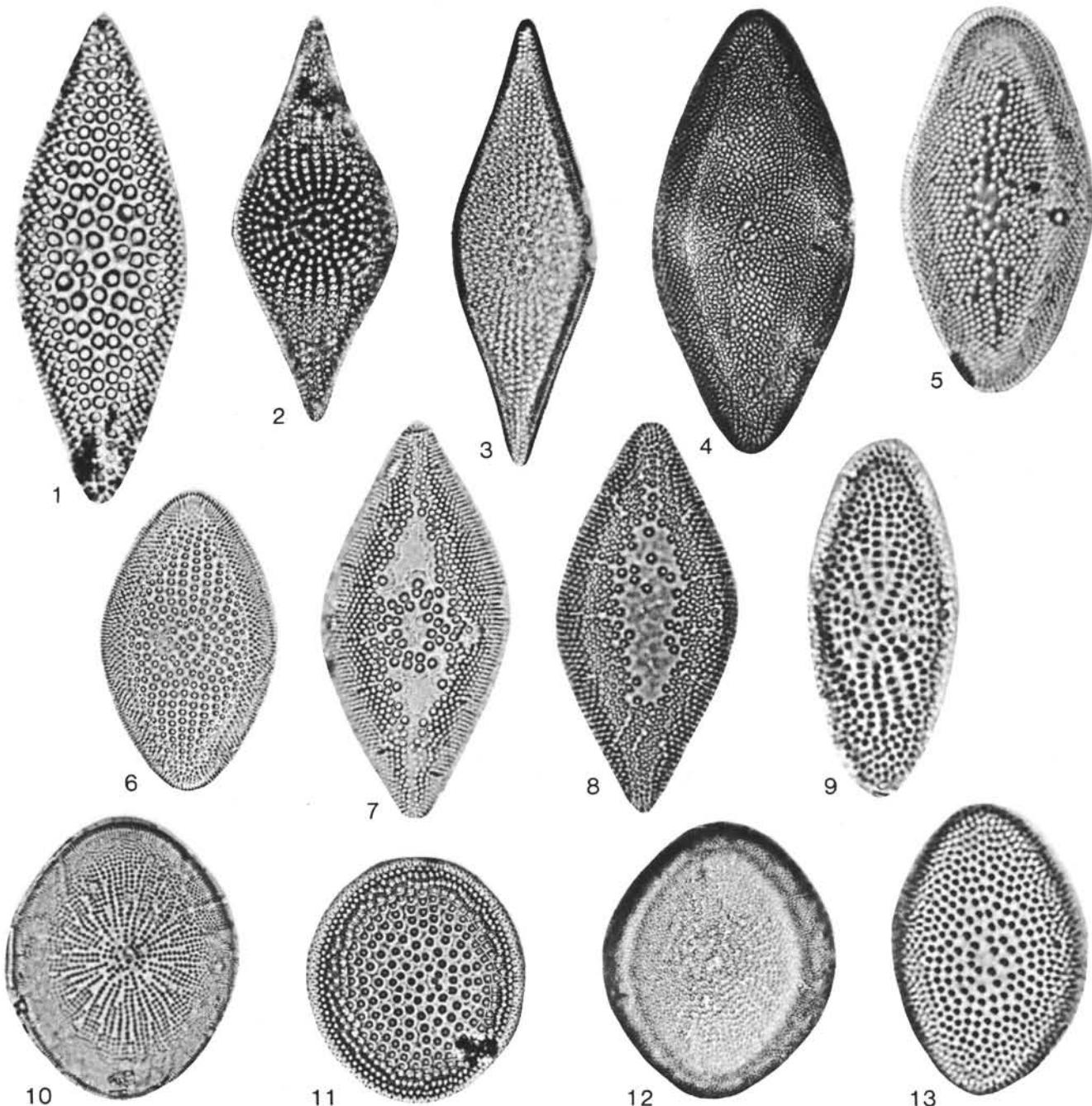


Plate 7. (All pseudonodules are at the 3 o'clock position.) 1. *Coscinodiscus rhombicus* Castracane, length 54 μ m, Sample 574C-17,CC. 2-3. *Coscinodiscus lewisiensis* var. *rhomboides* Barron, n. var., (2) Holotype USNM 370299, length 114 μ m, Sample 71-39-2, 87-89 cm, (3) USNM 370300, length 116 μ m, Sample 574C-20,CC. 4. *Actinocyclus ellipticus* f. *lanceolata* Kolbe, length 63 μ m, Sample 77B-12-1, 62-66 cm. 5. *Actinocyclus moronensis* Deby, length 44 μ m, Sample 574-11-4, 43-44 cm. 6. *Coscinodiscus lewisiensis* var. *similis* Rattray, length 65 μ m, Sample 575A-4-3, 42-43 cm. 7-8. *Cestodiscus peplum* Brun, (7) length 75 μ m, Sample 575B-11-1, 106-107 cm, (8) length 59 μ m, Sample 574-22-2, 43-44 cm. 9-10. *Coscinodiscus lewisiensis* var. *spiralis* Barron, n. var., Sample 575-5-2, 43-44 cm, (9) USNM 370302, length 38 μ m, (10) USNM 370303, length 70 μ m. 11. *Coscinodiscus lewisiensis* var. *robustus* Barron, length 56 μ m, Sample 575A-6-3, 42-43 cm. 12. *Actinocyclus ellipticus* var. *javanica* Reinhold, length 79 μ m, Sample 572D-11-1, 50-52 cm. 13. *Actinocyclus* sp. cf. *A. ellipticus* Grunow, early Miocene form, length 25 μ m, Sample 575A-5-2, 42-43 cm.

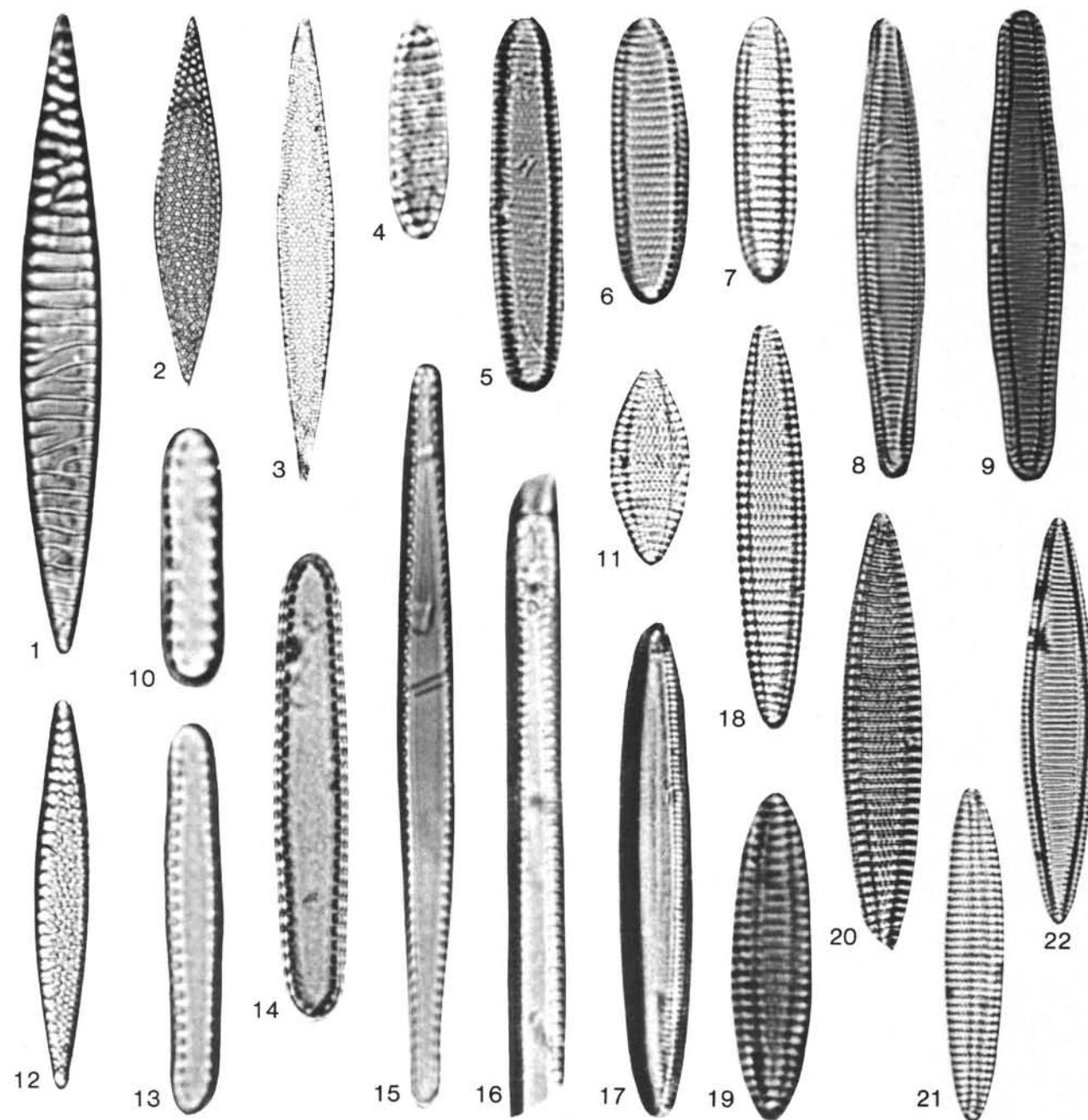


Plate 8. 1. *Rossiella praepaleacea* (Schrader) Gersonde, length 49 μm , Sample 572D-6,CC. 2. *Rossiella paleacea* (Grunow) Desikachary and Moshwari, length 69 μm , Sample 77B-28-2, 28-30 cm. 3. *Rossiella paleacea* var. *elongata* (Barron) Barron, n. comb., length 92 μm , Sample 574-10-6, 43-45 cm. 4. *Nitzschia porteri* Frenguelli sensu Burckle (1972), length 14 μm , Sample 573D-11-1, 50-52 cm. 5-6. *Nitzschia cylindrica* Burckle s. ampl., Sample 573-17-2, 62-63 cm, (5) length 34 μm , (6) length 28 μm . 7. *Nitzschia cylindrica* Burckle s. str., length 28 μm , Sample 573-12,CC. 8-9. *Nitzschia fossilis* (Frenguelli) Kanaya and Koizumi, (8) length 48 μm , Sample 572D-10,CC, (9) length 42 μm , Sample 573-13,CC. 10. *Thalassionema nitzschiooides* var. *parva* Heiden and Kolbe, length 12 μm , Sample 574-12-4, 43-45 cm. 11, 18. *Nitzschia jouseae* Burckle, (11) length 27 μm , Sample 574-3-4, 129-130 cm, (18) elongated form, length 50 μm , Sample 572A-6-3, 66-67. 12. *Bogorovia veniamini* Jousé, length 57 μm , Sample 575A-22,CC. 13, 15. *Thalassionema nitzschiooides* Grunow, (13) length 27 μm , Sample 574-20-2, 43-44 cm, (15) length 65 μm , Sample 572D-6-2, 50-52 cm. 14. *Thalassionema robusta* Schrader, length 41 μm , Sample 574-11-2, 43-45 cm. 16. *Thalassiothrix longissima* Cleve and Grunow, width 5 μm , Sample 574C-17,CC. 17. *Synedra jouseana* Sheshukova-Poretzkaya, length 51 μm , Sample 574C-17,CC. 19. *Nitzschia miocenica* Burckle, length 22 μm , Sample 77B-12-6, 30-32 cm. 20. *Nitzschia praereinholdii* Schrader, length 57 μm , Sample 572D-10,CC. 21. *Nitzschia miocenica* var. *elongata* Burckle, length 42 μm , Sample 573-12,CC. 22. *Nitzschia reinholdii* Kanaya and Koizumi, length 56 μm , Sample 572A-6-3, 66-67 cm.

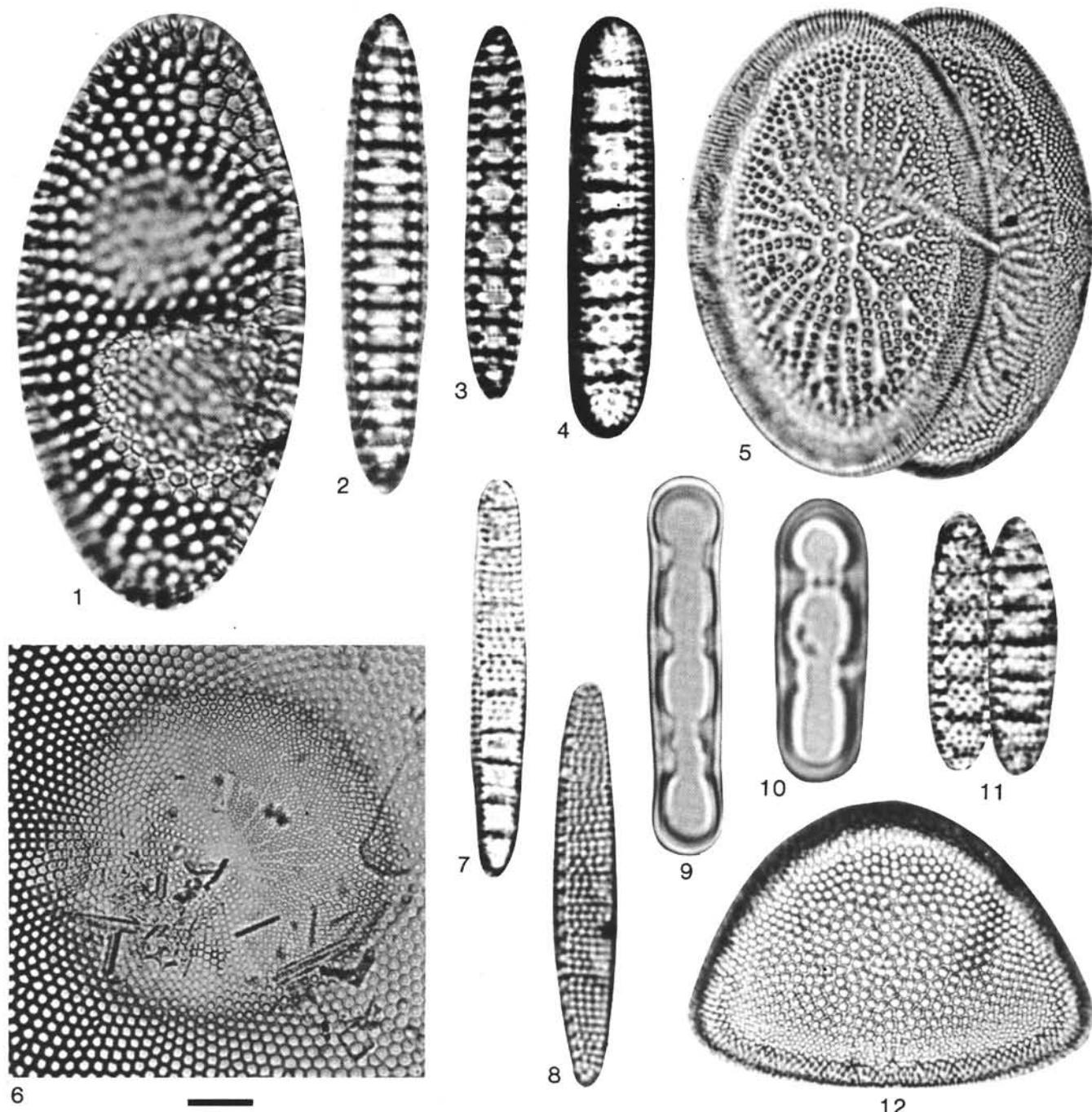


Plate 9. 1. *Coscinodiscus yabei* var. *ellipticus* Barron, n. sp., Isotype USNM 370308, length 46 μm , Sample 572D-10-4, 50–52 cm. 2–3. *Denticulopsis hustedtii* (Simonsen and Kanaya) Simonsen, (2) length 44 μm , Sample 572D-19-3, 50–52 cm, (3) length 35 μm , Sample 574-10-6, 43–45 cm. 4. *Denticulopsis* sp. cf. *D. kanayae* (Akiba) Barron, length 36 μm , Sample 575A-1-1, 50–51 cm. 5. *Coscinodiscus lewisianus* var. *spiralis* Barron, n. var., Holotype USNM 370301, high and low focus (note pseudonodule at 3 o'clock position), length 57 μm , Sample 575-5-4, 43–44 cm. 6. *Coscinodiscus gigas* var. *diorama* (Schmidt) Grunow, central area (scale bar = 20 μm), Sample 574-14, CC. 7. *Denticulopsis nicobarica* (Grunow) Simonsen, length 33 μm , Sample 575A-1, CC. 8. *Nitzschia maleinterpretaria* Schrader, length 35 μm , Sample 575A-6-1, 42–43 cm. 9–10. *Denticulopsis praedimorpha* (Akiba) Akiba, Sample 574-12-4, 43–45 cm, (9) length 21 μm , (10) length 16 μm . 11. *Denticulopsis punctata* f. *hustedtii* (Schrader) Simonsen, low and high focus, length 25 μm . 12. *Hemidiscus cuneiformis* Wallich, length 46 μm , Sample 572D-10, CC.